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Научный журнал
Издается ежемесячно с декабря 2013 года
Является печатной версией сетевого журнала
Universum: технические науки

Выпуск: 11(92)

Ноябрь 2021

Часть 6

Москва
2021

УДК 62/64+66/69

ББК 3

U55

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U55 Universum: технические науки: научный журнал. – № 11(92). Часть 6.

М., Изд. «МЦНО», 2021. – 108 с. – Электрон. версия печ. публ. –

<http://7universum.com/ru/tech/archive/category/1192>

ISSN : 2311-5122

DOI: 10.32743/UniTech.2021.92.11-6

Учредитель и издатель: ООО «МЦНО»

ББК 3

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MECHANICAL ENGINEERING AND MACHINE SCIENCE

DOI - 10.32743/UniTech.2021.92.11.12565

RESEARCH OF PARAMETERS AT THE APPEARANCE OF SHEARING FORCES
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ИССЛЕДОВАНИЕ ПАРАМЕТРОВ ПРИ ВОЗНИКНОВЕНИИ СРЕЗАЮЩИХ СИЛ
В СОСТАВНОМ НАТЯЖНОМ РОЛИКЕ ТРАНСПОРТНЫХ
И ТЕХНОЛОГИЧЕСКИХ МАШИНАХ**Юнус Умарович Мирзахонов**

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ABSTRACT

This scientific article discusses the development of a new design of a composite tension roller to prevent lateral slipping of the belt in transporting and technological machines, as well as theoretical studies of a raw cotton loader.

АННОТАЦИЯ

В данной научной статье рассматривается разработка новой конструкции составного натяжного ролика для предотвращения бокового схода ленты транспортирующих и технологических машинах, а также теоретические исследования перегружателя хлопка-сырца.

Keywords: roller, linear speed of the conveyor belt, required power on the drum shaft, power consumption of the electric motor, driving and driven pulleys, covering belt, signaling sensors, K.P.D. conveyor drive, tension forces, shear force, habasit belt, poli belt, rubbirized belt, resultant force.

Ключевые слова: ролик, линейная скорость конвейерной ленты, требуемая мощность на валу барабана, потребляемая мощность электродвигателя, ведущий и ведомый шкивы, защитная лента, датчики сигнализации, К.Р.Д. привод конвейера, силы натяжения, сила сдвига, лента хабасита, лента поли, прорезиненная лента, равнодействующая сила.

Introduction. Composite tension rollers are used mainly in conveying and technological machines, as well as drives with large gear ratios and small center distances. They make it possible to transmit more power with the same overall dimensions of the transmission. The compound idler is in a heavier condition due to additional bending in the opposite direction.

In this case, the variable component of the stress cycle will be greater than in a transmission without a tension roller. Fig. 1 shows a kinematic diagram of a composite tension roller with an automatic adjusting device for a flat-belt transmission when the axes of rotation of the pulleys and the angle of inclination of the axis of the side parts are not parallel when the composite tension roller rotates.

Literature review. Knowing that the power and rotational speed of the electric motor are known, we can determine the calculated speed of movement for different diameters of the drive pulley:

$$V_1 = \frac{\pi \cdot D_1 \cdot n}{60}, V_2 = \frac{\pi \cdot D_2 \cdot n}{60} \quad (1)$$

where D_1, D_2 are the diameters of the driving and driven pulleys. [1].

The circumferential force F_t and the resultant F_B force in the belt drive according to the kinematic diagram shown in Fig. 1 are determined by the formulas:

$$F_B = \frac{60 \cdot k \cdot P}{\pi \cdot D \cdot n_{ДВ}} \quad (2)$$

where P - is the power consumption of the electric motor;

K - is the coefficient taking into account the type of belt.

Figure 1. Kinematic diagram of a compound idler roller

1, 2-driving and driven pulleys, 3- covering belt, 4- integral tension roller, 5- signaling sensors, 6- roller axis tilt mechanism, 7- automatic adjusting device.

According to the kinematic diagram in Fig. 1, the shear force arising from the non-parallelism of the axes of rotation of the pulleys is determined

$$F_{CD} = \frac{60 \cdot k \cdot P}{\pi \cdot D \cdot n} \cdot \sin \beta \quad (3)$$

where η is the angle of deviation of the axis of rotation of the driven pulley relative to the axis of the driving pulley.

Methodology. In the future, we will consider the derivation of the formula for determining the shear force for the raw cotton loader when the drum axes are not parallel. Shear force in the conveyor of the raw cotton loader.

$$F_{\text{шб}} = \frac{k \cdot P_T}{\eta \cdot V} \cdot \sin \beta \quad (4)$$

where η - K.P.D. conveyor drive;

V - linear speed of the conveyor belt;

P_T - required power on the drum shaft:

$$P_T = \frac{\lambda \cdot T_{\text{ш}} \cdot \omega}{1000} \quad (5)$$

where λ is a coefficient taking into account the nature of the convey or operation .

The torque is determined according to:

$$T_{\text{ш}} = (S_{\text{шб}} - S_{\text{шз}}) \cdot \frac{D_{\text{ш}}}{2} \quad (6)$$

where $S_{\text{шб}}$, $S_{\text{шз}}$ - tension forces in the incoming and outgoing branches of the conveyor. Table 1 shows similar calculations for determining the shear force in a composite tension roller with an automatic regulating device for a flat-belt transmission according to (3).

Research results. Analysis of the calculation results given in Table 1 shows that the value of the shear force varies within 80 ... 200 N. With an increase in the linear speed of the conveyor belt of the raw cotton loader, the shear force decreases, so at $V = 6 \text{ m/s}$ $F_{CD} = 80 \text{ n}$, and at $V = 8 \text{ m/s}$ $F_{CD} = 77 \text{ n}$. It was revealed that the load from raw cotton has an insignificant effect on the change in the shear force. The main parameter affecting a significant change in the shear force of the conveyor of the raw cotton loader is the change in the angle of inclination of the rotation axes of the working drums, so at $\beta = 4^\circ$, $V = 6 \text{ m/s}$, $F_{CD} = 80 \text{ n}$, and at $\beta = 10^\circ$, $F_{CD} = 210 \text{ n}$. Analysis of the results of calculating the shear force for a composite tension roller of a flat-belt transmission showed that the change in the magnitude of the shear force not only depends on the change in the angle of inclination of the pulley axis and speed modes, but also on the type of belt. type of belts. When the angle of deviation of the axis of rotation β of the driven pulley for the Habasit belt

$$\beta = 4^\circ,$$

$F_{CD} = 31.63 \text{ n}$, and for the "Rubberized" belt $F_{CD} = 37.13 \text{ n}$. In other cases, the difference between the sheave sheaves at the same angles of misalignment of the pulleys for the types of belts under consideration does not exceed 3.5 ... 4.0 n. The maximum value of the shear force at $\beta = 4^\circ$ (rubberized belt), $V_1 = 5.58 \text{ m/s}$. This is due to the fact that the coefficient of friction of the belt with the pulleys is higher for the rubberized belt relative to "Habasit". It can be seen from the table that a change in the angle of non-parallelism of the axes of the pulleys significantly affects the magnitude of the shear force. It was also revealed that with an increase in the linear speed of the belt, the magnitude of the shear force decreases, the kinetic energy increases, as well as the inertia of the system.

Table 1.

Basic parameters affecting the lateral displacement of the conveyor belt of the raw cotton loader at idle and load conditions

			Without load			With load		
№	V, m/s	b, grad	F _В , N	P, Vt	F _{CD} , N	F _В , N	P, Vt	F _{CD} , N
		4			77			80
1.	6	6	1100	2286	80	1130	2359	123
		8			153			158
		10			210			217
		4			65			67
2.	7	6	925	2151	105	953		110
		8			130			133
		10			212			220

Dependence of the shear force $F_{сд}$ on the deflection angle of the axis β^0 of rotation of the driven drum at idle and load conditions.

Table 2.

Theoretical dependence of the shear force $F_{сд}$ on the change in the deviation angle of the driven pulley axis relative to the driving pulley axis at different speed modes of movement

Types Belts	Deviation-angle, grad	Shear force $F_{сд}$ (N) at		
		V_1	V_2	V_3
1. Habasit	1	8	7	5,82
	2	15,8	14	11,6
	3	23,7	20,85	17,38
	4	31,63	27,83	23,2
2. Poli-belt	1	8,62	7,6	6,3
	2	17,2	15,13	12,6
	3	25,8	22,7	18,9
	4	34,4	30,3	25,2
3. Rubberized	1	9,3	8,2	6,83
	2	18,6	16,34	13,6
	3	27,8	24,5	20,4
	4	37,13	32,7	27,2

In order to balance or eliminate the shearing force that occurs due to the non-parallelism of the axes of rotation of the drums (pulleys), the axis of the recommended composite tension roller must be installed obliquely in the opposite direction from the skew angle of the drum axes.

The resultant force is equal to:

$$\bar{F}_B = \bar{F}_B^n + \bar{F}_B^t \quad (7)$$

$\bar{F}_B^n$ и $\bar{F}_B^t$ – respectively, the normal and tangential components of the resultant force.

Frictional force during belt descent

$$F_{TP} = f \cdot F_B^n \quad (8)$$

where f is the coefficient of friction between the belt and the composite tension roller.

$$F_{сд}^1 = F_B^t = F_B \cdot \sin \alpha, \quad (9)$$

where α is the angle of inclination of the axes of rotation of the composite tension roller relative to the vertical plane

Condition for compensation of the belt coming off the pulley

$$F_{\text{тр}} + F_{\text{сд}} \cdot \cos(\alpha + \beta) \geq F_{\text{сд}}^1, \quad (10)$$

where $\square$ - is the angle of rotation between the axes of rotation of the driving and driven pulleys.

The formula for determining the angle of inclination of the axis of the composite tension roller relative to the vertical plane has the form [3]:

$$\alpha \geq \arctg \left(\frac{1 + \sin^2 \beta}{f + \frac{1}{2} \cdot \sin 2\beta} \right) \quad (11)$$

To clarify the calculated indicators of the belts of foreign firms "Habasit", "Poly Belt", Table 3 is given. It can be noted from the table that all data are indicative values under normal climatic conditions, i.e. $t = 20^\circ \text{C}$ and air humidity 65% [2].

Table 3.

Estimated indicators of conveyor belts of foreign firms "Habasit" and "Poly Belt"

Indicators		Habasit	Poli Belt
1.	Ribbon types	SNB-5E	SAB-5E
2.	Transport side, material	PVC	PVC
3.	Transport side, surface	Гладкая	Гладкая
4.	Running side, material: fabric	PES	PES
5.	Thickness, mm	1,6	1,6
6.	Mass of belt, kg/m^2	1,9	1,9
7.	Pulling force for 1% stretching per unit width, кН/мм	5	5
8.	Permissible pulling force per unit of width, КДОН (Н/мм)	9,5	9,5
9.	Tensile strength per unit of width (Н/мм)	75	75
10.	Friction index on the drive drum made of steel μ_a	0,15	0,15
11.	Friction index for the drive drum with adhesion coating, μ_G	0,35	0,35
12.	Friction value on a sliding base made of pickled sheet metal, μ_G	0,2	0,2
13.	Friction index on a sliding base made of Duroplast, μ_G	0,25	0,25
14.	Coefficient of Poisson	0,4	0,45
15.	Shear modulus, satin weave fabric, $G, \text{Н/м}^2$	20...35	20...35

According to the obtained conditions for determining the angle of inclination of the axis of the composite tension roller, a calculation was carried out for different types of belt, the results of which are given in Table 4.

Conclusion. The results of the calculations established the necessary values of the angle of installation of the axis of the composite tension roller, depending on the angle of non-parallelism of the conveyor pulleys of

the raw cotton loader ... So, for $\beta = 5^\circ$, $\alpha = 22^\circ$; at $\beta = 7^\circ$, $\alpha = 24^\circ 26'$ for Habasit and, accordingly, $\alpha = 21^\circ 22' 30''$ for a rubberized belt. It should be noted that the results obtained make it possible to select the necessary parameters of the composite tensioner to prevent the belt (belt) from coming off the pulleys, depending on the modes of movement and the angle of non-parallelism of the drums.

Table 4.

Dependences of the angle of inclination of the axis α° of the composite tension roller by the critical angle of the belt descent β° at normal load $T = T_{\text{nom}}$

Type of belts	Friction coefficient, f	β , grad	α , grad
Habasit	0,34	5	22°20'
		6	23°42'
		7	24°26'
		8	25°06'
		9	25°45'

Type of belts	Friction coefficient, f	β , grad	α , grad
Poli belt	0,32	5	22°06'
		6	22°45'
		7	23°30'
		8	24°00'
		9	24°48'
Rubberized	0,30	5	21°00'
		6	21°36'
		7	22°30'
		8	23°12'
		9	24°00'

The technical and economic efficiency of the proposed belt conveyor with a tensioning device is to increase the reliability and efficiency of the conveyor by eliminating the side slip of the belt.

To study the efficiency of the effective design of the centering tensioner, a prototype was made from the Kaprolon-V material and installed on a conveyor belt of the

TLKh-18 type (Fig. 3). The tests were carried out from 04/24/2018 to 04/23/2019.

Figure 4 shows a general view of the installation of a prototype of the recommended design on a conveyor belt of the TLH-18 type.

Production tests were carried out in a cotton ginning plant at “Expokoller Prin Teks” LLC in the Tashlak region of the Fergana region.

Figure 3. General view of the belt conveyor

Figure 4. General view of a prototype tensioner

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CONTROL MODELS AND INFORMATION SYSTEM OF COTTON STORAGE IN THE CLUSTER SYSTEM

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МОДЕЛИ УПРАВЛЕНИЯ И ИНФОРМАЦИОННАЯ СИСТЕМА ХРАНЕНИЯ ХЛОПКА В КЛАСТЕРНОЙ СИСТЕМЕ

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ABSTRACT

The article presents theoretical studies of the technology of minimal soil grinding for the cultivation of cotton and its combined aggregate and its refinement to determine the stability of the process in the process of removing the softening softener, which processes the soil without perverting, into a strip and is considered main robot organ.

АННОТАЦИЯ

В статье представлены теоретические исследования технологии минимального измельчения почвы для выращивания хлопчатника и его комбинированного агрегата и ее доработка для определения устойчивости процесса в процессе удаления смягчающего пластификатора, обрабатывающего почву без извращения, в полосу. и считается основным органом робота.

Keywords: combined unit, softening resistance, resistance to soil groove, speed, column, impacts, soil density, soil moisture.

Ключевые слова: комбинированный агрегат, смазка, сопротивление размягчению, сопротивление грунтовой канавке, скорость, столб, удары, плотность грунта, влажность грунта.

INTRODUCTION

High-moisture and dirty cottonseeds consist of drying and pre-cleaning to bring them to the weight norms specified in the standards. The implementation of such an operation will allow long-term storage of seed cotton in open and closed warehouses, as well as the impact on the overall technological process of the cotton plant to obtain a quality product, from the creation of information systems based on information systems and other parameters consists of.

METHODOLOGY

Flow cleaning equipment The cotton is dried in the ginning and ginning departments to conditioned humidity, and after being cleaned of weeds, it is sent to the ginnery's main building for ginning. Preliminary processing of ginned cotton is the main operation of the technological process.

in which the cotton fiber is separated from the seed [1].

The main building is a building assembled from several departments that produce finished products of the ginnery. The main body (Figure 1) can accommodate

mainly: ginning and fiber cleaning, fiber waste processing and finishing (pressing) of finished fibrous products.

Figure 1. The main production building of the ginnery

Construction and use of drying kilns. Heat supply of cotton dryers is carried out with the help of a special device heat generators. In them, liquid or natural gas is mixed with atmospheric air at the high temperature

obtained during combustion (up to the desired temperature and weight consumption) to reduce the temperature and transfer the gas-air mixture drying agent to the drying chamber (Fig. 2).

Figure 2. Technological process of drying wet seed cotton

Each cotton drying drum is connected to a heat supply device as usual. The device must be suitable for the heat production capacity, ensure complete combustion

of the fuel and prepare a drying agent in the amount that meets the requirements of the initial processing of cotton, sanitary and technological (Figure 3).

Figure 3. Hot air supply scheme for drying drums

When designing heat generators, it is allowed to use technical kerosene and natural gas from fuels that meet the requirements of current standards in terms of physicochemical composition. Installation and installation of heat generators must comply with the design and fire safety requirements for their assembly, tying, drying, storage and processing of cotton, as well as safety regulations in the gas industry.

- 1 air intake filter chamber;
- 2 heat generators;
- 3-fan;
- 4 smoke pipe;
- 5 gas pipeline;
- 6- spark arrestor;
- 7th supplier;
- 8- drying drum.

Heat generator: To stop the flow of gas in the event of an airflow interruption, it is equipped with control measuring devices and safety automation devices that

prevent the fire in the event of a fire due to a drop in gas pressure in front of the burners and the smoke extractor fails or stops.

Figure 4. Scheme of hot air supply to the drying drums through the generator ИЧ-1,9

Figure 5. Dusting equipment used in the drying and cleaning department

Centrifugal dust collector. Centrifugal dust traps (cyclones) are dry inertial traps that use centrifugal force created by the circulation of air in the trap body to separate the dust. The dust collector body can be cylindrical, cylindrical-conical or conical [2,4].

DISCUSSION AND RESULTS

Each device is characterized by a dust capture effect, which is determined by the following equation [1,4,6].

$$\eta = \frac{G_2}{G_1} * 100, \quad \%$$

where: G_1 - total weight of dust in the treated air, mg;
 G_2 - weight of dust held by the device, mg. The effect of

dust can also be determined by the difference between the air pollution entering and leaving the dust collector.

$$\eta = \frac{d_1 - d_2}{d_1} * 100, \quad \%$$

where: d_1 is the dust of the air entering the dust collector, mg / m³; d_2 is the dust of the air leaving the dust collector, mg / m³.

It is recommended that air be removed instead of the screw conveyor to prevent large amounts of dust from escaping from the dust vents. Figure 6 shows a diagram of different types of conical cyclones [3].

Figure 6. Drawing of a conical cyclone device

1 - rain valve; 2 - inlet pipe; 3 - inner full truncated cone; 4 - outer full truncated cone; 5 - Dust pipe. The total efficiency of several dust collectors installed in series is calculated as a percentage of the following equation:

$$\eta = [1 - (1 - \eta_1) * (1 - \eta_2) * k * (1 - \eta_3)] * 100, \%$$

where: η_1, η_2, η_n is the dust retention effect expressed in units of each step set in series.

Table 1.

Basic indicators of cyclones

Cyclone type	Cyclone diameters, mm	Height, mm	Air consumption, m ³ / s	Hydraulic resistance Pa	Cyclone cleaning fruit, %
SS-6	2300	6800	6	630	85
USV-ZM	1500	4500	3	650	90
SP-3, SL-3	1614	4450	3	650	86
USV-1,5	1000	3100	1,5	700	88

Opposite - anti-dust catchers. equipment with opposite circulation flow are dry type dust collectors. The manufactured VZP vacuum cleaner is also successfully used in chemical and other industries. One of the main features when comparing them with other cyclones is their high efficiency (Figure 7). The VZP-800 and VZP-1200 dust collectors consist of a cylindrical body with a tangential slide 2 at the bottom, an inlet pipe 3, which is placed and operates to transmit the primary flow of placed and dusted air. Cylindrical suction at the axial boundary of the rotated [3, 5].

Figure 7. Schematic of VZP vacuum cleaners

It is connected to the top of the cone. Placed on the outer surface of the rotator (insert washer) (5), its shape is truncated conical. The hopper part (6) is attached to the perforated vacuum cleaner vacuum-valve flange. At the top of the vacuum cleaner is a tube (7) for venting fresh air. This pipe also circulates the dusty air from the second stream at the same time. A secondary dust air distribution valve (9) is located in the primary dust air inlet pipe.

Improved VZP-MZ vortex dust collectors. They have been redesigned to increase the efficiency of VZP type vacuum cleaners. The improvement of the VZP dust collector was mainly carried out on the design of a secondary high-flow vortex, taking advantage of the spiral transmission of air flow. Work has been done to change the relative cross-section of the hull air duct and the inlet pipe. The modernized vortex vacuum cleaner VZP-MZ is shown in Figure 5, and the technical description is given in the table [6, 7, 8].

Table 2.

Technical description

Indicators	VZP-800	VZP-1200	VZP-MZ
Rated for fresh air productivity, (m ³ / s): amount of consumption.	3 0,65-0,85	6 0,65-0,85	3 0,65-0,85
Aerodynamic resistance, Pa 1 Pa - at 0.65	1100	850	1000
Pa - at 0.85	1800	1500	1500
Air purification efficiency, percent: fiber in the air transport system of cotton and in the fluff air transport system	93-95 97-98	91-93 97-98	94-96 —
in the air intake system of gin-linter machines	97-98	97-98	—
at the site of regeneration	98	—	—
in the aspiration system of the seed cleaner	98	—	—
Vacuum-valve engine power, kW	2,2	2,2	2,2
Overall dimensions, mm: Height diametric of bunker parts	4800 1200	7100 1800	5360 1200
weight, kg	600	910	600

Figure 8. Database structure

Figure 9 shows the tools and general structure indicators that can be used to monitor cotton control.

Figure 9. The mechanism of operation of the web system in the monitoring process

We can see the database architecture shown in Figure 13 for collecting signals from smart sensors and devices for storing and controlling cotton [9].

Web and mobile applications are created for the software based on the model and system, as shown in Figure 14.

Figure 10. Software for information system management and monitoring

CONCLUSION

The production of new progressive machines for the initial processing of seed cotton requires the expansion of design, experimental and research work, the development of the machine base and technology of ginning.

Based on the current tasks of modernization of technological equipment, in this dissertation the issues of improving the design of the PLA seed storage device were considered and the necessary calculations were made.

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METALLURGY AND MATERIALS SCIENCE

DOI - 10.32743/UniTech.2021.92.11.12560

TECHNOLOGY OF INTEGRATED PROCESSING OF STEEL-MELTING DUSTS

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ТЕХНОЛОГИЯ КОМПЛЕКСНОЙ ПЕРЕРАБОТКИ ПЫЛЕЙ
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ABSTRACT

The processing of dust from steel-making furnaces requires special attention, since, firstly, it is impossible to simply use them as an additive to the charge (this will worsen the quality of steel); secondly, it is not subject to burial in the ground, since soil poisoning is possible; thirdly, it is advisable to extract valuable components (except for iron) contained in such dust from such dust.

АННОТАЦИЯ

Переработка пыли сталеплавильных печей требует особого внимания, так как, во-первых, просто использовать их в качестве добавки в шихту нельзя (это ухудшит качество стали); во-вторых, она не подлежит захоронению в земле, так как возможно отравление почвы; в-третьих, из такой пыли целесообразно извлекать содержащиеся в ней ценные (кроме железа) компоненты.

Keywords: steel furnace dust, collection, petroleum coke, sintering.

Ключевые слова: пыли сталеплавильных печей, улавливание, нефтяной кокс, спекание.

Introduction. The introduction of modern technologies aimed at increasing the complexity of the use of raw materials, the use of resource and energy saving technologies, the utilization of all valuable components in waste and intermediate products of metallurgical production is caused by a decrease in the content of metals in processed ores, depletion of rich and easily opened ore deposits and increased requirements for environmental protection [1].

Ferrous metallurgy of the Republic of Uzbekistan is represented by such an enterprise as JSC "Uzmetkombinat" [2]. The main source of raw materials for steel smelting is iron-containing scrap of various compositions. Steel smelting at the enterprise is carried out in an arc steel-making furnace. Smelting produces a large amount of dust carried away by the waste gases. The dust of steel-making furnaces, in addition to iron-containing components, contains a significant amount of zinc in the form of zinc oxide (ZnO up to 17%) [3].

Scrap metal is the main source of impurities such as Zn and Pb entering steelmaking units (galvanized iron, brass and bronze parts, electrical cable sheaths, etc.).

The composition of the removed dust is significantly influenced by the composition of the charge [4]. This effect is especially noticeable when steel is smelted in electric arc furnaces. The processing of such dust requires special attention, since, firstly, it is impossible to simply use them as an additive in the charge (this will worsen the quality of the steel); secondly, it is not subject to burial in the ground, since soil poisoning is possible (burial in the ground is prohibited in a number of countries); thirdly, it is expedient to extract from such dust the valuable (except for iron) components contained in it [5].

Materials and research methods. The object of research was the dust of steel-making furnaces of JSC "Uzmetkombinat". To date, over 60,000 tons of zinc-containing dust from the gas cleaning plant of the ESPC have been accumulated in special warehouses. An additional 12,000 - 13,000 tons of zinc-containing dusts are generated annually [6].

The chemical composition of steel-making dusts obtained from JSC "Uzmetkombinat" is shown in Table 1.

Table 1.**Chemical composition of steel-making dusts**

Compounds	Content, %
Fe _{total}	31,2
Fe ₂ O ₃	41,6
FeO	4,6
P ₂ O ₅	0,2
SO ₃	0,9
SiO ₂	3,4
ZnO	16,2
PbO	1,36
CuO	0,36
C	2,4
CaO	3,4
Al ₂ O ₃	0,9
MnO	3,7
MgO	-
Cr ₂ O ₃	0,6
NiO	0,03
TiO ₂	0,14
Na ₂ O	10,4

Petroleum coke of the Fergana Oil Refinery (FOR) was chosen as reducing agents for zinc oxide and iron oxides contained in steel-making dust [7].

Petroleum coke is a complex dispersed system in which the dispersed phase consists of crystalline formations (crystallites) of different sizes and ordering in the mutual arrangement of molecules and pores, and the dispersion medium is a continuous gaseous or liquid phase that fills the pores of crystallites, from which adsorption-solvation layers are formed, or solvate complexes. Despite the unequal preparation conditions, the crystallites have similar sizes and are packets of parallel layers (planes). Crystallite sizes (in nm): plane length $a = 2.4-3.3$, packet thickness $c = 1.5 - 2.0$, interplanar distance $0.345 - 0.347$ [8].

Results and its discussion. To determine the optimal reductant and its consumption, experiments were carried out using petroleum coke from the Fergana Oil Refinery (FOR) and brown coal from the Angren open pit as reductants.

Based on the industrial experience of the process of Waelz zinc cakes and information obtained from the analysis of literature sources, it was decided to take the amount of coke from the FOR loaded into the charge

equal to 40% of the dust mass (average carbon content in the coke is 95%).

When brown coal from the Angren open pit was used as a reducing agent, a lower carbon content in it (73.44%) was taken into account compared to coke, based on this, the amount of coal added to the charge was increased to 52% of the dust mass ($95: 73.44 * 40 = 52$).

The weighed amount of dust for the preparation of the charge with petroleum coke was 20 g, and the amount of added coke was 8 g.

The weighed amount of dust for the preparation of the charge with brown coal was also 20 g, and the amount of added coal was 10.4 g.

The prepared charge was loaded into a fireclay crucible and installed in a shaft furnace preheated to 1200°C and fired for 90 minutes. After a specified time, the crucibles with weighed portions were removed from the furnace and cooled to room temperature.

The residual content of zinc in the clinker and the degree of reduction of iron oxides were carried out on an atomic absorption analyzer in the laboratory "Physicochemical research methods" of the State Enterprise "Institute of Mineral Resources". The results of the analyzes are shown in table. 2.

Table 2.

Zinc content in the original sample and after firing

№	Sample name	Average Zn content, %
1	Initial sample of dust	16,78
2	Clinker (charge: dust 20 g + petroleum coke 8 g)	14,5
3	Clinker (charge: dust 20 g + coal 10.4 g)	13,4

From the data given in the table it can be seen that when using coal as a reductant, the zinc content in clinker is lower than when using petroleum coke. Based on the results obtained, as well as taking into account the cost of petroleum coke (about 2.4 million soums per ton), which exceeds the cost of coal (about 0.5 million soums per ton) and the high sulfur content in coke, which is a harmful impurity for steel, it was accepted solution to use Angren brown coal as a reducing agent.

The results of the experiment show that the zinc content in the clinker remains high, this can be explained

by many reasons, the main of which is the lack of reducing agent and insufficient firing temperature.

To determine the optimal amount of the reducing agent, it was decided to increase the consumption of the reducing agent (coal). Three samples were prepared with a coal content of 65, 80 and 90% of the dust mass in the charge. All three samples were fired under the same conditions (1200°C , 90 min). The firing results are shown in Table 3 and Fig. 1.

Table 3.

Zinc content in clinker versus the amount of reducing agent in the charge

№	The amount of reducing agent in the charge in% of the mass of dust	Residual zinc content in clinker, %
1	52	13,4
2	65	10,56
4	80	7,98
5	90	7,98

Figure 1. Dependence of the zinc content in clinker on the consumption of the reducing agent

From the research results given in Table 3 and Figure 1, it can be seen that with an increase in the amount of coal in the charge to 80-90% of the dust mass, the zinc content in the clinker decreased to 7.98%. The extraction of zinc in sublimates is 52.4% $(16.78 - 7.98) : 16.78 = 52.4\%$.

The choice of the optimal temperature 1200 °C is explained by the fact that at this temperature the degree of zinc sublimation according to the reaction $\text{ZnO} + \text{Fe} = \text{FeO} + \text{Zn (g)}$ has large values (Table 4.).

Table 4.

Zinc vapor pressure during its sublimation

Temperature, °C	Zinc vapor pressure, barr
1000	85
1100	363
1200	1260

Based on the data given in the table, it can be concluded that a further increase in temperature will favorably affect the stripping of zinc, however, the limitation of the temperature regime is caused by the presence of low-melting components, which, when reflowed, cover the pores of solid particles, causing an obstacle to the stripping of zinc into the gas phase.

Iron present in steelmaking dust during the reduction roasting process is also reduced from oxide compounds to metal. The reduction of iron oxides with carbon is described by the reactions:

The resulting metallic iron during the reduction firing of steel-making dusts will increase the extraction of zinc into sublimates; it will restore zinc from oxide by the reaction:

In addition, due to the carburization of iron at a temperature of 1150 °C, cast iron will be formed. As a result of reductive roasting, the zinc content in the dust will decrease due to the distillation of zinc into the gas phase and a solid product, the so-called "clinker", is obtained, in which the bulk of the iron will be in metal form, which will allow it to be remelted in steel-making furnaces without preliminary preparation.

The results on the reduction of iron oxide when carrying out a reductive roasting with coal as a reducing agent are shown in Table 5.

Table 5.

Iron oxide reduction rates

№	Sample name	Fe, %	FeO, %
1	Initial steelmaking dust	31,3	2,54
2	Clinker after reduction firing	31,8-34	< 0,02

Atomic absorption analysis determined the content of zinc in the sublimates. The zinc content in sublimates is 64.41%.

Conclusion. The problem of involving dust in the steelmaking industry is especially acute at the present time, when the enterprises of the ferrous metallurgy of the Republic are experiencing a shortage of raw materials. At present, the warehouses of Uzmetkombinat JSC have accumulated 60 thousand tons and annually generate 10 thousand tons of steel-making dusts with a ZnO content of up to 17%.

One of the solutions to this problem may be to reduce the amount of zinc charged into the steelmaking furnace along with the raw materials.

The studies carried out have established that the stripping of zinc and the reduction of iron oxides, possibly by means of reductive roasting. The use of brown coal from the Angren deposit is proposed as a reducing agent.

For the practical implementation of the proposed technology, it is proposed to use the existing technology and hardware design of the Waelz zinc cakes used at the zinc plant of the Almalyk Mining and Metallurgical Combine.

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DOI - 10.32743/UniTech.2021.92.11.12633

**RELEVANCE OF THE USE OF FERROUS ALLOYS FOR MELTING HIGH-QUALITY STEEL
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ABSTRACT

The article discusses a characteristic feature of modern metallurgy and the mineralogical composition of poor iron-titanium-vanadium ores of the Tebinbulak deposit for smelting high-quality steel. For this study, an average representative sample of the ore was worked out. The results obtained show that the use of such ores will increase the productivity of high-quality steel.

АННОТАЦИЯ

В статье рассмотрены характерной особенности современной металлургии и минералогический состав бедных железо-титано-ванадиевых руд месторождения Тебинбулака для выплавке качественной стали. Для проведения этого исследования была отработана среднее представительная пробы руды. Полученные результаты показывает, что использование таких руд позволит повысить производительность качественной стали.

Keywords: steel, properties, beneficiation, ore, size, concentrate, density, composition, fusibility, mineral, magnetite.

Ключевые слова: сталь, свойства, обогащения, руда, крупность, концентрат, плотность, состав, плавкость, минерал, магнетит.

INTRODUCTION. A characteristic feature of modern metallurgy is the fact that the quality of the currently mined metals is unsuitable for the direct production of metals from them, and their processing is economically unprofitable without preliminary enrichment. When enriching the resulting concentrates with a high content of the valuable component, the volume of the material subjected to metallurgical smelting is significantly reduced [1].

The development of enrichment technology significantly expanded the raw material base of the industry, made it possible to involve new deposits of ferrous and non-ferrous metals in active reserves. Currently, concentration processes play a primary role, and in the use of ore raw materials, in the production of almost all types of metals [2].

Modern processing plants process millions of tons of minerals every year. Every year, the enrichment technique is being improved, new technological schemes, new more productive equipment are being created, new types of minerals are being mastered and the extraction of valuable components from them is increased [3].

THE RESULTS OF THE RESEARCH OBJECT METHODOLOGY. The ores of the Tebinbulak deposit are disseminated (prevailing at 97%), densely disseminated and massive. The main ore mineral is titanomagnetite, which consists of magnetite with thin lamellar ilmenite injections. Hematite is also present. Both ores and barren pyrrhotites with pyrite-chalcopyrite mineralization contain native gold and platinum, as well as gold tellurides, sulfides and platinum arsenides. In terms of the average content of the main components (Fe - 16.2%, TiO₂-2%, and vanadium pentoxide - 0.15%), the Tebinbulak ore is similar to the Ural - Kachkanarsky (Russia), from which they differ only by a 1.5-fold increase in the content titanium dioxide.

For research, the average representative sample of ore was worked out, the composition of which for the main components is presented above.

The conducted mineralogical analysis showed that washing by washing is not suitable for this ore [4].

Taking into account the difference in specific gravity of useful materials and waste rock and rather large dissemination of ore particles, the study of the possibil-

ity of gravity concentration. The experiments were carried out on a laboratory concentration table. The size of the original ore varied from 1 to 0.1 mm.

Experiments with enrichment on a concentration table did not give positive results. No tailings were received. A large amount of iron and titanium is lost in the tailings and slags, apparently due to the iron-titanium-containing minerals of the gangue. It follows from the above data that the enrichment of the studied ore by concentration on steels is not effective.

The possibility of enriching the original ore by wet magnetic separation was investigated. The size of the original ore ranges from -1 to -0.074 mm. The strength of the magnetic field was taken from 600% to 1200 oersted. With a magnetic field direction of 900 oersted. With a magnetic field of 900 oersted, the concentrate yield was only 9.15%. The results of experiments carried out at other magnetic field strengths show that this ore is not amenable to enrichment by the method of wet magnetite separation with satisfactory technical and economic indicators. Regardless of the size of the starting material, the number of cleanings of the concentrate and the strength of the magnetic field, a rather low concentration of iron and titanium dioxide in the concentrate is observed. In the best experiments, the concentrate contains 31, 37% Fe with a yield of about 15%. The work provides data on the studies carried out on the magnetic enrichment of this type of ore at the Institute of Mineral Resources of the Ministry of Geology of Uzbekistan and the Uralmekhanobr Institute (Russia). At the same time, iron-vanadium concentrates were obtained, with an iron content of 63.8%, and titanium dioxide (4.6%), vanadium pentoxide (0.6%). Titanium magnetite concentrate contains an insignificant amount of sulfur (0.018%), therefore, during metallurgical processing, sulfur will not practically affect the quality of the metal [5].

The above data are much better than those obtained in our studies. Most likely, the studies were carried out with different starting materials. The thing is that at the Tebinbulak deposit there are areas with different iron contents. The iron content in them ranges from 16.2 to 65.4%. Apparently, the studies carried out in the Institute of Mathematics and Mechanics and Uralmekhanobra were carried out with richer materials than ours. In the work itself, the composition of the source material is not given. In any case, even a concentrate containing more

than 60% iron cannot be used without preliminary reduction in the charge of steel-making furnaces.

The possibility of flotation recovery of ilmenite from the original ore was also investigated. A wide variety of reagents and flotation modes have been tested. Reindeer acid, tall oil, oxidized petrolatum, pre-saponified soda, and the cationic reagent AIP-14 were used as collectors. All these collectors were tested in a wide range of their flow rates and pulp pH values [6].

CONCLUSION. In terms of the implementation of this program, the JSC "Uzmetkombinat" built and put into operation a modern arc steel-making furnace of the

"Stove ladle" technology, which made it possible to reduce the time of one melting hour 4 hours to 60 minutes. In order to obtain a high-quality stage, a vacuum unit was put into operation, which made it possible to obtain steels with specified properties and characteristics. Already in 2018, a furnace for the production of ferrosilicon was put into operation, previously importing at high foreign exchange costs. All this taken together allowed the JSC "Uzmetkombinat" to rise to a higher modern level of production.

In this regard, the study of the processes of obtaining high-quality steel from poor iron-titanium-vanadium ores using ferroalloys of local production is very relevant.

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INVESTIGATION OF THE POSSIBILITY OF INCREASING THE DURABILITY OF STEEL CASTINGS 110Г13Л

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ИССЛЕДОВАНИЕ ВОЗМОЖНОСТИ ПОВЫШЕНИЯ ДОЛГОВЕЧНОСТИ СТАЛЬНЫХ ОТЛИВОК 110Х13Л

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ABSTRACT

The study of the structure and properties of modern steels for cast parts of mining equipment showed that high-manganese austenitic steels 110Г13Л (Hadfield steel) remain promising for their manufacture. The purpose of this work is to analyze the technology for the production of cast linings for ore-grinding equipment from this steel grade. The results of factography, macro- and microstructural analysis of the alloy structure, carried out at Production Association "Navoi Machine-Building Plant", showed that porosity and voids are formed in the central part of the casting, and microporosity

- along the entire section of the casting, including in thin sections. This will make it possible to adjust the technology for producing castings from 110Г13Л steel. Microstructural analysis carried out by specialists of Production Association "Navoi Machine-Building Plant" showed that in the cast state for steel 110Г13Л, the desired steel structure is the dendritic structure of austenite grains, in the body and along the grain boundaries of which excess carbides are located. The modification helps to reduce the grain size of the austenite. Heat treatment helps to relieve casting stresses and obtain a homogeneous austenitic structure by dissolving excess carbides. The most desirable structure after heat treatment is an austenitic structure, with martensite on the surface of the casting resulting from a high cooling rate.

АННОТАЦИЯ

Изучение структуры и свойств современных сталей для литых деталей горнорудного оборудования показало, что высокомарганцевые аустенитные стали 110Х13Х (сталь Хадфилда) остаются перспективными для их изготовления. Целью данной работы является анализ технологии производства литых футеровок для рудоразмольного оборудования из данной марки стали. Результаты фактографии, макро- и микроструктурного анализа структуры сплава, проведенного на Производственном объединении "Навоийский машиностроительный завод", показали, что пористость и пустоты образуются в центральной части отливки, а микропористость - по всему сечению отливки, в том числе в тонких сечениях. Это позволит скорректировать технологию производства отливок из стали 110Х13М. Микроструктурный анализ, проведенный специалистами Производственного объединения "Навоийский машиностроительный завод", показал, что в литом состоянии для стали 110Х13Х желаемой стальной структурой является дендритная структура.

Keywords: mill linings; crusher linings; mining equipment; steel; Foundry; chemical composition; mechanical properties; carbides, structure; modification; heat treatment.

Ключевые слова: футеровки мельниц; футеровки дробилок; горное оборудование; сталь; литейное производство; химический состав; механические свойства; карбиды, структура; модификация; термическая обработка.

INTRODUCTION

With the development of the mining industry in the Republic of Uzbekistan, in the 60s, the Navoi Mechanical Repair Plant (now the Production Association "Navoi Machine-Building Plant") was built. The development of castings from high-manganese wear-resistant steel 110Г13Л at this plant began immediately after its launch, since wear-resistant steels have already firmly established themselves in this industry [6, 9, 10]. Today, they are used to manufacture linings for ore grinding mills, caterpillar tracks, excavator bucket teeth, tooth crowns, incl. lining of the bowl and cones for crushers MP - 1000, weighing 6.4 and 7.3 tons, respectively. To date, the volume of production of 110Г13Л steel castings at the plant is more than 250 tons. in year.

Failure of the above units and mechanisms, caused by their breakdown or rapid wear, is the main factor determining the overhaul life of equipment, and leads to a reduction in ore extraction, reduces productivity and production efficiency.

Parts operating under conditions of shock-abrasive wear are traditionally made of steel 110Г13Л. This is due to the operational properties of this steel, in particular, its high resistance to impact and abrasive wear.

The chemical composition and mechanical properties of 110Г13Л steel are regulated by ГОСТ 977-78 (see Table 1). However, the wide range of concentrations of carbon, silicon and manganese, all other things being equal, do not guarantee the constancy of mechanical and operational properties even for parts of the same purpose. Insignificant deviations of chemical elements (C, Si, S) from the requirements of ГОСТ 977-78 and insignificant changes in the melting conditions of steel 110Г13Л lead to inconsistency in the mechanical properties of the alloy with the requirements of regulatory and technical documentation [1, 2, 9, 10].

Today, there are various ways to improve the quality of 110Г13Л steel. One of the promising methods is alloy modification. Modification makes it possible to qualitatively change the technology for producing castings. However, the widespread use of modification in the practice of foundry production is hindered by the instability of the achieved effect due to the sensitivity of the process to the conditions of melting, pouring and uniform distribution of modifiers in the volume of the melt [3, 4, 9, 10]. Creation and application of ultradispersed (fraction sizes up to 1000 nm) and nanodispersed (fraction sizes up to 100 nm) modifiers will provide changes in the structure of liquid melts, increasing the properties of castings.

Microstructures of 110Г13Л steel samples obtained according to the existing technology and after the introduction of a modifier of the "MS" type produced according to TU 1760-001-64101572-2011 were investigated at PO "Navoi Machine-Building Plant".

Analysis of the results of metallographic studies showed that the modification of the melt of steel 110Г13Л made it possible to reduce the amount of non-metallic inclusions, improve the homogeneity of the structure, refine the grain size of austenite, and reduce the number of gas pockets, which, in turn, led to an increase in the density of castings. This improves the operational characteristics of castings - uniformity of load distribution, a decrease in the likelihood of cracking under shock loads, the formation of gas pores, thereby reducing the number of chips on castings [4, 5, 7, 8].

The purpose of this work is to analyze the technology for the production of cast linings for the MP-1000 crusher.

METHODIC

The studies were carried out with the use of the equipment "TEKHNOPARKA" of the Navoi State Mining Institute and the Central Laboratory of the Production Association NMP.

Models, molds, melting and knocking out of experimental casts of lining of the crusher MR - 1000 were produced in the foundry of PO NMP using the following equipment: mixer 1504M; shaking pneumatic casting molding machine with a transfer table, model 234MK; three-phase arc furnace ДСП-6 and knock-out grate model 31215.

To determine the chemical composition of the steel, a SPECTROMAX optical emission spectrometer (made in Germany) was used.

Determination of hardness is carried out on a TSh-2M hardness tester (TOCHPRIBOR, Russia).

The microstructure of the steel was studied using an MMP-4 metallographic microscope (LOMO, Russia).

Mechanical properties were determined on a R-50 tensile testing machine (Russia) with a force of 500 kN.

For the experiments, 110Г13Л steel was taken, the chemical composition of which is shown in Table 1.

Table 1.

Chemical composition of steel 110Г13Л

The elements	C	Si	Mn	S	P	Cr	Ni	Mo	Cu
Experimental melting № 295	1,10	0,45	12,08	0,038	0,113	0,47	0,17	0,03	0,08
According to ГОСТ 977-88	0,90-1,50	0,30-1,00	11,50-15,0	≤0,05	≤ 0,12	≤ 1,0	≤ 1,0	-	-

RESULT AND DISCUSSIONS

The results of studies of the macro- and microstructure are shown in Fig. 12.

The microstructure of 110Г13Л steel in the cast state is coarse-grained austenite and carbides located in the body and along the grain boundaries of austenite (Fig. 1a).

Figure 1. Micrograph of a 110Г13Л steel sample before (a) and after (b) heat treatment, x100

During quenching, carbides located in the body and along the boundaries of austenite grains are completely dissolved. After quenching, the microstructure of the steel is coarse-grained austenite (Figure 1b).

The study of the fracture surface of the witness specimens cast together with the linings was carried out using an MB-8 microscope. The macrostructures of the samples before (in the cast state) and after quenching are shown in Fig. 2.

Figure 2. View of the fracture of the cast witness specimen (a) and the witness specimen after heat treatment (b)

In Fig. 2a, an uneven structure of the cast sample is observed, the fracture of the cast sample is brittle-ductile. After heat treatment, the austenite grain is crushed (Fig. 2b), the value of the viscous component is greater than in the as-cast state, less shiny crystals indicate a higher toughness of the alloy.

The mechanical properties of 110Г13Л steel in the cast state and after heat treatment were determined on a R-50 tensile testing machine with a force of 500 kN. The research results are presented in table. 2.

Table 2.

Mechanical properties of samples

Mechanical properties	$\sigma_{0,2}$, MPa	σ_b , MPa	δ , %	Ψ , %	Hardness, HB
Cast steel condition	301	436	0,02	0,06	231-246
After heat treatment	352	650	36	38	187-193, 205
Reference data from the steel brand	350-380	650-830	34-50	34-43	186-229

Brinell hardness as cast HB 231-246, after heat treatment (austenitization) HB 187-193. On the surface of the sample, due to the high cooling rate, martensitic regions with a hardness of HB 250 are observed.

The conducted studies of the structure and properties show that this steel can be used for the manufacture of linings operating for impact-abrasive wear. However, during the operation of the linings, the cases of their premature destruction became more frequent (see Fig. 3). To establish the causes of the breakage, a macrostructural and microstructural analysis of the lining fracture was carried out.

Macrostructural analysis of the lining fracture showed that over the entire surface of the casting there are micropores, porosity and voids (casting cavities) are also present in the central part of the casting, see Fig. 3. Visual inspection of the fracture was carried out using a magnifying glass x6 and x10 times.

Samples from the broken part of the lining for metallographic studies were cut out on a MECATOME T330 cutting machine (made in France), using a coolant. The preparation of the microsection was carried out on the NERIS grinding and polishing machine (made in Latvia).

In fig. 4 shows a diagram of cutting out samples for studying the microstructure. Porosity and voids are observed in the central part of the casting, and microporosity is observed throughout the entire section of the casting. An accumulation of gas pores is visible on the surface of the lining with the naked eye.

Numerous pores and non-metallic inclusions observed at small (X30 -50) magnifications in all microsections (see Fig. 7 - 12) are the result of poor-quality charge or insufficient deoxidation of the metal during smelting.

Figure 3. Lining failure surface

Figure 4. Scheme of cutting out samples for metallographic studies

A schematic of cutting out samples for metallographic studies is shown in Fig. 4.

Figure 5. Micrographs of image No. 1 before (a) and after (b) etching, magnification x50 and x100

From the provided micrographs of sample No. 1, it can be seen that micropores are observed over the entire surface of the sample, porosity and voids (casting cavities) are also present in the central part of the casting, see Fig. 5.

Manganese oxide is observed on the surface of sample No. 2 along the grain boundaries of austenite. Figure 6 shows the location of manganese oxide. An un-etched section is characterized by the presence of a black eutectic, which stretches along the grain boundaries of austenite. Etching of a thin section for the detection of manganese oxide with a 10% solution of hydrochloric acid in alcohol causes almost complete etching of the eutectic (Fig. 6b). This allows us to state that the above eutectic mainly consists of manganese oxide. There is an inverse relationship between the tensile strength, the narrowing

of the cross-section, the relative elongation, the impact toughness of the steel and the content of manganese oxide in it, i.e. with an increase in the amount of manganese oxide in the metal, the above properties decrease. The concentration of manganese oxide in manganese steel varies widely and ranges from 0.01 - 0.15%. With an increase in the content of manganese oxide in the metal, its relative wear increases. Consequently, a decrease in the content of manganese oxide in manganese steel is one of the effective factors that provides a significant increase in the wear resistance of castings. The nature of the effect of manganese oxide in steel on the wear resistance of the latter can be explained by the fact that manganese oxide is located at the grain boundaries of austenite, see Fig. 6.

Figure 6. Micrographs of image # 2 x100, before etching (a) and after etching (b) at x300 magnifications

Figure 7. Micrograph of sample No. 3: a - after etching, grains and dendrites of austenite are observed, x100; b - non-etched microsection, gas pores and non-metallic inclusions are observed over the entire surface of the microsection, x50

Figure 8. Micrographs of samples No. 4 and No. 5: Grains and dendrites of the solid solution of austenite, non-metallic inclusions and micropores are observed along the entire plane of the microsection. Increase. X100

Thus, the analysis of the reasons that caused the destruction of the lining showed:

1. The surface of the fracture is non-common and on the surface of the fracture, with the naked eye, an accumulation of non-metallic inclusions is observed. Gas pores are observed over the entire fracture surface.

2. The microstructure shows the presence of non-metallic inclusions, obviously associated with poor quality charge or insufficient metal deoxidation during smelting.

3. Refined results of macro- and microstructural analysis showed that steel requires more thorough deoxidation.

In world practice, to improve the quality of steel, methods of out-of-furnace treatment by modification

with the help of modifiers in the form of powders are widely used. The positive effect of modification on the macrostructure, grain size and a decrease in the number of non-metallic inclusions and on their shape is noted [5, 6, 9, 10, 11]. Considering the above, for industrial testing and study of the effect of the modifier on the structure of steel 110Г13Л, an experimental set of cone and bowl linings weighing 6.4 and 7.2 tons, respectively, for the MP-1000 crusher was made. A comparative study of the microstructure of castings obtained by the existing technology PO "NMZ" (pl. B103) and after the introduction of the modifier of the type "MS" according to TU 1760-001-64101572-2011 (pl. B106).

The chemical composition of the experimental castings is shown in table. 3.

Table 3.

Chemical composition of experimental melting

Element	The chemical composition of the experimental linings, %		
	B106 (Cone)	B103	according to ГОСТ 977-88
C	0,95	0,95	0,90-1,50
Si	0,48	0,35	0,30-1,00
Mn	13,21	12,71	11,50-15,00
P	0,069	0,047	No more 0,050

Element	The chemical composition of the experimental linings, %		
	B106 (Cone)	B103	according to ГОСТ 977-88
S	0,023	0,019	No more 0,120
Cr	1,64	1,04	No more 1,00
Ni	0,21	0,22	No more 1,00
Mo	0,03	0,03	-
Cu	0,20	0,14	-

One of the promising ways to improve the quality of castings is to modify them with ultradispersed (fraction size up to 1000 nm) and nanodispersed (fraction size up to 100 nm) powdered materials. This direction allows you to qualitatively change the very technology of modification.

The introduction of the modifier was carried out by loading the modifier to the bottom of the ladle, the movement was carried out due to the energy of the falling stream of molten metal. The filling was carried out at a temperature of 1430 +/- 10 C

After the modification of 110Г13Л steel, samples were taken to study the macro- and microstructure and to test them for mechanical properties.

To study the microstructure of modified alloys, microsections were made on a NERIS grinding and polishing machine (Kaunas, Latvia). To reveal the structure, a 4% alcoholic solution of nitric acid was used.

The structure of 110Г13Л steel in the cast state is a dendritic structure of austenite grains, with the location of excess carbides (Mn, Fe) C in the body and along the boundaries of austenite grains (Fig. 28a, b).

Figure 9. Microstructure of a cast steel 110Г13Л without modifier (a) and with modifier MS (b), magnification x100

The micrographs show that the modification contributed to a decrease in the size of the austenite grain.

Figure 10. Micrographs of the unmodified (a) and modified (b) reference specimen, which underwent heat treatment, magnification x100

Carbides in the body of the grain and along the grain boundaries of ausenite are neutralized by subsequent heat treatment (quenching). Micrographs of witness specimens that have undergone heat treatment are shown in Fig. 10.

As a result of the study of the samples without the use of the modifier, the microstructure of the samples was austenite with a value of "-1" points (according to ГОСТ 5939-78) with non-metallic inclusions along the boundaries and in the body of the grain (Fig. 9a). Also, when cutting the samples, gas pores and excess carbides are observed, which reduce the strength and toughness of the steel. The microstructure of the modified samples was austenite, grain size 3 points according to ГОСТ 5639-78, and minor non-metallic inclusions along the boundaries and in the body of austenite grain, see Fig. 9b.

CONCLUSION

The results of research and experimental industrial tests of the microstructure of high-manganese steel samples revealed the effect of the modifier on the microstructure of the samples in comparison with melts obtained using the existing technology, namely: modification of the melt of 110Г13Л steel made it possible to significantly improve the uniformity of the steel structure, reduce the size of the austenite grain, the number of gas pores, the number and size of nonmetallic inclusions, which in turn contributes to an increase in its density and leads to an improvement in its operational properties - it improves the uniformity of the distribution of loads, reduces cracking, the formation of pores and chips.

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**INSTRUMENTATION, PRECISION AND ACCURACY,
DATA MEASUREMENT TOOLS AND SYSTEMS**

DOI - 10.32743/UniTech.2021.92.11.12609

SYNTHESIS OF REGULATORS FOR ASYNCHRONIZED FAN MOTOR**Odil Jumaev**

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**СИНТЕЗ РЕГУЛЯТОРОВ
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ABSTRACT

The modern development of the use of intelligent technologies in control and management systems is successfully solving the problem of replacing adaptive ACS with high-speed systems with high flexibility, functioning in conditions of uncertainty, the potential advantages of intelligent ACS. In this regard, the task of creating a series of high-speed servo drives with intelligent controllers in order to comprehensively study their properties under conditions of uncertainty

is of undoubted theoretical and practical interest. Currently used energy-saving variable frequency drives based on asynchronous motors with wound rotor is the main type of variable speed drive. The application of the laws of vector torque control provides the required quality of regulation and significantly increases the efficiency of the electric drive.

АННОТАЦИЯ

Современным развитием применения интеллектуальных технологий в системах контроля и управления успешно решается задача замены традиционных адаптивных САУ на быстродействующих систем с высокой гибкости, функционирующих в условиях неопределенности, благодаря потенциальным преимуществам интеллектуальные САУ. В этой связи задача создания серии быстродействующих следящих приводов с интеллектуальными регуляторами с целью комплексного исследования их свойств в условиях неопределенности представляет несомненный теоретический и практический интерес. В настоящее время используемые энергосберегающие частотно-регулируемые электроприводы на основе асинхронных двигателей с фазным ротором является основным типом регулируемого электропривода. Применения законов векторного управления моментом обеспечивает требуемое качество регулирования и значительно повышает КПД ЭП.

Keywords: fuzzy controllers, fuzzy regulator, neural network, multi-loop control structure, symmetric optimum, asynchronous valve motor, PI controller.

Ключевые слова: нечеткие регуляторы, нечеткий регулятор, нейронная сеть, многоконтурная структура управления, симметричный оптимум, асинхронный вентильный двигатель, ПИ-регулятор.

At present, with the introduction of new circuit solutions resting on the active development of power electronics, microelectronics and microprocessor control systems, automated electric drives can achieve the necessary adjusting characteristics of the machines and mechanisms used, and also significantly reduce electric consumption [1].

Typical control systems based on fuzzy controllers belong to the class of expert systems and are nonlinear controllers of the characteristic surface. In the field of EP, one of the options for using fuzzy logic is associated with the regulation of the operating parameters of mechanisms based on a fuzzy controller with adaptive properties. The block diagram with a fuzzy regulator (controller) is shown in figure 1.

Figure 1. The block diagram with a fuzzy regulator

In the presented diagram, an additional corrective link is introduced into the vector of input values of the fuzzy controller for the dynamics of the transient process, the nature and parameters of which are set using the functional converter FP. At the same time, changing the FP parameters allows you to correct both dynamic and static characteristics of the system. This structure of the regulator, combined with the optimal choice of the parameters of the knowledge base of the fuzzy controller, carried out using genetic algorithms, allows the developer, with a minimum of settings, to implement adaptive control systems for uncertain and non-stationary mechanisms, regardless of their structure. Among the advantages of new control methods belonging to the category of intelligent control systems is the ability to:

- implement any non-linear control algorithm required for the process;

- to have an incomplete, inaccurate description of the control object, and for a neural network and the absence of a description;

- to create a soft adaptation that ensures the robustness of the system in case of instability of parameters. The considered methods and control systems for electronic devices make it possible to implement the whole range of problems of controlled control with the required technological process.

- requirements for high accuracy and a large control range, high speed and cost-effectiveness necessitate the use of closed-loop systems.

- There are two methods of automatic control of coordinates [2]:

- regulation on the deviation of the coordinate from the set value using negative feedback on the controlled value;

• regulation by disturbance, where with the help of positive feedback the influence of disturbance on the controlled value is compensated.

The electric drive is mainly used for deviation control, since it can provide the required accuracy regardless of the nature of the disturbance. In the general case, when regulating several coordinates, a closed EP system is built according to one of three structures:

- a structure with a summing amplifier;
- the structure of the independent regulation of coordinates;
- the structure of the subordinate regulation of coordinates.

The method of sequential correction with subordinate coordinate control is a generalization of the method of sequential correction as applied to EP systems, in which the structural model is represented by a sequential connection of inertial and integrating links.

The control object has a transfer function of the form

$$W_0(s) = \prod_{i=1}^m \left(\frac{k_i}{T_i p + 1} \right) \quad (1)$$

where k_i , T_i are the parameters of the i -th link of the structural model. The time constants T_i of the control object can be conditionally divided into two groups - large and small. The links of the structure, which correspond to large time constants, determine the main dynamics of transient processes in the system, its speed[3]. To implement the idea, a multi-loop control structure with nested - subordinate loops is used (in figure 2), while in each internal loop the regulator compensates for no more than two time constants. The adjustment of the regulators of such a system is performed independently in each circuit.

Figure 2. Multi-circuit system with slave regulation

When tuning the system to the technical optimum, a requirement is put forward as a criterion - the modulus of the closed-loop frequency response should be close to unity over the largest possible frequency range. This requirement is essentially a condition for reproducing the input signal. The transfer function takes the form

$$H(s) = \frac{a_2}{(a_0 p^2 + a_1 p + a_2)} \quad (2)$$

In order for the modulus of the frequency response at small to be close to unity, it is sufficient that the conditions of the "optimal" tuning are satisfied:

$$a_1^2 = 2 * a_0 * a_2 \quad (3)$$

The transient response of the system tuned to the technical optimum has the following parameters:

- overshoot $\delta = 4.3\%$;
 - the time of the first agreement $t_1 = 4.71\theta$;
 - the time of the transient process $t_p = 8.4\theta$;
- where $\theta = \sum T_i$ is the sum of small time constants.

In the case of tuning the closed-loop system to a symmetric optimum, its logarithmic amplitude frequency response takes the form symmetric with respect to the cut-off frequency and the maximum phase stability margin falls on the vicinity of the cutoff frequency. The closed-loop transfer function of such a system takes the form [4]

$$H(s) = \frac{a_3 + a_2 p}{(a_0 p^3 + a_1 p^2 + a_2 p + a_3)} \quad (4)$$

The condition for the "optimal" setting in this case

$$\begin{aligned} a_1^2 &= 2a_0 a_2 \\ a_2^2 &= 2a_1 a_3 \end{aligned} \quad (5)$$

The transient response of a system tuned to a symmetric optimum has the following parameters:

- overshoot $= 4.3\%$;
- the time of the first agreement $t_1 = 3.1\theta$;
- the time of the transient process $t_p = 16.5 \theta$.

The transient characteristics of closed systems tuned to the technical (curve "б") and symmetric optimum (curve "а") are shown in figure 3.

Figure 3. Transient characteristics for technical and symmetric optima

The transient process of a system tuned to a symmetric optimum is characterized by significant overshoot, which can be reduced if a low-pass smoothing filter is consistently installed outside the closed loop:

$$W_{\Phi}(p) = \frac{1}{4\theta p + 1} \quad (6)$$

The transient process of such a system, shown in figure 3 (curve "в") is characterized by the following parameters:

- overshoot $\delta = 8.1\%$;
- the time of the first agreement $t_1 = 7.6\theta$;
- the time of the transient process $t_p = 13.3\theta$.

Using the obtained transfer functions (2 and 3) and the equations of the circuits, it is possible to construct a structural diagram of the AED with vector frequency-current control with a direct orientation along the vector of the main magnetic flux and a fixed excitation frequency $f_2 = \text{const}$ (in figure 4).

The following variables are controlled here:

- $\psi_{\delta} = \text{const}$;
- $i_{sx} = 0$;
- i_{sy} .

If we do not take into account the mutual connections between the circuits, then the stator and rotor of the AED are inertial links with time constants $T_{ls \text{ экв}}$ and T_r , which determine the nature of the dynamic processes in the drive. Thus, an asynchronous valve motor is a complex non-linear automatic control system. To compensate for the influence of the time constants $T_{ls \text{ экв}}$ and T_r in transient modes, it is necessary to use regulators of the main magnetic flux, current, torque and speed in a closed-loop control system.

Considering the following assumptions:

- excitation voltage (rotor) is sinusoidal;
- the current of the starter circuit of the motor is continuous;
- the control characteristic of the inverter is linear;
- moment of inertia, given to the motor shaft, is constant[5].

Figure 4. Structural diagram of AED

The inertia of the feedback circuits for flow, current, torque and speed is not taken into account due to its smallness, the following block diagram of the regulation

of an electric drive with an AED can be proposed (in figure 5):

Figure 5. Linearized block diagram of AED

Optimization of the loops of the subordinate control system (in figure 4) is performed according to the condition of technical maintenance TO and symmetric CO optimum. Consider the rotor circuit first, then the stator circuit. In a single-loop excitation circuit, it is necessary to compensate for the large rotor time constant T_r , while the uncompensated time constant will be determined by the inertia of the valve converter $T_{\mu\Pi} = T_n = T_\mu$, that is, the control object is represented by series-connected inertial links, one of which has a time constant that is significantly larger than all the rest[6]. Then the synthesis problem is solved by the use of a PI controller, which allows tuning the closed loop to TO. The open loop system has a transfer function

$$W_{PI}(p)W_{KI}(p) = \left(\frac{k_{PI}(T_{PI}p+1)}{T_{PI}p} \right) \left(\frac{k_n}{T_n p+1} \right) \left(\frac{L_m/(R_r K_u)}{(T_r p+1)} \right) \quad (7)$$

Let us take $T_{PI} = T_r$ and using the conditions of tuning (in figure 4) of the circuit for maintenance, determine the coefficient of the PI flow controller.

$$k_{PI} = \frac{T_r R_r K_u^*}{2T_{\mu\Pi} k_n k_{om} L_m} \quad T_{PI} = \frac{T_r}{k_{PI}} \quad (8)$$

The control channel in the stator circuit consists of three control loops. In accordance with the principles of subordinate regulation, synthesis begins with an internal KT. For it, as well as for the gearbox, the adjustment for maintenance is performed in order to compensate for the large time constant of the stator T_s under the condition $T_{\mu\Pi} = T_n = T_\mu$. As a result, we obtain a PI controller with the following coefficients:

$$k_{PTy} = \frac{T_{IS\text{ЭKB}} R_s \text{ЭKB} K_{ur}^*}{2T_{\mu T} k_n k_{om}} \quad T_{PTy} = \frac{T_{IS\text{ЭKB}}}{k_{PT}} \quad (9)$$

With further synthesis, the transfer function of the closed current loop with a sufficient degree of accuracy

(due to the smallness of the uncompensated time constant $T_\mu T$) is approximated by the expression:

$$W_{PT}(p) = \left(\frac{1/k_{om}}{2T_{\mu T}(T_{\mu T}p+1)+1} \right) \approx \frac{1/k_{om}}{2T_{\mu T}p+1} \quad (10)$$

The open loop system has a transfer function:

$$W_{PT}(p)W_{KM}(p) = W_{PM}(p) \left(\frac{1/k_{om}}{T_{\mu T}p+1} \right) \frac{3}{2P_n} \quad (11)$$

As a result, the control object is represented by an inertial link with a small time constant, and the synthesis problem is solved by using an I-controller. The uncompensated time constant of the KM will be determined as $T_\mu M = 2T_\mu T$, then the open loop will take the form:

$$W_{PT}(p)W_{KM}(p) = \left(\frac{1}{T_{PM}p} \right) \left(\frac{1/k_{om}}{2T_{\mu T}p+1} \right) \frac{3}{2P_n} \quad (12)$$

Using the conditions of adjustment (12) of the circuit for maintenance, we determine the coefficient of the I-torque regulator:

$$T_{PM} = \frac{6k_{om}P_n T_{\mu T}}{k_{om}} \quad (13)$$

The presence of an integral component in the KM will compensate for the static error that occurs when the moment of resistance on the motor shaft changes[7].

In turn, the torque control loop is internal to the speed control loop. Here, too, due to the smallness of the uncompensated time constant $T_\mu M$, the transfer function is approximated with a sufficient degree of accuracy by expression (13), and the uncompensated time constant is $T_\mu C = 2T_\mu M = 4T_\mu T$. The open loop system has a transfer function:

$$W_{PC}(p)W_{KC}(p) = W_{PC}(p) \left(\frac{1/k_{om}}{4T_{\mu T}p+1} \right) \left(\frac{1}{Jp} \right) \quad (14)$$

As a result, the control object is represented in the form of series-connected links - inertial, with a small time constant, and an integration link, with a large time constant J . For KC, tuning is performed on CO in order to maintain the speed at a given level. Using the PI controller, we get the following open loop transfer function[8]:

$$W_{PC}(p)W_{KC}(p) = \left(\frac{k_{PC}(T_{PC}p+1)}{T_{PC}p} \right) \left(\frac{1/k_{om}}{4T_{\mu T}p+1} \right) \left(\frac{1}{Jp} \right) \quad (15)$$

Using the conditions for setting (1.2) of the CO loop, we determine the coefficient of the PI controller speed:

$$k_{PC} = \frac{k_{om}J}{8k_{oc}T_{\mu T}}; \quad T_{PC} = 16T_{\mu T} \quad (16)$$

Setting the KC to CO allows you to compensate for the static error that occurs when the moment of resistance on the motor shaft changes and thereby maintain the set speed. The KC tuned to the symmetric optimum is characterized by a significant overshoot, to reduce which it is necessary to consistently put a filter calculated according to (15) taking into account $\theta = T_{\mu C}$:

$$W_{\phi}(p) = \frac{1}{4T_{\mu C}p+1} \quad (17)$$

When implementing the principle of vector control, it is necessary to $\psi_{\delta x} = \text{const}$, which will make it possible to control the electromagnetic moment by changing the projection of the stator current i_{sy} onto the longitudinal axis of the x, y coordinate system. At the same time, to ensure a constant magnetic flux, it is necessary to control the projection of the stator current i_{sx} onto the transverse coordinate axis in such a way that for any changes in the transverse component of the rotor current i_{rx} , the main magnetic flux $\psi_{\delta x} = \psi_{\delta \text{const}}$.

Due to the existing cross-links, a change in the projection of the stator current i_{sx} affects the longitudinal component i_{sy} , which determines the electromagnetic moment. Therefore, in the vector control system, it is necessary to ensure the operation mode of the stator current control loop, at which $i_{sx} = 0$. For this, the control system includes a component regulator $i_{sx}=0$. Changing the current projection is carried out by adjusting the opening angle of the thyristors in the stator ИТ, its structural diagram is shown in figure 6.

Figure 6. Structural diagram of the vector control system

The synthesis of the controller transfer function will be similar to the i_{sy} component of the stator current, provided that a zero value is set at the input. Based on the

structure of the subordinate regulation synthesized in this paragraph, we will calculate the parameters of the regulators and build a simulation model of the control system of the ED with AED with vector control.

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CIVIL ENGINEERING AND ARCHITECTURE

EARTHQUAKE-SAFE BUILDINGS

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И СЕЙСМИЧЕСКОЙ БЕЗОПАСНОСТИ ЗДАНИЙ И СООРУЖЕНИЙ*Усманходжаева Лола Асадовна**доцент,
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ABSTRACT

This article discusses options for assimilation of earthquake-proof building technologies and methods from widely used in Japan in the context of Uzbekistan. This is an attempt to analyze if base isolation or earthquake safety structure is expedient for use in our country.

АННОТАЦИЯ

В статье рассматриваются варианты освоения сейсмостойких строительных технологий и методов из широко используемых в Японии в контексте Узбекистана. Это попытка проанализировать, целесообразно ли использовать изоляцию основания или сейсмостойкую конструкцию в нашей стране.

Keywords: earthquake, earthquake-proof, earthquake-resistant, seismic, magnitude, Uzbekistan, Japan, safety, technology, structure, base isolation, building, isolator, law.

Ключевые слова: землетрясение, сейсмостойкость, сейсмическая защита, сейсмичность, магнитуда, Узбекистан, Япония, безопасность, технология, конструкция, изоляция основания, здание, изолятор, закон.

The issue of constructing earthquake-proof buildings has always been a major hazard all around the world, because earthquakes are one of the most destructive natural disasters. This obviously applies to Uzbekistan coupled with its location, where part of the country including the capital rests on one of geographic faults, which may possibly generate earthquakes with a magnitude of up to 7.5. Uzbekistan has a seismic hazard map where seismic intensity is shown according to the region

(see Pic. 1.). Earthquake-resistant buildings must stand up the uttermost earthquakes or at least give enough time to people to evacuate from the building to a safe place. To address this problem, there are two methods called earthquake-resistant and base isolated structure commonly used in Japan that can guarantee safety of the people and buildings. In Uzbekistan, these methods are used rarely and only in extremely expensive buildings, because these methods are costly.

Picture 1. Seismic intensity is shown according to the region [1]

According to Economist Intelligence Unit's Safe Cities Index, Japan is considered as one of the safest countries around the world due to its excellence in earthquake-proofing technologies. Thus far, Japan has mainly been using earthquake-resistant structure and base isolation structure, which have proven to be effective in global practice. Moreover, Tokyo University has researched that 87% of the Tokyo's structures were built in accordance with modern anti-seismic requirements [1]. Every year, around 500,000 measurable earthquakes occur across the world, approximately 20 of which are major [2].

Uzbekistan is located in one of the earthquake-prone regions in Central Asia. Earthquakes with a magnitude of up to 7.5 are possible in this area. In 1966, Tashkent was hit by a catastrophic earthquake with magnitude of 5.2 leading to a total devastation of Tashkent, the capital city. This accident pushed Uzbekistan to seriously consider earthquake safety and since then we have been gaining more experience, knowledge and preparedness in this area. The President signed a Law on 13 September 2021 "On Ensuring Seismic Safety of the Population and Territory of the Republic of Uzbekistan", which will come into effect in six months [3]. This is especially relevant now when our country is experiencing a boom in housing and other type of construction at the moment. To help enforce the recent law, it is advisable to consider the two methods discussed in this article.

Seismic-resistant structures are the most typical for detached buildings in Japan. A seismic-resistant structure permits the primary building structures such as

posts, walls, and floors, to absorb seismic shocks. Buildings are classified into two types: stiff structures (built rigorously to prevent collapse) and flexible structures (the main structural parts of which bow flexibly in order to spread the force of seismic motions). In an earthquake, conventional structures tremble together with the ground. They may withstand structural damage but are designed to remain standing. Thus, the magnitude of an earthquake is directly proportional to the movement of the building, the higher the intensity of the earthquake, the more the building moves in return. Consequently, if the building shakes too much, structural parts such as beams, columns, walls, and braces might be destroyed, leaving the structure nonfunctional [4].

Dr. Bill Robinson, invented base isolator bearings, which consist of layers of rubber and steel with a lead core in mid-1970s [5]. Seismic base isolation, which is commonly utilized as part of the foundation of high-rise structures, places quake-absorbing devices (isolators) such as laminated rubber that prevents seismic vibrations from reaching the building. Base isolation method enables a building to float on a system of bearings such as metallic or lead-core rubber bearing, heavy-duty springs, padded cylinders, sliders or even air cushions, while remaining upright during a quake. The goal of seismic base isolation is to passively absorb or deflect earthquake kinetic energy by placing an elastic or sliding buffer between the foundation and the building superstructure. Seismic isolated structures can lower seismic intensity by up to 80% in comparison to earthquake-resistant structures. Buildings that implement base isolation are more likely to survive and function after a big

earthquake. For instance, Apple's futuristic new headquarter near San Francisco (USA) sits on 700 base isolators [1]. Another example is of an architect for a large Japanese construction company in Kobe, Mr. Yasuhisa Itakura. During the Great Hanshin earthquake of January 17, 1995, that killed more than 6,000 people in and around the industrial port city, Mr. Itakura had been cushioned from the violence of the earthquake because his three-story office building was sitting on an experimental foundation made from rubber — an early version of an engineering technique called base isolation [4].

The current context in Uzbekistan including plentiful new construction and developments in the relevant legal and regulatory framework is ideal for piloting

well-proven anti-seismic technologies: earthquake-resistant structures or seismic base isolation. Although construction of seismic-resistant structure is less expensive than seismic base isolation structure as it does not require extra equipment and monitoring, which possibly allow for savings on purchases and maintenance, in my opinion, seismic base isolation is more reliable and safer, because the whole structure swims not affecting the building and people as can be seen from Yasuhisa Itakura's example. In addition, you may end up spending more money on equipment and maintenance, but you will gain in overall building safety, which will save you more money, but more importantly, people's lives.

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TRANSPORT, MINING AND CONSTRUCTION ENGINEERING

DOI - 10.32743/UniTech.2021.92.11.12585

EFFICIENCY ASSESSMENT THE BRAKING EQUIPMENT OF FREIGHT CARS
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E-mail: Kamal.78@list.ru*ОЦЕНКА ЭФФЕКТИВНОСТИ ТОРМОЗНОГО ОБОРУДОВАНИЯ ГРУЗОВЫХ ВАГОНОВ
НА УЧАСТКЕ АНГРЕН-ПАП ЖЕЛЕЗНЫХ ДОРОГ**Хуснидинович Иноятлов Камолитдин***ст. преподаватель кафедры "Вагоны и вагонное хозяйство",
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ABSTRACT

Based on the study of data on equipment failure at the Angren-Pap section of the railways of the Republic of Uzbekistan, the article systematizes the main malfunctions of the braking equipment of loaded freight cars. Methods of analysis of the scheme and longitudinal profile of the Angren-Pap line are used to identify the most stressed sections in terms of the complexity of the car passage, and to establish the main malfunctions of the brake system. It was stated that the electrified railway line Angren-Pap is an important link not only for railway transport, but also for the entire economy of the Republic of Uzbekistan. It is shown that the main problems are the gross wear of brake shoes and an increase in their temperature. The analysis of malfunctions of the braking equipment of freight cars operated on the Angren-Pap section is performed. The main characteristic problems and malfunctions of the braking equipment of freight cars operating at the Angren-Pap section were identified. The wear of cast iron shoes and the assessment of the dependence of wear on the speed of rolling stock, the wear thickness of the shoes at different heat flux distribution ratios in the shoes and slope ratios were calculated. The critical time of continuous braking was also calculated. Conclusions were drawn on the basis of calculations and damage assessment.

АННОТАЦИЯ

На основе изучения данных об отказе оборудования на участке Ангрэн-Пап железных дорог Республики Узбекистан в статье систематизированы основные неисправности тормозного оборудования груженых грузовых вагонов. Методы анализа схемы и продольного профиля линии Ангрэн-Пап используются для выявления наиболее напряженных участков с точки зрения сложности проезда автомобиля, а также для установления основных неисправностей тормозной системы. Было заявлено, что электрифицированная железнодорожная линия Ангрэн-Пап является важным звеном не только для железнодорожного транспорта, но и для всей экономики Республики Узбекистан. Показано, что основными проблемами являются грубый износ тормозных колодок и повышение их температуры. Проведен анализ неисправностей тормозного оборудования грузовых вагонов, эксплуатируемых на участке Ангрэн-Пап. Были выявлены основные характерные проблемы и неисправности тормозного оборудования грузовых вагонов, работающих на участке Ангрэн-Пап. Был рассчитан износ чугунных башмаков и оценка зависимости износа от скорости подвижного состава, толщины износа башмаков при различных коэффициентах распределения теплового потока в башмаках и коэффициентах наклона. Также было рассчитано критическое время непрерывного торможения. Выводы были сделаны на основе расчетов и оценки ущерба.

Keywords: Researchers, network, equipment, railway line, construction, rolling stock.

Ключевые слова: Исследователи, сеть, оборудование, железнодорожная линия, строительство, подвижной состав.

1. Introduction

With the acquisition of state independence in the Republic of Uzbekistan, much attention was paid to the development of railway transport [1-3, p.183]. Today railway transport is an integral part of the formation of the country's economy and plays a key role [4, p.101].

To master the increasing volumes of traffic on the railway network of Uzbekistan, it was decided to develop the production of new freight and passenger cars on the basis of existing car-repair enterprises of JSC "O'zbekiston Temir Yullari" [5-10].

Thereby, on the basis of OJSC "Tashkent plant for the repair of passenger cars" (after putting into operation the production of cars, the plant was renamed into OJSC "Tashkent plant for the construction and repair of passenger cars"), serial production of modern compartment-type passenger cars with air conditioning of 68-907 model [11-13] and bogies of a passenger carriage of 68-908 (68-909) model began [14-15]; the design and development of design documentation for these cars were carried out jointly with the specialists from JSC "NVC "Wagons", St. Petersburg, Russia.

On the basis of the Subsidiary Enterprise "Andijan Mechanical Plant", the production of new freight cars of various types was set, at the first stage, tank cars for the transportation of oil products [16], and later the production of tank containers for the transport of dangerous goods [17-19, p.65-78] and tank cars for sulfuric acid [20-22,].

On the basis of the Subsidiary Enterprise "Foundry and Mechanical Plant" (the production base modernized in 2012-2013) [3, p.89], the construction of new models of freight cars: covered train cars of 11-9923 model with widened doorways, with a body volume of 158 m³ [23-24, p.99], universal gondola cars of 12-9922 model with gate arrangement, with a body volume of 92 m³ [25-26, p.145] and hopper cars for cement transportation of 19-9596 model was developed [27-30, p.75].

Researchers from the Tashkent Institute of Railway Engineers have developed containers for the transportation of fruits and vegetables [31-33, p.75]

Today, the development of the transport system in the Republic of Uzbekistan is becoming more and more intensive. Currently, specific measures are being taken to build and reconstruct highways of international importance, upgrade and modernize the railway and motor transport fleet, create integrated logistics centers and improve the regulatory framework, establish a flexible system of tariffs for the transportation of goods, simplify customs procedures, reduce the time required to pass customs checkpoints and electronic exchange of documents [34, 35].

The electrified railway line Angren-Pap was built to create a new China - Central Asia - Europe railway corridor, and to form a unified railway network of Uzbekistan. It is an important railway link affecting the entire economy of the Republic of Uzbekistan [36, p.25].

Due to the difficult conditions of cargo transportation along the Angren-Pap section and the importance of transporting goods along this line, a number of problems must be solved that negatively affect the carrying capacity of the railway section. Such problems include malfunctions of the braking equipment of freight cars and the need to use effective braking systems [37, p. 145].

2. Methods

Description of the scheme and profile of the Angren-Pap section. The electrified railway line Angren-Pap with a length of 124 km consists of 7 sections with a length from 13 to 24 km (Figure 1) [20]. From the point of view of carriage operation, this line is a difficult section with mountainous terrain, where the slope reaches 27 ‰ (Figures 2, 3), which leads to the need for constant braking during downward journey and the friction system operation in a heavy mountain mode.

Figure 1. Scheme of the Angren-Pap railway section

Figure 2 shows the longitudinal profile of the Sardala station - Junction 2 section.

Figure 2. Schematic longitudinal profile of the Sardala station – Junction 2 section

Figure 3. Schematic longitudinal profile of the section Junction 2 - Junction 3 - Koshminor station

The Angren-Pap line belongs to the third category of railway lines (a railway line providing mainly freight and passenger transportation of local significance) and has a length of tracks with a down slope of 34.83 km, in an up slope - 28.4 km. The speed norm for a freight train is 60 km/h, for a passenger train - 70 km/h. The weight norm of freight trains is 2100–2400 tons [18, p.90].

The transportation of goods increases along the Angren-Pap line since this direction reduces the distance of transportation.

3. Results and Discussion

Analysis of malfunctions of the braking equipment of freight cars on the Angren-Pap line. The main problem is the topographic location of the railway line. In

particular, the slope, which negatively affects the condition of the braking equipment of cars and creates a number of malfunctions, such as rapid wear of brake shoes, heating of shoes and wheelsets. In addition to the wear of shoes, other malfunctions were identified. So, in 2019, on the Angren-Pap line, the largest number of failures related to the operating conditions of train cars was registered (the total number of faulty cars in terms of brake equipment for the year was 52 pcs.), the reasons were the pressing of shoes - 28%; air distributor failure - 21%; breakage of the feed pipeline 14%; pressure drop in the line - 20%; incorrect adjustment of the BLV incorrect adjustment of the BLV - 17%. Figure 4 shows a diagram of the distribution of the reasons for setting up maintenance of freight cars by types of malfunctions of brake equipment on the Angren-Pap line in 2019.

Figure 4. Distribution of reasons for failure of freight cars by types of malfunctions of braking equipment on the Angren-Pap line

The analysis of the main malfunctions of the braking equipment is given. According to [39], the air distributors of freight cars are switched to mountain mode in up trains at Chodak station. In the production of full service brake application, the push rod egress of the air brake cylinders of freight cars with cast iron shoes is adjusted by 75–125 mm, with composite shoes - by 50–100 mm, and in passenger cars - 130–160 mm with cast iron and composite shoes. The charging pressure in the brake line of trains on the Angren-Pap section in freight cars is 0.5–0.6 MPa [20, p.157].

In freight up trains at the Angren station and down trains at the Pap station, the air distributors of the railcars are set to mountain mode with full testing of the brakes with a 10-minute timing in the braked state. When departing up and down freight trains from Angren-Pap stations, the following was established: the thickness of the cast-iron shoes of the cars is no less than 30 mm, the thickness of composite shoes is no less than 25 mm. The installation of brake shoes on one wheelset with a difference in thickness of no more than 5 mm is provided.

It was established that in a mountainous area of the Angren-Pap line, the braking system of the car is subject to accelerated wear of the brake shoes due to constant braking when descending on the tracks with a slope of up to 27 ‰ [19, p.78]. To cool the wheelsets and brake shoes of the rolling stock, it is recommended to make technical stops at the stations: in the down line in Orzu

– for 10 minutes; in the up line in Kon and Temiryulobod – for 20 minutes, at the Koshminor station – for 10 minutes [20, p.102]. When parked, the temperature of the brake shoes and wheelsets becomes lower. However, from the point of view of maintenance, such stops lead to excessive consumption of fuel and an increase in the delivery time of the cargo.

The situation is aggravated by the use of composite brake shoes on freight cars, which practically do not remove thermal energy from the shoe-wheel contact area, in contrast to cast iron shoes [17 p.48]. In addition, composite shoes lead to the formation of such a defect as annular wear on the rolling surface of the wheel.

Table 1 shows a cast iron brake shoe with brake shoe wear typical of freight cars. More than 50% of the railcar shoes aimed for repair have a wear area that does not fit into the worn-in area due to normal operation of the brakes and occupies 20–30% of the working surface [11, p.39]. When braking, this area does not participate in the creation of the braking force due to the lack of contact with the wheel. There are shoes with more complex wear. Brake shoes wear depends on pressing force, shoe material, type and adjustment of lever gear.

At a time when uniform wear occurs as a result of continuous braking, wedge wear, sag wear, one-sided wear and fracture of top (bottom) shoe can be considered a consequence of improper adjustment of the BLV the consequences of incorrect adjustment BLV.

Table 1.

Typical wear of the brake shoe of a freight car [7]

Type of wear	Shoe wear characteristics	Amount of wear, %	Longitudinal view
I	Uniform wear across the thickness of the cast iron shoe	64,5
II	Wedge-shaped wear (tip up, down) of composite shoes	11,7
III	Wear from sagging of composite shoes	4,5
IV	Ridge wear (sliding at the bottom, top, along the entire length) of the cast iron shoe	3,3
V	One-sided wear of the cast iron shoe	3,5
VI	Fracture of the upper (lower) part of the cast iron shoe	4,5
VII	Crushing (plastic strain of the cast iron shoe)	4
VIII	Galling of the composite shoe	4

The wear of brake shoes under operating conditions substantially depends on the force of pressing, material, type and duration of braking action, adjustment of the lever gear, the position of the shoe relative to the rolling surface of the wheel in both braking and released states and on a number of other factors. The amount of wear m for one braking action ΔH can be calculated for cast iron shoes according to the following formula [12, 13]:

$$\Delta H = \frac{0,04}{\left(\frac{5 \cdot 10^9 F_k}{\alpha_K B_T v t} - \frac{525}{\sqrt{t}} \right) Y}, \text{ м} \quad (1)$$

where F_k is the geometric friction area of the shoe acting on the wheel, m^2 ; α_K is the coefficient of heat flux distribution in the shoe (taken as 0.2–0.3 under one-sided pressing); t is the duration of braking action, s; B_T is the

average braking force acting from the shoe on the wheel during the braking time, N; v – is the average velocity of motion, m/s; Y is the quality factor of the shoes (when meeting the standard requirements $Y = 1$).

The duration of braking action for a given length of braking and average speed is easy to find. The average force with a known axle load, kN, and long-term braking on the downward journey can be calculated by the following expression (taking into account the average specific resistance to motion):

$$B_T = 0.5 \cdot (i_c - w_{cp}'') \cdot q_0 \cdot H, \quad (2)$$

where w_{cp}'' is the average specific resistance to motion (taken as 2 N/kN).

Substituting the indices of the initial condition (see Table 2), we obtain the following indices of wear of cast iron shoes (Table 3).

Table 2.

Indices of the initial conditions for calculating the wear of cast iron shoes

Parameter	Value
Geometric area of the cast-iron shoe F_K , m ²	0,0305
Axle load q_0 , т	20
Track slope i_c , ‰	20
	25
	27
Average braking force B_T , N	1800
	2300
	2500
Heat flow distribution coefficient in the shoe α_K	0,2
	0,3
Shoe quality factor Y	1
Maximum track length at slopes S , km	10,850
	10,408
	12,06

Table 3.

Indices of wear of cast iron shoes

Railcar speed v , km/h	Duration of braking action t , h			Wear of a cast iron shoe in thickness (ΔH), mm (for $\alpha_K=0,2$)			Wear of a cast iron shoe in thickness (ΔH), mm (for $\alpha_K=0,3$)		
	$i=20\%$	$i=25\%$	$i=27\%$	$i=20\%$	$i=25\%$	$i=27$	$i=20\%$	$i=25\%$	$i=27\%$
10	1,08	1,04	1,21	1,3	1,7	2,3	2,1	3,2	4,5
20	0,54	0,52	0,60	1,5	2,0	2,9	2,8	4,4	7,14
30	0,36	0,35	0,40	1,6	2,4	3,5	3,5	6,3	13,1
40	0,27	0,26	0,30	1,8	2,7	4,3	4,3	9,8	42,6
50	0,22	0,21	0,24	1,9	3,1	5,3	5,5	19	-

The greater wear of the brake shoes at a higher velocity of the downward journey is explained by the fact that in this case, more heat is focused in the friction area, the temperature of the shoe increases and the wear of the shoe accelerates. The heat flux distribution coefficient in the shoe α_K and the slope i proportionally affect the wear of the shoes. At the maximum track length of the

Angren-Pap section with a slope of 27‰ ($S_T=12.06$ km), the speed of 50 km/h is not acceptable due to the wear above the allowable standard. Figure 5 shows a graph of dependence of the wear of the shoe in thickness on the speed of the rolling stock for different coefficients of heat flux distribution in the shoe α_K and slopes i .

Figure 5. Dependences of the wear of the shoe in thickness on the speed of the rolling stock for different coefficients of heat flow distribution in the shoe α_K and slopes i

The critical time $t_{кр}$ of continuous braking, after which catastrophically rapid wear of the cast-iron brake shoes occurs, is determined by the expression given in [42, 43]. Equating the denominator of formula 1

$$\left(\frac{5 \cdot 10^9 \cdot F}{\alpha_k \cdot B_T \cdot v} - \frac{525}{\sqrt{t}} \right) \cdot Y = 0$$

to zero, the critical time $t_{кр}$ of continuous braking, after which catastrophic wear of cast iron brake shoes occurs, is

$$t_{кр} = \left(\frac{95 \cdot 10^5 \cdot F_k}{\alpha_k B_T v} \right)^2, c \quad (3)$$

The critical time of continuous braking depends also on the slope value and the heat flux distribution in the shoe. Calculations of the dependence of the critical time of continuous braking on the speed, slope and heat flux distribution coefficient in the shoe are given in Table 4.

Table 4.

Calculations of the dependence of the critical time of continuous braking on speed, slope and heat flux distribution coefficient in the shoe

Railcar speed v , km/h	Critical time of continuous braking $t_{кр}$, h (for $\alpha_k = 0,2$)			Critical time of continuous braking $t_{кр}$, h (for $\alpha_k = 0,3$)		
	$i=20\%$	$i=25\%$	$i=27\%$	$i=20\%$	$i=25\%$	$i=27\%$
10	24,6	15,11	12,8	10,36	6,72	5,4
20	5,84	4,95	3,02	2,6	1,59	1,35
30	2,6	1,58	1,34	1,16	0,71	0,6
40	1,5	0,89	0,76	0,65	0,4	0,33
50	0,94	0,58	0,49	0,42	0,26	0,21

Let us plot the graph (Figure 6) based on the calculation data from Table 4.

Figure 6. Dependences of the critical time of continuous braking on the speed, slope and distribution coefficient of the heat flux in the shoe during the rolling stock motion

Composite shoes are characterized by other patterns of wear - they practically do not achieve the conditions of catastrophic wear since the working layer formed under the influence of heat at the point of contact between the shoe and the wheel, and the friction mass of the shoe has low thermal conductivity. It prevents the physical

and mechanical properties of shoe material from the effect of heat. This explains, in particular, the different ratios of wear resistances of composite and cast iron shoes for operating conditions on a flat track profile and steep long slopes.

Thus, the elimination of nonuniform wear of the brake shoe consists in the correct diagnosis of malfunctions. At the same time, when conducting an external inspection, it must be borne in mind that, despite the relatively simple mechanism of operation of the brake shoes, the malfunctions associated with them can be the consequences of improper operation of other parts of the brake equipment.

4. Conclusions

Thus, the study shows that the main delays of freight cars for the Angren-Pap line of Uzbek Railways are associated with malfunctions of brake equipment and friction units; the most typical of them are wear and an increase in the temperature of the shoes. In addition, on the basis of the results obtained, an assessment of the main characteristic problems and malfunctions of the brake equipment of freight cars was done, depending on the operating conditions in mountainous conditions.

It was established that in 2019 on the Angren-Pap line, the largest number of failures was associated with a decrease in the pressing force of the shoes; failure of the air distributor; breakage of the feed pipeline; pressure drop in the line and incorrect adjustment of the BLV. incorrect adjustment of the BLV. The studies carried out show that further work is required to eliminate the cause of failures associated with the difficult operating conditions of freight cars on the Angren-Pap section of Uzbekistan railways. The calculation of the wear of cast iron brake shoes showed that an increase in the speed of a freight car leads to an increase in the wear thickness and reduces the critical time of continuous braking, after which catastrophic wear of the cast iron brake shoe sets in. We also determined that the value of the slope, speed and distribution coefficient of the heat flux in the shoe is proportional to the values of the wear thickness of the cast iron shoe and the critical time of constant braking.

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TECHNOLOGY OF MATERIALS AND PRODUCTS OF THE TEXTILE AND LIGHT INDUSTRY

COMPLEX ASSESSMENT AND CORRELATION COEFFICIENT CALCULATION OF THE QUALITY INDICATORS OF T-SHIRT FABRICS IN A MIXTURE OF FIBERS OF DIFFERENT COMPOSITION

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КОМПЛЕКСНАЯ ОЦЕНКА И РАСЧЕТ КОЭФФИЦИЕНТА КОРРЕЛЯЦИИ ПОКАЗАТЕЛЕЙ КАЧЕСТВА ТКАНЕЙ ДЛЯ ПЛАТЯ В СМЕСИ ВОЛОКОН РАЗЛИЧНОГО СОСТАВА

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ABSTRACT

In this article, threads are taken from a mixture of different fibers, namely 68,4% cotton+31,6% a mixture of lavsan fibers, 42% cotton+58% a mixture of lavsan fibers, 6% wool+17% lavsan+67% a mixture of cotton fibers, 100% viscose fiber and 8,5% wool+4% lavsan+87,5% a mixture of cotton fibers. In the laboratory of the Department of "Technology of textile fabrics" in the modern weaving workshop, shirt-top fabrics were obtained and their physico-mechanical properties were determined.

АННОТАЦИЯ

В данной статье нити были взяты из смеси различных волокон, т.е. 68,4% хлопка+31,6% лавсановых волокон, 42% хлопка+58% лавсановых волокон, 6% шерсти+17% лавсана+67% хлопковых волокон, 100% вискозного волокна и 8,5% шерсти+4% лавсана+87,5% хлопковых волокон, а ткани на основе платья были получены в современном ткацком цехе кафедры «технология текстильных тканей» и были определены их физико-механические свойства, а также проведена оценочная работа.

Keywords: experimental, organoleptic, expert, sociological, calculated, differential, Komplex and mixed, radius vectors surface density.

Ключевые слова: экспериментальный, органолептический, экспертный, социологический, расчетный, дифференциальный, комплексный и смешанный, поверхностная плотность радиус-векторов.

One of the main tasks facing textile enterprises in the conditions of a market economy based on free competition is the production of quality, competitive and in-demand textiles. In order for the produced tissues to be competitive and in demand, its quality indicators should be able to meet the requirements of the world market in relation to this product, that is, the demand for world standards. At the same time, the costs incurred for the production of products should be low, advanced techniques and technology were introduced in the Enterprise, high labor productivity was achieved. In solving these problems, it will be of great importance to increase the indicators of labor productivity in textile enterprises, reduce labor consumption, increase manual labor, full use of internal opportunities, the introduction of automatic control of technology through computer systems. New textile enterprises established in the years of independence and the advanced new technology being installed in the existing enterprises being re-equipped, along with a sharp increase in the efficiency of enterprises, are producing quality products. In order to produce quality products at all kinds of industrial enterprises of our country, as well as to increase its competitiveness in the world markets, it is necessary, first of all, to equip with the equipment of foreign countries, which are modern in place of the old equipment available at the enterprises, to comply with the requirements laid down in the period. At the same time, it is the development and restoration of economic, technical, cultural relations between states, the harmonization of standards produced by international organizations. As a result of increasing the export potential of the products being produced, it leads to an improvement in the level of its production. From the quality of the product, one can estimate the technical improvement and development of the state. It is necessary that the properties of the tissues produced meet the requirements of consumption. These requirements are aimed at maintaining its shape in the process of tissue exploitation, improving hygienic and physico-mechanical properties, it is necessary to ensure that the tissues are at the required level of consumers. The evaluation of the quality of T-shirt fabrics and other types of products will be based on the results obtained from the work on the determination and measurement of its quality indicators, as well as on its assessment in comparison with the standard and normative documents. Because, the methods of determining the properties of the product are mainly listed in detail in the standards and other regulatory documents.

Shirt fabrics are often used for technical purposes. Therefore, it is desirable to conduct a comprehensive assessment of the physical and mechanical properties of tissue tissues. There are several methods for assessing the quality of textile fabrics, including experimental, organoleptic, expert, sociological, calculated, differential, complex and mixed.

The advantage of a comprehensive assessment of the physical and mechanical properties of textile fabrics is that when determining the surface from the test results obtained, it becomes clear that a fabric with a large surface area is good. Therefore, now this method has become widespread. The dependence of product quality indicators on the nature of the comprehensive assessment is divided into actual and approximate comprehensive assessment. These end-to-end assessments have a specific physical purpose, which is often the flexibility of the fiber as well as the lifespan of the object being used. A true composite estimate is better than any continuous rough estimate. For example, the amount of defects and waste in the composition of cotton fiber is called a true complex property. The advantage of an integrated assessment is that it ends with a series of final assessments. This assessment has both advantages and disadvantages, that is, we do not have complete information about its individual properties.

For the correct selection of raw materials, it is necessary to know the rational use of the material during the management and use of the technological process. It should be noted that the initial properties of this or that material can have a positive and negative impact on the quality of the product being produced, as well as on the movement of the technological process. The thinner the fiber, the higher the comparative strength of the thread being prepared from it, and the less uneven it will be, and the more smooth the appearance will be. It should not be forgotten that this or that quality assessment can be obtained from different calculations of individual quality indicators.

The average composite score for a number of quality indicators may not change, some may be low and some may be high. Thus, it is possible to undergo a comprehensive assessment without changing the individual quality indicators of the material.

There are various methods for a comprehensive assessment of the quality of shirting fabrics. For example, n is given a dimensionless value for m material in terms of n and is estimated using a significance factor if it has different significance factors.

In order to recommend the most optimal options for indicators of geometric, physical and mechanical properties obtained in our research work, we use a graphical method of complex assessment. The advantage of this method is that in this case it is possible to objectively evaluate the most optimal options for generalized qualitative indicators of the properties of requirements for materials.

Comprehensive assessment work was carried out on the basis of tensile strength, elongation in length and width, surface density, coefficient of variation of tensile strength in the composition of shirts with different fiber content and is shown in Figure 1.

Figure 1. Scheme for a comprehensive assessment of the quality indicators of fabrics with different fiber content

From the center (m) on the properties for evaluation, polygons are plotted on the axes or decreasing values are marked in the appropriate scales using radius vectors.

When distributing the axes, the intended purpose of the material, physical and mechanical properties, compliance with the established standards should be taken into account. For example, radius vectors are determined by surface density, longitudinal and transverse density from the center, impact strength, air permeability, elongation at break.

Formed polygons are distributed into triangles, and on the basis of their surface and texture indicators, the variants are the sum of the surface of the triangles.

After a comprehensive assessment of the test results obtained in determining the physic-mechanical properties of tissue tissues with different compositions of raw materials, their surfaces were determined, and the results are presented in the form of a histogram in Figure 2.

Figure 2. Comparative histogram of quality indicators of fabrics with different fiber content

As can be seen from the comparative histogram of the qualitative parameters of the T-shirt gaskets, the surface of the T-shirt gaskets obtained by Option 1 is 6989 mm², the surface of the T-shirt gaskets obtained by Option 2 is 12044 mm², the surface of the T-shirt gaskets obtained by option 3162 mm², the surface of the surface of the resulting T-shirt bag according to the physic-

mechanical properties of the gauze was 5484 mm². It follows that in the 2-th variant, the surface of the T-shirt on the quality indicators of the drape is proved to be larger than the surface of the other T-shirt drapes. In conclusion, the resulting T-shirt on Option 2 was found to be the most optimal option of the finishing. The correlation coefficient is determined in the quantitative

evaluation of the interdependence of two variable dimensions. The coefficient of correlation is proportional from one variable to another: the higher the deviation in the studied shirt bag, the smaller the coefficient of correlation.

The coefficient of correlation is determined using the following formula.

$$r = \frac{\sum XY}{\sqrt{\sum X^2 \sum Y^2}} \quad (1)$$

here: - deviation from the average arithmetic mean of two correlation rows; - deviation from the average arithmetic mean of two correlation rows.

The error of the correlation coefficient is determined using the following formula.

$$m_r = \pm \frac{1-r^2}{\sqrt{n}} \quad (3)$$

When calculating the correlation coefficient, the power of disconnection of shirt-top gaskets from a mixture of 68,4% cotton+31,6% lavsan fiber in Option 1 and 42% cotton+58% lavsan fiber in Option 2 was taken into account.

The following table 1 shows the results of the calculation of the correlation coefficient based on the power of interruption of shirt-top gaskets in the direction of the weft.

Table 1.

The results of the calculation of the coefficient of correlation of the T-shirt gaskets on the basis of the shear strength of the body direction

X	Y	$X - M_x$	X^2	$Y - M_y$	Y^2	XY
605,0	584,0	16,7	278,9	-55,1	3036,1	-920,2
601,2	608,4	12,9	166,4	-30,7	942,5	-396,0
545,5	620,5	-42,8	1831,8	-18,6	345,9	796,1
635,2	598,6	46,9	2199,6	-40,5	1640,3	-1899,5
612,8	690,9	24,5	600,3	51,8	2683,2	1269,1
577,6	704,5	-10,7	114,5	65,4	4277,2	-699,8
643,2	688,8	54,9	3014,0	49,7	2470,1	2728,5
612,4	604,3	24,1	580,8	-34,8	1211,0	-838,7
488,9	612,2	-99,4	9880,4	-26,9	723,6	2673,9
511,6	679,6	-76,7	5882,9	40,5	1640,3	-3106,4
$\sum X = 5833,4$	$\sum Y = 6391,8$	$\sum X = -49,6$	$\sum X^2 = 24549,6$	$\sum Y = 19,4$	$\sum Y^2 = 18970,2$	$\sum XY = -393$

Shirt from Option 1, the average value of the drape in the direction of the weft of the drape is calculated as follows.

$$M_x = \frac{\sum X}{n} = \frac{5833,4}{10} = 583,3$$

Shirt from Option 2, the average value of the drape in the direction of the drape on the weft is calculated as follows.

$$M_y = \frac{\sum Y}{n} = \frac{6391,8}{10} = 639,1$$

The coefficient of correlation is determined as follows.

$$r = \frac{\sum XY}{\sqrt{\sum X^2 \sum Y^2}} = \frac{-393}{\sqrt{24549,6 \cdot 18970,2}} = -0,18$$

The error of the correlation coefficient is determined as follows.

$$m_r = \pm \frac{1-0,18^2}{\sqrt{10}} = \pm \frac{0,97}{3,2} = \pm 0,3$$

The reliability of the correlation coefficient is determined as follows.

$$\frac{r}{m_r} = \frac{0,18}{0,3} = 0,6$$

In our example, we can confirm that there is a strong inverse correlation even lower than the correlative link between the investigated results, and that the calculations are at the limit of experimental reliability according to the criteria of proper performance.

The following table 2 provides the results of calculating the correlation coefficient based on the power of interruption of the T-shirt gaskets in the arc direction.

Table 2.

**The results of the calculation of the coefficient of correlation
of the T-shirt gaskets on the basis of the shear strength of the arc direction**

X	Y	$X - M_x$	X^2	$Y - M_y$	Y^2	XY
540,6	588,5	28,9	835,21	21,2	449,4	612,7
498,4	567,4	-13,3	176,9	0,1	0,01	-1,33
476,5	524,7	-35,2	1239,0	-42,6	1814,8	1499,5
520,2	602,1	-9,2	84,6	34,8	1211,0	-320,2
500,4	598,6	-11,3	127,7	31,3	979,7	-353,7
480,2	567,2	-31,5	992,3	-0,1	0,01	3,15
540,3	544,2	28,6	817,9	-23,1	533,6	-660,7
500,2	560,7	-11,5	132,3	-6,6	43,6	75,9
540,6	578,2	28,9	835,2	10,9	118,8	315,0
519,6	541,4	7,9	62,4	-25,9	670,8	-204,6
$\sum X = 5117$	$\sum Y = 5673$	$\sum X = -17,7$	$\sum X^2 = 5303,5$	$\sum Y = -0,1$	$\sum Y^2 = 5821,7$	$\sum XY = 1316,3$

1-T-shirt from the option, the average value of the drape in the direction of the back of the drape is calculated as follows.

$$M_x = \frac{\sum X}{n} = \frac{5117}{10} = 511,7$$

Shirt from option 2-Bop the average value of the drape in the direction of the back is calculated as follows.

$$M_y = \frac{\sum Y}{n} = \frac{5673}{10} = 567,3$$

The coefficient of correlation is determined as follows.

$$r = \frac{\sum XY}{\sqrt{\sum X^2 \sum Y^2}} = \frac{1316,3}{\sqrt{5303,5 \cdot 5821,7}} = 0,23$$

The error of the correlation coefficient is determined as follows.

$$m_r = \pm \frac{1 - 0,23^2}{\sqrt{10}} = \pm \frac{0,95}{3,2} = \pm 0,3$$

The reliability of the correlation coefficient is determined as follows.

$$\frac{r}{m_r} = \frac{0,23}{0,3} = 0,8$$

In our example, $r = 0,23$ is equivalent, which means that it can be confirmed that the correlation between the test results has a lower strong feedback than $r < 0,5$, and that the calculations were performed correctly within the experimental reliability according

to the $\frac{r}{m_r} \leq 3$ criterion.

Based on the tensile strength of clothing fabrics in the direction of the body and back, it can be concluded that the guaranteed correlation coefficient can be reduced by a factor of ± 0.3 between X and Y . However, this error can also be due to additional random factors. In such cases, since the correlation coefficient is inversely proportional and within the reliability limits, it is necessary to increase the number of experiments and determine the regression coefficients and confirm their reliability.

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CHANGE OF PHYSICO-MECHANICAL PROPERTIES OF T-SHIRT FINISHING WITH DIFFERENT FIBER CONTENT

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ИЗМЕНЕНИЕ ФИЗИКО-МЕХАНИЧЕСКИХ СВОЙСТВ ПЛАТЕЛЬНЫХ ТКАНЕЙ С РАЗЛИЧНЫМ СОДЕРЖАНИЕМ ВОЛОКОН

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ABSTRACT

In this article, threads are taken from a mixture of different fibers, namely 68,4% cotton+31,6% a mixture of lavsan fibers, 42% cotton+58% a mixture of lavsan fibers, 6% wool+17% lavsan+67% a mixture of cotton fibers, 100% viscose fiber and 8,5% wool+4% lavsan+87,5% a mixture of cotton fibers. In the laboratory of the Department of "Technology of textile fabrics" in the modern weaving workshop, shirt-top fabrics were obtained and their physico-mechanical properties were determined.

АННОТАЦИЯ

В данной статье нити были взяты из смеси различных волокон, а именно 68,4% хлопка+31,6% лавсановых волокон, 42% хлопка+58% лавсановых волокон, 6% шерсти+17% лавсана+67% хлопковых волокон, 100% вискозного волокна и 8,5% шерсти+4% лавсана+87,5% смеси хлопковых волокон, и в лаборатории кафедры "технология текстильных тканей" были получены ткани для одежды и определены их физические и физико-механические свойства.

Keywords: air permeability and abrasion resistance, T-shirt gaskets lightweight, air permeability high, durable, density on body and back.

Ключевые слова: воздухопроницаемость и стойкость к истиранию, лёгкие прокладки для платья, высокая воздухопроницаемость, долговечность, плотность по основу и утку.

In a market economy based on free competition, one of the main tasks of textile enterprises is the production of quality, competitive and popular shirts. In order for the fabric to be produced to be competitive and in demand, its quality indicators must meet the requirements of the world market for these products, that is, the requirements of world standards. At the same time, the cost of production should be low, the enterprise should introduce advanced equipment and technologies, and high labor productivity should be achieved.

By solving these problems, it is possible to increase labor productivity in textile factories, reduce labor costs, mechanize manual labor, make full use of internal resources, and automatically control technology through computer systems [1-4].

Decree of the President of the Republic of Uzbekistan "On measures to accelerate the development of the textile and clothing industry" PF-5285 dated December 14, 2017 "On measures to further deepen the reform of the textile and clothing industry and expand its exports." potential "2019 This dissertation research to a certain extent contributes to the implementation of the tasks set by Resolution No. PQ-4186 dated February 12, 2012 and other regulations related to this activity.

One of the main conditions for the development of the country's economy is a systematic improvement in product quality. Improving product quality, expanding the range and meeting consumer demand is one of the important tasks of a modern market economy. To ensure the level of product quality, it is necessary to carry out systematic control work in accordance with the regulatory requirements of standards and technical conditions [5-8].

At the same time, in order to improve product quality, it is necessary to raise the scientific and technical level of standards, regularly update standards and specifications, guarantee product quality and a high technical level. In addition, new management conditions in a market economy place new demands on product quality. More importantly, textiles must meet the ever-growing demands and needs of the population. Each line, each industrial enterprise must have a clear path of production renewal. Raising the quality of the product to the level of world standards will ensure the entry of the product into world markets [9].

Assessing the quality of the desired product - textile materials - means justifying regulatory requirements for important material properties in determining rational processing and application possibilities [10].

The results of assessing product quality depend not only on the level of general properties and the accuracy of sufficient measurements, but also on the level of demand for these properties.

It is also the selection of reasonably justified indicators of the quality of the products used or processed for a specific purpose.

The fabrics currently produced in the textile industry are diverse. They differ in structure, purpose, fiber composition and properties.

One of the main characteristics of a shirt fabric is breathability, tear strength, abrasion resistance, color tear strength and so on.

For example, the jacket has the ability to conduct air, water, gas, steam, dust, smoke liquids, radioactive pomegranates from the gaskets themselves. Air permeability is the ability to conduct air from the sample itself, which is assessed by the air permeability coefficient. The air permeability coefficient indicates the amount of air volume passing through the surface of 1 square meter in one second under the conditions of a known difference in air pressure on both sides of the sample.

The higher the density of the jacket gaskets on the body and in the direction of the arc, the lower the air permeability coefficient. Therefore, any shirt is produced by paying attention to the season in the production of suede fabrics.

In addition to it, the crumpling of the T-shirt fabrics is one of their negative properties. It spoils the appearance of the piece. Easily crumpled finishes quickly break off, because they are much more friction in Bent and twisted places.

It is understood that the T-shirt fabrics do not wrinkle-they have a resistance to wrinkle and come to their original condition after the wrinkle.

Alternatively, one of the main indicators of the shirt-top drape is its resistance to friction.

The friction resistance of the gaskets depends on the fiber content, density, thin or creamy of the threads, thickness and other indicators. For example, the more friction the gaskets, the more the structure of the gaskets is broken, the threads in the composition are cut off, the power of the break is reduced.

The absorption of T-shirt fabrics is mainly due to the friction effect. The friction resistance of the gaskets depends on their fiber content, the structure of the surface. The ends of the fiber, which first come out on the surface of the gaskets, are under the influence of friction.

T-shirt begins to absorb the fibers that go out to

the bent places of the threads in the gauze. Some areas of the fiber surface are damaged and the fibers are cut off. Due to the fact that some fibers or parts of the fiber come out of the structure of the thread, the threads are also cut off.

The bent areas of the threads coming out on the surface of the gaskets are the first to be absorbed in the friction effect. These places are considered the base surface of the gaskets, that is, the larger the base surface of the gaskets, the better its resistance to absorption. By tilting the base surface of the gaskets, it is possible to increase its resistance to absorption. To do this, long-coated plaques (satin, satin), friction-resistant fibers (Kapron, lavsan) or finishing processes (appretization) are used in the fiber composition.

The absorption in the friction of T-shirt fabrics with thick fibers and especially synthetic fibers in the composition usually begins with the appearance of pilling.

In the most frictionless areas of the workpiece, rain balls are formed from loose fibers-Pillar. First, the ends of the fibers come out on the surface of the gauze. Then, they get confused. When spinning, some fibers break out of the structure of the gauze. Then in the oven, the fibers in the batteries break off from the surface of the gaskets. As a result, the thickness of the gaskets decreases and it is easily absorbed.

Research work was carried out to determine the physico-mechanical properties of the gaskets.

The results obtained by the test are presented in table 1.

Table 1.

The effect of different fiber content on the physical properties and non-wrinkle performance of T-shirt fabrics

t / r	Fiber content of the finishing	Air permeability, dm ³ /m ² sek	Water permeability, mm.water.top	Non-wrinkle, %	
				According on the weft	According on the back
1.	68.4% cotton+31.6% lavsan fiber	83,3	160	62,2	60,5
2.	42% cotton+58% lavsan fiber	92,1	145	67,1	65,8
3.	6% wool+17% lavsan+67% cotton	53,2	150	59,1	60,7
4.	100% viscose	79,9	240	50,0	52,2
5.	8.5% wool+4% lavsan+87.5% cotton fiber	50,4	142	68,1	65,8

Based on the results from the table, the graph of the variation in air permeability, non-wrinkle, friction resistance of shirt-top gaskets obtained from a mixture of fibers of different composition was drawn in Figure1-2.

Figure 1. A change in the air and water permeability of T-shirt fabrics, the fiber content of which is different

Figure 2. The difference in the composition of the fiber is that the T-shirt fabrics of different types do not wrinkle

If we analyze the results of the tests carried out, then 68,4% cotton+31,6% shirt derived from a mixture of lavsan fibers compared to the quality indicators of the gauze, 42% cotton+58% shirt derived from a mixture of lavsan fibers air permeability of the gauze increased by 9,6%, water permeability decreased by 9,4%, non-wrinkle the air permeability of the jacket gaskets from the mixture to 36,2%, water permeability to 6,2% , the air permeability of 100% viscose fiber T-shirts decreased by 4,1%, the water permeability increased by 33,3%, the air permeability of the T-shirts increased by 19,6%, the air permeability of the T-shirts decreased by 13,7%, the air permeability of 8,5% wool+4% lavender+87,5%, the air permeability of the T-shirts obtained from the water permeability decreased by 39,5%, water permeability by 11,2%, non-wrinkle on the direction of the body increased by 8,7%, non-wrinkle on the back increased by 8,1%. As can be seen from the results of the research, 42% cotton+58% shirt from a mixture of lavsan fibers, the air permeability of the gauze, the non-wrinkle in the direction of the body and back were higher in comparison with other fiber-containing fabrics.

From the results of the analysis, it was determined that the air permeability of the T-shirt gas obtained from a mixture of 42% cotton+58% lavsan fibers increased by 9,6%, water permeability decreased by 9,4%, non-wrinkle in the direction of the body increased by 7,3%, non-

wrinkle in the direction of the back by 8,1% compared to the

When washing, soaking, soaking, soaking the gauze, its dimensions change when stored in air with a large relative humidity. Such a change in dimensions is the introduction of gases, in the process of which, most often, the dimensions of the gases are smaller. Entry in this case is called positive entry. The dimensions of some gaskets increase. Such an introduction is called a negative introduction.

In weaving, the material is moistened-when heated, its dimensions either decrease (the process of ironing with the introduction) or increase (the process of ironing with the sink). When heated by soaking, the introduction is called mandatory-introduction.

With the help of forced entry, weaving items are given a certain desired shape. With the help of forced entry, weaving items are given a certain desired shape. Other inputs from forced input are negative indicators of gaskets. As a result of the ingress of the gaskets, it is possible that the pieces and pieces sewn from them become smaller and the shape is distorted.

The penetration and change in paint strength of the different types of fibers with different finishes was investigated, and the results of the test obtained were presented in table 2.

Table 2.

The penetration of T-shirt fabrics and the durability of the paint fiber content change

t / r	Fiber content of the finishing	The paint in soap processing is durable, ball	Toobey, %		Paint durability, points	
			According on the weft	According on the back	dry	wet
1.	68.4% cotton+31.6% lavsan fiber	5/5/5	-2,5	-1,0	4	3
2.	42% cotton+58% lavsan fiber	5/4,5/4	-1,5	-1,0	4	4
3.	6% wool+17% lavsan+67% cotton	5/5/5	-2,0	-1,5	3	2
4.	100% viscose	5/5/5	-3,5	-1,5	4	2
5.	8.5% wool+4% lavsan+87.5% cotton fiber	4,5/4/4,5	-2,5	-1,5	3	3

Based on the results of the study, graphs of the change in the strength of the paint in dry and wet friction were constructed on the input of shirt-top gaskets in the

direction of the body and back, depending on the fiber content in Figure 3 and 4.

Figure 3. The change in the penetration of T-shirt fabrics with different fiber content on the body and back directions

Figure 4. A change in the consistency of the paint on dry and fine friction of the T-shirt fabrics, the fiber content of which is different

If we analyze the results of the test, 68,4% cotton+31,6% dye strength obtained from a mixture of lavsan fibers 5/5/5 points, penetration on the weft -2,5 points, penetration on the back -1,0 points, dye strength in Dry Friction 4 points, dye strength in fine friction 3 points, 42% cotton+58% dye strength obtained from a mixture of lavsan ball point, entry on the weft -1,5 ni, entry on the back -1,0 ni, paint consistency on dry friction 4 NI, dyeing strength in wool friction 4 ni, 6% wool+17% lavsan+67% T-shirt finishing obtained from a mixture of cotton fibers paint strength in soap processing 5/5/5 points, entry -2,0 on the weft, entry -1,5 on the back, paint strength in Dry Friction 3 ni, paint strength in wool friction 2 ni, 100% viscose fiber T-shirt finishing ballni, entry -3,5 on the weft, entry -1,5 on the back, paint consistency in dry friction 4 on the back, paint

consistency in wet friction 2 on, 8,5% wool+4% lavsan+87,5% T-shirt from a mixture of cotton fibers, the consistency of the paint in the treatment of gauze with soap 4,5/4/4,5 ballni, the entrance on the weft -2,5 ni, the entrance on the back -1,5 ni, the durability of the paint in Dry Friction 3 ni, the durability of the paint in wet friction 3 ni.

As can be seen from the results of the research, it was found that the paint strength in dry and mild friction was higher than in other constituent Gaskets, with a T-shirt coating obtained from a mixture of 42% cotton+58% lavsan fibers, with a paint consistency obtained from a mixture of 68,4% cotton+31,6% lavsan fibers and it was found that the jacket obtained from a mixture of 6% wool+17% lavsan+67% cotton fibers is higher in the gassing than other gasses.

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RESEARCH OF OPERATIONAL PROPERTIES OF THREADED CONNECTIONS OF CLOTHING PARTS

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ИССЛЕДОВАНИЕ ЭКСПЛУАТАЦИОННЫХ СВОЙСТВ НИТОЧНЫХ СОЕДИНЕНИЙ ДЕТАЛЕЙ ОДЕЖДЫ

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ABSTRACT

This article presents the results of studies of the influence of various technological factors on the slippability in the seams of materials with movable structures. The research of influence of pattern cutting method relative to warp thread and direction of seams in garments on fabric thread slippage along seams in order to select rational design solutions is presented. The dependence between thread extensibility in the seams and plastic deformation of the fabric, allowing for reasonable selection of seam allowance values in the garment, is presented. Results of research into the influence of stitch length and design of joining seams on the value of seam extensibility in garments made of materials with high thread

extensibility are also presented. The information obtained about the nature of thread extensibility in the seams will scientifically substantiate recommendations for improving the quality of thread connections in garments depending on the direction of seams and choose a rational design and technological solution. The article presents the results of research for Uzbek abr cloth adras.

АННОТАЦИЯ

В данной статье представлены результаты исследований влияния различных технологических факторов на раздвигаемость в швах из материалов подвижных структур. Представлены исследования влияния способа раскроя деталей относительно нити основы и направления швов в одежде на раздвигаемость нитей ткани вдоль швов с целью выбора рациональных конструктивных решений. Представлена зависимость между раздвижкой нитей в швах и пластической деформацией ткани, позволяющая обоснованно выбирать величины припусков в одежде. Также представлены результаты исследования влияния длины стежков и конструкции соединительных швов на величину раздвигаемости в швах изделий из материалов с высокой раздвигаемостью нитей. Полученная информация о характере раздвигаемости нитей в швах позволит научно обосновать рекомендации по повышению качества ниточных соединений в одежде в зависимости от направления швов и выбрать рациональное конструктивное и технологическое решение. В статье представлены результаты исследований для узбекской абровой ткани адрас.

Keywords: seam extensibility, fabric density, relative elongation of sample, connecting seam, cutting direction, base, weft, stitch frequency, stitch length, stitch design, stitch strength, abr cloth.

Ключевые слова: растяжимость шва, плотность ткани, относительное удлинение образца, соединительный шов, направление резки, основание, уток, частота стежков, длина стежка, дизайн стежка, прочность стежка, абровая ткань.

In the manufacture of garments, knowledge of the properties of materials necessary for the right choice of product design, its features, means of shaping and shaping, technological techniques and methods of processing various parts and components of the garment, as well as to ensure the quality of products during operation. Properties of materials depend on the types of fibers, weave, raw materials, methods of production and finishing, so it is necessary to study the structure, chemical composition and properties of textile fibers [1].

Thread slippability in seams is one of the technological properties of materials. The aim of the study is to investigate the process of slippability in various textile materials, as well as to study the influence of various factors on slippability in seams. It is known that slippage occurs in low density fabrics of weakly fixed structure. Here, the nature of the fiber should also be considered. For example, viscose, silk, polyacrylonitrile fibers have a smooth surface and are easy to shift.

The fiber composition of the fabric affects sliding. Sliding occurs in fabrics made from smooth yarns and in fabrics with different densities of warp and weft yarns. For example, in abr cloths, the weft yarns are several times thicker than the warp yarns. Thus, in cotton-silk abr cloths, the filling threads remain unbent, and the smooth warp threads bend around them. This increases the warp's slippage relative to the weft.

Studies carried out by scientists of materials science [2-6] have shown that slippability of threads in seams depends on the structural characteristics of fabrics: weave, surface density of fabric, linear density of threads, fabric density on warp and weft, fiber composition, the number of overlaps per 1 cm². Minimum values of sliding ratio are characteristic of plain weave fabrics, and maximum values are typical of twill weave fabrics. Fabrics of equal density are less subject to thread slippage at the seams, compared to fabrics with different warp and weft densities. Increasing the density of the

fabrics results in increased curvature of the yarns, making it more difficult for them to move in the warp or weft direction.

The strength in the different directions is not the same. When force is applied at an angle to the warp and weft yarns, the strength of the fabric is less than in the longitudinal and transverse directions. This is explained by the fact that when tensile samples cut at an angle to the warp and weft yarns, only part of the threads of the sample are clamped in the vise of the tensile machine. Moreover, the strength of even this part of the threads, fixed by both ends, is not fully used, since they are situated at a certain angle to the acting force [7].

Textile materials of different purposes, fiber composition, weave, and surface density were selected for research. They were divided into six groups. They are abr, suit and coat, lining, jacquard, dress and shirt, and furniture and decorative fabrics. This article presents the results of research for adras-type abrasive materials [8].

The influence of cutting direction on the indicator of thread slippage in seams was investigated. Samples were prepared from selected materials, cut at different angles to the warp thread (15°, 30°, 45°, 60°, 75° and 90°). These angles were chosen because they are characteristic of the direction of the seams in the garment. The slidability of the threads in the seams at these angles to the warp thread was studied according to the method of Kostroma State Technological University [9].

The sample in the chosen direction was subjected to stretching along the cylindrical surface and measured the slippage in the seams along the studied direction (1_a), as well as the change in linear dimensions of the sample (ϵ_a) between the control marks. The magnitude of the load is equal to operational (9 daN), loading time 30 min. Time of loading of samples of 30 min. was chosen experimentally and is sufficient for reaching the equilibrium state. Increase of test time from 30 to 60 min does not lead to increase of threads extendibility values in seams.

Table 1.

**Influence of cutting direction on thread separation in seams (l_a)
and change in linear dimensions (ε_a) of abr cloths**

№	Surface density, g/m ²	Fiber composition	Thread expansion in seams (l_a), mm / relative elongation, %						
			Angle value to the fabric grain						
			0°	15°	30°	45°	60°	75°	90°
1	137,8	FSI FCot	0,9/2,0	0,3/6,2	0,8/6,6	1,4/9,8	1,5/8,3	2,4/3,3	3,8/2,0
2	166,3	FCot-100	0,5/4,4	0,8/7,2	0,6/10,2	0,2/11,7	1,5/11,7	2,5/9,8	3,5/2,9
3	119,6	FCot-100	1,8/1,6	1,5/10	1,0/11,4	1,0/8,5	1,5/10	2,8/9,6	4/3,2
4	92,5	FSI -29,9 FPAM-70,1	0,5/1,5	0,8/2,2	0,6/5,8	0,3/9,6	1,8/5,9	2,4/5,0	4,0/3,8

The research assesses the amount of thread separation in the seams by the displacement of the threads in the seams. Fig. 1 shows the results of the study of the

dependence of slippage in the seams of abr cloths on the direction of cutting relative to the warp thread.

Figure 1. Dependence of slippage l_a and relative elongation ε_a on angle α of fabric cutting, where (a) adras cotton with a surface density of 166 g/m²; (b) cotton-silk adras with a surface density of 137,8 g/m²

For adras fabrics, the lowest slippage is when cutting at an angle of 45° to the warp threads. At 15° and 30° cutting, the slippage rate is insignificant. For cotton-silk adras, the smallest spread occurs when cutting 15° to the warp thread. Relative elongation is inversely proportional to slippability. The lower the extensibility, the higher the relative elongation.

In the study, simultaneously with the value of extensibility of the threads in the seams, the presence of plastic deformation of the samples was observed. An inverse relationship was observed between the extensibility and the value of plastic deformation. For samples with minimal sliding, the greatest plastic deformation was observed compared to those with maximum sliding [8, 10]. For all fabrics, the greatest plastic deformation is characteristic in the 45° direction to the warp threads, the least plastic deformation is observed in the direction of warp and weft threads. Applying force along an oblique line changes the angles between warp and weft yarns in the fabric system, which causes a change in the linear dimensions of the fabric. With a change in net angles, warp and weft yarns are more densely arranged, making it more difficult for them to shift relative to each other [8, 10].

Prediction of the ability of materials to extend at seams in different directions of cutting provides information about changes in linear dimensions of materials when extensibility at seams occurs, as well as the possibility to choose a rational number and arrangement of design lines in garments with minimal or no extensibility of threads at seams. Consequently, when cutting, it is necessary to take into account the ability of fabrics to move the threads in the seams, especially those subjected to repeated stretching, and strive to ensure that the moving threads are located at a certain angle to the cut [8, 10].

Thus, evaluation of the values of seam extensibility has shown that the method of pattern cutting relative to the warp thread has a significant impact on the extensibility of threads in the seams. The results of research on the dependence of thread extensibility in seams on the angle of cutting allow us to scientifically substantiate recommendations for improving the quality of thread connections in garments depending on the direction of seams and select a rational design solution. On the basis of the above, we have developed rational variants of garment partitioning for fabrics with high slippage (Fig. 2) [8].

Figure 2. Recommended cutting direction for garment parts made of fabrics with high slidability in the seams

Further, the influence of stitch frequency on slippability of threads in seams of researched materials was investigated. Thus, in the manufacture of products of the upper range of products recommended stitch length for static seams 2,5 cm, for finishing 3-3,5 cm. If the seam falls on a heavy load, it is recommended to increase the frequency of stitching of 1 cm, i.e., use a stitch length of 1,5-2,0 cm. In this regard, to determine the effect of stitch frequency on the extensibility of the threads in the seam, samples were sewn with stitches of length 1,5; 2,5 and 3,5 mm. Tests were carried out on a cylindrical crossbar, covered with leather at a static load of 9 daN according to the methodology.

The results of the study of the effect of stitch frequency on the slippage of the threads in the seams (Fig. 3), showed that for all tested materials, reducing the stitch length of the thread stitch reduces the slippage of the threads in the seams. If the stitch length is increased from 1,5 mm to 2,5 mm, the slippage is increased by 30% on average, and if the stitch length is increased to 3,5 mm, the slippage is increased to 70%. That is, the higher the stitch frequency in 1 cm, the lower the extensibility of the stitches. Seam extensibility with a stitch length of 3,5 mm is 1,5 to 2 times higher than seam extensibility with a stitch length of 1,5 mm. Consequently, for fabrics with high slidability it is necessary to increase the stitch frequency of 1 cm.

Figure 3. Dependence of fabric threads slippage l_a on stitch length (frequency) for abr cloth

In the manufacture of garments, stitches of various designs are used. These are join stitches, edge stitches and finishing stitches. The load falls mainly on the connection stitches that connect the side, shoulder, middle sections and relief sections of products. These seams can be stitched in a blow-out or blow-in, sewn, stretching [12, 13].

In order to determine whether the stitch design affects slackness in thread seams, research was conducted.

For selected samples of materials, studies were conducted to determine the effect of thread joint design on the slidability of the threads in the seams. Reinforced lavsan sewing threads №331l were used as a binding element. The studies were conducted on a cylindrical crossbar with a radius of 4 cm, covered with leather. Presents the types and design of joints used in the research on the effect of joint design on extensibility in joints (Table 2).

Table 2.

Design of thread connection sutures for the studied samples

№	Seam name	Joint design	Joint width, in mm.
№1	Stitching in the open seam		10
№2	Inseam bartack seam		10
№3	Stitching seam with open seams		10; 2
№4	Stitching with a closed seam		10; 5
№5	Unstitched seam		10; 2
№6	Backstitching		10; 5

Figure 4. Diagram of dependence of thread slippage in seams l_a on the design of the seams for abrasive fabrics

As shown by the results of the sample study, the slippage of the threads in the seams also depends on the seam design (Fig. 4). Thus, the greatest resistance to sliding in all fabrics is observed when using a split seam, where seam allowances are fixed with additional stitches at a distance of 2 mm. In this case, the strength of the seam to sliding is due to the fact that in this variation of the design provides for fixing the structure of the fabric on both sides by additional stitches.

The greatest sliding of fabric threads in the seams are observed in samples where a seam is applied in a seam with over stitching and back stitching. This is due to the fact that the seam and the fabric structure are not fixed. In the case of the adjustable stitches, the sliding motion is greatly reduced, but on the unstitched side it occurs. A complex linen lockstitch construction slightly reduces sliding. It also occurs on the loose side.

Consequently, for fabrics with high slippage, it is more acceptable to use a split seam. For example, for abraded fabrics, the slippage is reduced by a factor of 17. However, for fabrics of the upper range of fabrics a double seam or a tie stitch is used more often, depending on the model, also tie stitches, i.e. stitches with the highest degree of expansion are used. Consequently, when making garments from fabrics of sparse structures, it is necessary to fix the fabric along the seams to prevent sliding [14, 15].

Based on obtained results on character of threads expansion in seams, recommendations on rational design

solution for manufacturing products from fabrics with increased fabrics threads expansion in seams are given.

Thus, evaluation of seam slippability values has shown that the way of pattern cutting relative to warp threads has a significant impact on thread slippability at seams. The information obtained about the nature of thread extensibility at seams makes it possible to scientifically substantiate recommendations for improving the quality of thread connections in garments depending on the direction of seams and select a rational design solution. For example, for fabrics with high slippability, vertical seams should be avoided if warp threads are moved apart relative to weft, and transverse seams should be avoided if weft threads are moved apart relative to warp. Dependences between sliding threads in seams and plastic deformation of fabric have been revealed, allowing for reasonable selection of seam allowance values in garments. When designing articles of sliding fabrics it is recommended to choose design lines with seam directions at angles of 30° , 45° and 60° to warp threads. When cutting, it is necessary to take into account the ability of fabrics to extend the threads in the seams, especially those subjected to repeated stretching, and strive to ensure that the extensible threads are located at a certain angle to the cut. To reduce thread slippage in the seams, the stitching frequency should be increased so that the friction between the fabric threads increases and their ability to shift is reduced.

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CHEMICAL ENGINEERING**OIL POLLUTION PROBLEMS****Gaffar Avalbaev***Senior Lecturer,
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The ability of the World Ocean to absorb oil that has fallen for various reasons and recommendations for eliminating their consequences are given. Shown are the processes of weathering of oil that got to the sea and its duration depending on various factors, the responsibility of various international organizations to prevent oil from entering the World Ocean.

АННОТАЦИЯ

Описана способность Мирового океана поглощать нефть, выпавшую по разным причинам, и даны рекомендации по устранению их последствий. Показаны процессы выветривания попавшей в море нефти и их продолжительность в зависимости от различных факторов и ответственность различных международных организаций по предотвращению попадания нефти в Мировой океан.

Keywords: oil pollution, weathering, oil gathering devices, tanker transport, oil slick, environmental program.

Ключевые слова: нефтяное загрязнение, выветривание, нефтесборные устройства, танкерный транспорт, нефтяное пятно, экологическая программа.

According to the National Academy of Sciences of the United States, about 5.1 million tons of hydrocarbons of petroleum origin fall into the oceans and seas every year (according to 2018 data). More than half of the total volume of pollution comes from sources that are to a small extent associated with the oil industry.

The ability of the oceans to absorb polluting oil is great, but not infinite. In deep waters, adverse consequences are rare, but the consequences of oil spills near the shores, estuaries of rivers or low coastal areas flooded at high tide can be catastrophic. The volume of annual oil transportation by sea exceeds 3 billion tons, which is more than the total volume of transportation of all other goods. Since as a result of international trade in oil, some of it ends up in the sea, in order to solve the

problem, it is necessary to take measures on an international scale at the level of governments of various countries.

Some of the oil ends up in the sea independently of human activity and independent of human activity and cannot be controlled, for example, due to oil seepage in some areas of the seabed or erosion processes. Such uncontrolled pollution accounts for 400 thousand tons of oil per year. About 1.95 million tons, or 45%, goes to the sea with municipal industrial and storm water flows from urban areas. Another 420 thousand tons of oil at sea during the transportation of various goods and as a result of accidents not related to the oil industry.

In 2018, 950 million tons of oil were produced in offshore areas, and of this amount, about 60 thousand

tons fell into the sea. According to an estimate by the National Academy of Sciences, this represents only 1.5% of the total oil that entered the sea, although the degree of pollution from such a source is different (it is higher in areas characterized by high exploration and development of oil fields, such as the Gulf of Mexico or North Sea). Oil discharges into the sea are increased as a result of open flowing events. Drilling of one and 750 wells ends with open flowing and every third of these flowing wells is a source of oil pollution in the seas. However, it should be noted that cases of open flowing, in which large amounts of oil enter the sea, are very rare.

Tanker transport of oil into the sea receives about 30% of the total volume of oil pollution, with 20% during normal tanker operations. On return voyages, tankers take water as ballast and in the past it was common practice to discharge ballast water before loading oil into tanks. The remaining oil from the previous voyage of the tanker was also dumped with the water. The use of modern technology for cleaning tanks from oil residues in recent years has made it possible to reduce its discharge into the sea with ballast waters.

As a result of tanker accidents, 12% of the total volume of oil pollution fell into the sea. During this period, there were several accidents with very large discharges of oil into the sea. However, in subsequent years, the number of accidents with crude oil of 900 m³ and more sharply decreased.

After a spill on the surface of the water, oil that could not be collected by oil-gathering devices undergoes many physical and chemical transformations. Typically, oil spreads over the surface of the water in the form of a film several millimeters thick, depending on its viscosity and water temperature. The film thickness of heavy oils in cold sea water can reach 6 ... 7 mm. Winds and sea currents allow the oil slick to travel long distances and even reach the coast.

Subsequently, under the influence of air, sun and sea water, chemical reactions occur with oil in combination with processes of dissolution, evaporation, photochemical reactions and microbiological degradation. All these processes are united by one term weathering. The weathering time largely depends on the viscosity of the oil, the temperature of the seawater and its turbulence. Typically, according to the US Environmental Protection Agency, the degradation of the oil slick proceeds in the following sequence: the spread of low molecular weight oil, which occurs during the first few days; dissolution of low molecular weight oil components and polar components in the surrounding water (this process is characterized by duration and occurs during the entire weathering process); emulsification, when one liquid is dispersed in another liquid that does not shift with it (the emulsion can be water-oil or oil-water); autooxidation - light hydrocarbons react with atmospheric oxygen to form polar components, which are then dissolved in water: microbiological degradation - aerobic or anaerobic microorganisms use hydrocarbons as food; immersion - occurs as the light components weather and the density of the remaining oil increases, followed by the latter sinking to the bottom, where it degrades as a result of the action of anaerobic microorganisms; the spread of oil on the seabed - occurs

as a result of the impact on the submerged oil of anaerobic microorganisms (its density decreases and oil spreads along the seabed).

These processes can be repeated until the oil slick disappears completely or reaches the coast.

The immediate threat from an oil spill is a fire hazard. They can spread through water very quickly and pose a great danger to piers, ships and marine berthing facilities. Heavy oil products are less fire hazardous, but they can lead to severe pollution of shores, estuaries and tidal zones. In some cases, the pollution persists for 10 years.

The main focus is on preventing the oil slick from reaching the shore, but this is often not possible as the weathered forms of the oil become asphalt-like and highly resilient; sooner or later they reach the shore. Sometimes chemical dispersants are used to decompose oil at a considerable distance from the coast, but these reagents can be more dangerous to marine life than oil itself, therefore their use is sharply limited in coastal waters of the United States in accordance with the adopted emergency response plan. The deliberate burning of spilled oil is also dangerous and prohibited.

Oil spill prevention and response is an international issue. After the accident with the tanker "Torrey Canyon", when more than 110 thousand m³ of oil got into the sea off the south-west coast of Great Britain, it became obvious that the world was not prepared to deal with large spills of oil or other dangerous products.

About 80% of accidents involving oil spills are due to human error, so one of the real ways to prevent them is to improve the quality of personnel training and tighten standards. Several international organizations, the most famous of which is the International Maritime Organization, worked on the creation of new rules and regulations that increase the reliability of the development of oil fields and oil transportation. As an integral part of the UN, it unites 178 states closely cooperating with each other. As a result of this cooperation, rules, norms and recommendations are developed aimed at improving the existing Standards. These standards come into force after their adoption as laws by the member states of the International Maritime Organization. The global oil industry is represented in this organization by the International Offshore Oil Companies Forum and the Offshore Oil Companies Forum.

The UN Environment Program encourages and supports the creation of regional plans and agreements aimed at reducing the risk of marine oil pollution, cooperation with the International Maritime Organization, the development of training programs for personnel and the exchange of information. The oil industry is also represented in this program through the International Environmental Association of Petroleum Companies.

The aforementioned Forums and the International Chamber of Cargo Transportation are actively involved in identifying the causes of accidents, developing standards for the operation of ships and facilities for the development of offshore fields, aimed at reducing the risk of oil pollution of the seas and creating conditions for personnel training. Oil companies engaged in offshore development are taking measures to improve the reliability of

the equipment used and to train personnel. A number of specialized maritime colleges offer courses for offshore oil company personnel. In some countries, boatmasters are required to complete such courses. The significant decrease in the number of accidents in recent years is a consequence of the increased emphasis on personnel training.

Improvements in technology have helped to reduce the incidence of marine pollution from drilling ships and platforms, production facilities and oil transfer depots. Oilfield wastewater can be discharged into the sea only after it has been cleaned from oil to permissible limits; Contaminated water is treated using efficient separators that provide a high degree of separation of hydrocarbon fluids from drilling fluids discharged into the sea, especially oil-based fluids, in which the hydrocarbon content can reach 15%. In addition, there is a trend towards increasing use in oil-based fluids low-emission oils instead of diesel fuel. Since the introduction of top loading on tankers, oil emissions from tankers have sharply decreased. This method is used by companies in accordance with the Convention on the Prevention of Marine

Pollution, which prohibits the dumping of oil or its mixtures into the sea. It is allowed to discharge oily liquids into the sea at a very low concentration of oil and at a distance of at least 80 km from the coast. New tankers should be equipped with separate tanks for oil and ballast water, and existing tankers should use a special technique for flushing tanks from oil residues. In theory, the culprit of the pollution is legally responsible in each case and is obliged to eliminate its consequences. However, in practice, in many cases, the culprit cannot be identified. The government of the country where the pollution has occurred should itself take measures to limit the spread of oil pollution and carry out clean-up work. In accordance with the UN Sea Pollution Prevention Program, signatory countries must have contingency plans to deal with the consequences of pollution. The plans should define a clear sequence of emergency clean-up operations with the establishment of the priority of each operation. In almost all countries, offshore emergency plans must be approved by local authorities. The adverse effects of pollution can be significantly reduced as a result of the cooperation of all companies operating this field.

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**DEVELOPMENT OF TECHNOLOGY FOR THE PRODUCTION
OF ACETYLENE DIOLS AND THEIR VINYL ETHERS****Lola Yusupova**

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**РАЗРАБОТКА ТЕХНОЛОГИИ ПРОИЗВОДСТВА ДИОЛОВ АЦЕТИЛЕНА
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ABSTRACT

The research work aims to elaborate on the technology of obtaining acetylene diols and their vinyl ethers. The reaction of formation mono-, divinyl ethers as a result of vinyl butyn-2-diol-1,4, by acetylene and the influence of solvents, the catalyst and its quantity, duration of reaction, temperatures were investigated. Reaction velocity was defined. Recommended vinyl-3-butyn-2-diol-1,4, acetylene in the presence of highly basic systems at atmospheric pressure.

АННОТАЦИЯ

Целью исследований является разработка технологии получения ацетилендиолов и их виниловых эфиров. Исследована реакция образования моно-, дивиниловых эфиров ацетиленом в результате образования винилбутин-2-диола-1,4, а также влияние растворителей, катализатора и его количества, продолжительности реакции, температуры. Определена скорость реакции. Рекомендуется винил-3-бутин-2-диол-1,4-ацетилен в присутствии высокоосновных систем при атмосферном давлении.

Keywords: butyn-2-diol-1,4, vinyl ethers, homogeneous catalysis, acetylenic diol, KOH-DMSO.

Ключевые слова: бутин-2-диол-1,4, виниловые эфиры, гомогенный катализ, ацетиленовый диол, KOH-ДМСО.

At present, acetylene-based products are used in chemical production and engineering, medicine, to obtain the growth of regulatory drugs and pesticides, light industry, perfumery, food and other fields [1,2,5,8]. Particular attention is paid to the technology for the production of vinyl ethers and, on their basis, new drugs, unique polymeric materials, high-quality solvents for radio engineering, as well as reagents for directed organic synthesis [3,4,10].

Butyne-2-diol-1,4, a valuable chemical compound, enters into many organic reactions, forming many promising

materials. Undoubtedly, in this aspect, the study of the vinylation reaction of butyn-2-diol-1,4 is of increased interest, since it has not yet been studied.

For the synthesis of various vinyl ethers for research purposes, Watanabe's transvinylation method of available vinyl ethers of alcohols and acids with other alcohols and diols in the presence of mercury, palladium, or iridium salts is widely used.

The second most important method for the synthesis of vinyl alkyl ethers is the acetal dealkoxylation reaction [2], which is usually accelerated by using various acid catalysts:

1,2-Divinyl-1- and 1,2-divinyl-2-propenes (I), (II) were first obtained with a total yield of 68% upon heating (100-110 °C) glycerol and acetylene in the superbasic KOH- DMS, successfully proven in vinylation reactions. The synthesis of propenes (I) and (II) was carried out in an autoclave under acetylene pressure using a significant excess (90-130 mol %) of KOH to glycerol. Under these conditions, 4-vinyloxymethyl-2-methyl-1,3-dioxolane is also formed with a yield of up to 9% [14].

β -substituted vinyl ethers can also be obtained by isomerization of allyl ethers under the action of strong bases [9] or metal complex catalysts [9,11]. According to this method, in the presence of ruthenium complexes, monoalkyl ethers of diols are easily isomerized to the corresponding monovinyl (1-propenyl) ethers of diols [12]:

For the synthesis of various vinyl ethers for research purposes, Watanabe's method of transvinylation of available vinyl ethers of alcohols and acids with other alcohols and diols in the presence of mercury, palladium, or iridium salts is widely used [6, 7].

It is known that the vinylation of saturated alcohols has been well studied, while that of acetylenic alcohols and diols has been insufficiently studied. Our research goal is to develop a technology for producing acetylene diols and their vinyl ethers.

Research and methodology

0.215 g of KOH and 40 ml of DMSO were placed in a flask equipped with a reflux condenser, a stirrer and a tube for supplying acetylene, then the mixture was heated with constant stirring to 97-100 °C, after which it was slowly cooled to 35 °C, 4.3 g (0,05 mol) butyn-2-diol-1,4 and acetylene was passed through the reaction mixture at a temperature of 110 °C.

After 8 hours, the process was stopped and, after cooling, the reaction mixture was extracted with ether

and dried with MgSO₄. Then the solvent was distilled off and the distillation was carried out in the presence of the hydroquinone inhibitor. After that, a fraction with a boiling point of 177-178 °C was obtained (at 10 mm Hg) corresponding to 2.69 g of monovinyl ether of butyn-2-diol-1,4 with Bp = 92-93 °C (at 10 13 mm Hg).

Product yield - 2.69 g, 48.1% (of theory),

$$d_4^{20}=0,870 \text{ g/cm}^3, n_D^{20} = 1,4615$$

Similarly to the above procedure, vinylation was carried out at various reaction times, temperatures and amounts of catalysts, which were also used as LiOH and NaOH.

Results and discussion

In this part of the study, an attempt was made to carry out the vinylation of butyn-2-diol-1,4 with acetylene in a super basic medium. It was found that in the reaction mono- and divinyl ethers of diol were formed. Reaction scheme:

The role of the KOH-DMSO system in the implementation of the vinylation reaction is reduced to the formation of a highly basic low-solvated dimsil anion:

However, the role of DMSO is not limited to this. In the general case, changes in such factors as the dielectric constant of the medium, the degree of hydrogen

bonding, and others can play a significant role in the implementation of reactions.

The conditions and yields of the reaction products were presented in Table 1 on the example of vinylation of butyn-2-diol-1,4. As follows from the data obtained, the dependence of the yield of mono and divinyl ethers on temperature was significant: at 100-120 °C it is 49.4% and 70%, respectively.

The kinetics of the synthesis of vinyl ethers of butyn-2-diol-1,4 were studied. The main factors were determined - the nature of the solvents, the temperature,

and the amount of catalyst that affect the course of the process. Benzene, dioxane, DMSO, and DMF were used as a solvent, and LiOH, NaOH, and KOH served as catalysts. It was revealed that the optimal solvent is DMSO, and the catalyst is KOH. The results obtained under these conditions are shown in Table 1.

Table 1.

Synthesis conditions and yield of vinylation products of butyn-2-diol-1,4

Experience	Reagent ratio			Temperature, °C	Time, hour	The yield of the vinyl ether of butyn-2-diol-1,4, %.	
	Diol 1, mol	KOH, mole	DMSO, ml			monovinyl	divinyl
1	0,1	0,1	90	95	6	28,0	43,0
2	0,2	0,2	200	100	4	40,0	32,0
3	0,2	0,2	200	100	6	31,0	45,2
4	0,1	0,1	90	100	6	29,0	49,5
5	0,1	0,1	90	120	6	27,3	52,4
6	0,2	0,2	200	100	7	26,4	49,2
7	0,1	0,2	100	140	7	24,5	31,6
8	0,15	0,3	200	100	4	44,2	48,0
9	0,2	0,5	20	100	4	31	14,3

The influence of the nature of the catalysts on the yield of vinyl ethers was also investigated (Table 2).

In this case, the amount of catalyst was 5% by weight of alcohol.

Table 2.

Effect of the nature of the catalyst on vinylation of butyn-2-diol-1,4

Catalyst	The yield of vinyl ethers of butyn-2-diol-1,4, %	
	monovinyl ether	divinyl ether
LiOH	24,2	36,8
NaOH	35,3	38,4
KOH	27,1	43,4

It can be seen from the results obtained that the nature of the alkaline catalyst affects the yields of butyn-2-diol-1,4 ethers. In the order of the used catalysts LiOH, NaOH, and KOH, their yields increase. The values for monovinyl ether were respectively: 24.2; 35.3 and 27.1%, and for divinyl ether 36.8; 38.4 and 43.4%.

Thus, in the synthesis of vinyl ethers, KOH was the most active catalyst in synergy with dimethyl sulfoxide.

The amount of catalyst also affects the product yield. To determine this factor, the influence of the amount of KOH in the range of 2-10% of the mass of butyn-2-diol-1,4 was investigated. The data obtained are shown in Table 3.

Table 3.

Effect of the amount of KOH catalyst on the product yield vinyl

The amount of catalyst KOH,% (based on the mass of butyn-2-diol-1,4)	The yield of vinyl ethers of butyn-2-diol-1,4, %	
	monovinyl ether	divinyl ether
2	34,0	36,6
3	30,4	39,5
4	28,5	41,8
5	27,1	43,4
7	25,6	44,6
10	25,3	45,7
12	24,5	46,8
15	24,0	47,3

It follows from Table 3 that with an increase in the content of the catalyst in the studied interval, the yield of monovinyl ether of butyn-2-diol-1,4 noticeably decreases from 34.0 to 24.0%, respectively. A further increase in the amount of catalyst does not significantly affect the product yields.

With an increase in the amount of catalyst, the yield of divinyl ether increases symbiotically. This fact is explained by the fact that in the process, monovinyl ether

was first formed. An increase in the yield of divinyl ether always leads to a decrease in the yield of butyn-2-diol-1,4 monovinyl ether.

When the reaction was carried out under homogeneous conditions, the product yield and the selectivity of catalytic systems were significantly affected by the nature of the solvent. Data on the study of the effect of the nature of solvents (benzene, dioxane, DMSO, DMF) on the yield of the reaction product were given in Table 4.

Table 4.

**Influence of the nature of solvents on the yield of monovinyl ether of butyn-2-diol-1,4.
(The reaction time is 8 hours, the temperature is 130 ° C, the catalyst is KOH (5%)).**

Solvent	Product yield,%	
	monovinyl ether	divinyl ether
Benzene	12,5	5,4
Dioxan	20,6	15,3
DMFA	29,5	32,6
DMSO	27,1	43,4

Of the solvents used, DMSO was found to be the most suitable. In its presence, the yields of mono- and divinyl ethers are, respectively, 27.1 and 43.4%.

The role of DMSO boils down to the fact that, firstly, acetylene dissolves well in it, and secondly, it forms a super-basic system with KOH. In this case, the basicity of KOH increases due to the separation of ion

pairs. Vinyl ethers were formed by nucleophilic addition of diol mono- and di-potassium alcoholate.

It is known that the reaction time and temperature have a great influence on the product yield. In this regard, the effect of temperature (in the range of 100-150 °C) and reaction time (4-10 hours) on vinylation of butyn-2-diol-1,4 in the presence of KOH was also studied (Table 5).

Table 5.

**Influence of the reaction time and temperature on the yield of butyn-2-diol-1,4 divinyl ether
(DMSO solvent, KOH catalyst in an amount of 5% by weight of alcohol)**

Reaction time, hour	Temperature, °C	The yield of divinyl ether butyn-2-diol-1,4; %
4	100	25,6
6	100	33,2
8	100	35,7
10	100	37,5
4	120	27,5
6	120	40,5
8	120	46,0
10	120	47,4
4	130	32,3
6	130	38,6
8	130	43,4
10	130	49,2
4	150	30,0
6	150	36,6
8	150	47,0
10	150	47,3

To identify the dynamics of the process and improve its preparative characteristics, kinetic experiments were carried out. Fig. 4 shows the curves reflecting the change in the concentration of mono - (2) and divinyl (1) ethers of butyn-2-diol-1,4. The appearance of the obtained kinetic curves corresponds to a simple sequential reaction: the initially formed monovinyl ether easily binds to the second acetylene molecule to form divinyl ether, the

concentration of which gradually increases and after 5-6 hours reaches a plateau (Curve 1).

The maximum on the kinetic curve of monovinyl ether was reached after 2 hours (curve 2). At elevated temperatures (110-140 °C), favourable conditions were created for the detected elimination of acetylene from the divinyl ether.

Figure 4. Kinetic curves of the accumulation of divinyl (1) and monovinyl (2) ethers during the vinylation of butyn-2-diol-1,4 in the KOH-DMSO system at a temperature of 95 °C and a ratio of diol: KOH = 1:1

It follows from the table that with an increase in the duration of the reaction at all temperatures studied, the yield of vinyl ether passes through a maximum.

It should be noted that with an increase in the process temperature, the optimal value of the reaction time decreases. For example, at a temperature of 100 °C with an increase in the reaction time from 4 to 6 hours, the yield of the product increases from 25.6 to 33.2%, and at 150 °C in the range of 4-8 hours, the yield of ether increases from 30 to 47.0%.

The study of the effect of temperature in the range of 100-150 °C showed that the product yield passes through a maximum. The maximum yield (49.2%) of butyne-2-diol-1,4 divinyl ether was observed at 130 °C and its partial polymerization occurs.

Thus, the optimal conditions for vinylation of butyn-2-diol-1,4 are the reaction time of 10 hours and the temperature of 130 °C.

The effect of the nature of the catalyst on the yield of butyn-2-diol-1,4 divinyl ether (temperature 130 °C, solvent DMSO) was also studied. LiOH, NaOH, and KOH were used as catalysts. The results were shown in Table 6.

Table 6.

**Influence of the nature of the catalyst on the yield of vinyl ether butyn-2-diol-1,4
(temperature 130 °C, solvent DMSO)**

Catalyst	Reaction time, hour	Divinyl ether yield butyn-2-diol-1,4, %
LiOH	4	19,4
	6	22,0
	8	24,2
	10	24,6
NaOH	4	28,6
	6	32,2
	8	35,3
	10	36,8
KOH	4	32,3
	6	38,6
	8	43,4
	10	49,2

It was found that with an increase in the duration of the reaction in the range of 4-10 hours in all cases, the product yield increases.

Among the catalysts used, the highest yield was achieved with the use of KOH. It follows from this that the greater the basicity of the catalyst, the higher the likelihood of its positive effect on the product yield.

The yield of the products and their purity were determined by gas-liquid chromatography. In fig. 1 shows the gas-liquid chromatogram of the catalyzate formed upon

vinylation of butyn-2-diol-1,4 with acetylene. It was shown that the catalyzate contains vinyl ether of butyn-2-diol-1,4 (1,2), unreacted butyn-2-diol-1,4 (3), solvent DMSO (4), and a small amount of a substance of an unknown structure.

In fig. 2 shows the chromatogram of the synthesized vinyl ether of butyn-2-diol-1,4. The kinetics of the synthesis of the vinyl ether of butyn-2-diol-1,4 has been studied (Table 7).

Figure 2. Gas-liquid chromatogram of the catalyzate of the vinylation reaction of butyn-2-diol-1,4

- 1: butyn-2-diol-1,4 divinyl ether;
- 2: butyn-2-diol-1,4 monovinyl ether;
- 3: butyn-2-diol-1,4;
- 4: solvent is DMSO.

Figure 3. Gas-liquid chromatogram of butyn-2-diol-1,4 divinyl ether

Table 7.

**Kinetic data for the synthesis of the vinyl ether of butyn-2-diol-1,4
(catalyst KOH, 5% by weight of alcohol, solvent DMSO)**

Reaction time, hour	Temperature, °C	The yield of di-VE butyne-2-diol-1,4		Average reaction rate			
		%	mol / L	% / hour	mol / l. hour. (W)	lgW	1+lgW
4	100	25,6	0,3	6,4	0,48	-0,32	0,68
	120	27,5	0,35	6,875	0,6	-0,22	0,79
	130	32,3	0,4	8,075	0,8	-0,097	0,903
	150	30,0	0,38	7,5	0,7	0,155	0,845
6	100	33,2	0,4	4,3	0,29	-0,54	0,46
	120	40,5	0,5	6,75	0,56	-0,25	0,75
	130	43,7	0,55	7,3	0,67	-0,17	0,83
	150	36,6	0,46	6,1	0,47	-0,328	0,673
8	100	35,7	0,45	4,5	0,25	-0,602	0,398
	120	46,0	0,57	5,75	0,41	-0,33	0,67
	130	48,1	0,6	6,01	0,45	-0,35	0,65
	150	47,0	0,58	5,8	0,42	-0,37	0,63
10	100	37,5	0,46	3,75	0,172	-0,77	0,23
	120	47,4	0,59	4,74	0,28	-0,55	0,45
	130	49,2	0,6	4,92	0,29	-0,54	0,46
	150	47,3	0,59	4,73	0,28	-0,55	0,45

Based on the results obtained, the dependence of lgW on 1/T was constructed (Fig. 3) and, according to

the Arrhenius equation, the value of the activation energy for the formation of the divinyl ether of butyn-2-diol-1,4 was calculated, which is 51.7 kJ/mol.

Figure 4. Dependence of lgW on 1 / T in the formation of divinyl ether of butyn-2-diol-1,4

Conclusion

The optimal conditions for vinylation of butyn-2-diol-1,4 providing the maximum yield of butyn-2-diol-1,4 divinyl ether were determined. The best effect as a solvent among the investigated benzene, dimethyl sulfoxide, has dimethyl sulfoxide. With an increase in the

reaction time, the yield of divinyl ether increases, reaching a maximum after 8 hours. The relatively low value of the calculated activation energy, equal to 51.7 kJ / mol, indicates a fairly high rate of the vinylation reaction of butyn-2-diol-1,4.

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ENERGY INDUSTRY**METHODS FOR INCREASING POWER FACTOR****Mirsoli Uzbekov**

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МЕТОДЫ ПОВЫШЕНИЯ КОЭФФИЦИЕНТА МОЩНОСТИ**Узбеков Мирсоли Одилжанович**

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ABSTRACT

The article considers the issue of reactive power compensation, which is one of the main issues to be solved both at the design stage and at the stage of operation of industrial power supply systems, and includes the selection of appropriate sources, the calculation and regulation of their power, the placement of sources in the power supply system. Methods of increasing the power factor, reducing the loss of electricity are considered.

АННОТАЦИЯ

Статья рассмотрена вопрос о компенсации реактивной мощности являющийся одним из основных вопросов, решаемых как на стадии проектирования, так и на стадии эксплуатации систем промышленного электроснабжения, и включает выбор целесообразных источников, расчет и регулирование их мощности, размещение источников в системе электроснабжения. Рассмотрены методы повышения коэффициента мощности, снижение потери электроэнергии.

Keywords: energy, electricity, power supply, components of electrical energy, power, active power, reactive power, compensation of electrical energy, compensating devices, capacitor bank.

Ключевые слова: энергия, электроэнергия, электроснабжение, составляющие электрической энергии, мощность, активная мощность, реактивная мощность, компенсация электрической энергии, компенсирующие устройства, конденсаторная батарея.

An industrial enterprise is a consumer of active and reactive energy. The main consumers of reactive energy are asynchronous motors, as well as transformers, overhead power lines, which constitute the overwhelming majority of consumers at the enterprise. Capacitive electrical receivers: static capacitors, cable lines are sources of reactive energy.

The ratio of the active power P to the total power consumption of the enterprise S is called the power factor $\cos\varphi$:

$$\cos\varphi = \frac{P}{\sqrt{P^2 + Q^2}} \quad (1)$$

The power factor of an electrical installation without the use of special means to increase it is called natural, and for most enterprises is 0.6-0.8.

Generators to provide the enterprise with electricity are designed to operate with their rated power factor of at least 0.8, at which they are capable of delivering rated active power. A decrease in the power factor of consumers below this value can lead to the fact that the power delivered by the generators will be less than the rated power at the same apparent power. Therefore, at low power factors at the consumer, in order to ensure the transmission of active power, it is necessary to build

more powerful power plants or take measures to increase the $\cos \varphi$.

When reactive power flows in electrical networks, the latter causes additional losses of active power and additional voltage losses ΔU :

$$\Delta U = \frac{PR+QX}{\sqrt{U_n}} \quad (2)$$

where R and X are the active and reactance of the network.

The loss of active power in this case:

$$\Delta P = \frac{P^2}{\sqrt{U_n^2 \cos^2 \varphi}} R \quad (3)$$

To increase the voltage at the consumer and reduce losses, one should strive to reduce the transmitted reactive power. This is achieved by increasing the power factor by:

Rationalization of the work of electrical equipment or natural compensation of electrical receivers;

Reactive power compensation.

Natural compensation of reactive power does not require large material costs. One of the main conditions for the rational power supply of the enterprise is the correspondence of the power of the electric motors and the power consumption of the mechanisms set in motion by these electric motors.

Natural compensation of reactive power includes:

- Streamlining the technological process leading to the alignment of the load schedule (uniform distribution of loads in phases, shift of lunch time for different shops, etc.),
- Creation of a rational power supply system by reducing the number of transformation stages,

- Replacement of old-design transformers with a new one with lower magnetization reversal losses,
- Replacement of lightly loaded transformers and motors with transformers and motors of lower power and their full load,
- Limiting the duration of the idling mode of electric motors,
- Disconnection of some power transformers at low load (for example, on weekends),
- Replacement of asynchronous motors with synchronous ones, since synchronous motors, when overexcited, can operate with a power factor close to unity, and even supply reactive power to the network.

Thanks to natural compensation of reactive power, it is possible to only partially unload the power supply system from reactive power. In most cases, natural reactive power compensation is not sufficient to increase the power factor to the required value. Therefore, to ensure the operation of generators with rated parameters and to unload the network from reactive power, it is advisable to generate a part of this power at the place of its consumption. This compensation is called "lateral" compensation.

The main sources of reactive power installed at the point of consumption are synchronous compensators and capacitor banks. The most widely used static capacitors are for voltages up to 1000V and 6-10kV. In cases where compensating devices remain connected to the network, and reactive power consumers are disconnected from it, overcompensation occurs. The result is an increase in total power losses and an increase in the complexity of voltage control devices. Therefore, controllable compensating devices based on semiconductor devices have found application.

Figure 1. Schemes without compensation (a) and with compensation (b) reactive power and their vector diagrams

A visual representation of the essence of reactive power compensation is given in Fig. 1. Before compensation, the consumer had an active power P , respectively a current I_r and a reactive power from a reactive load Q with a corresponding current I_x . The vector I_n corresponds to the full power. Power factor before compensation $\cos \varphi_1$.

After compensation, that is, after connecting a capacitor with a power Q_c in parallel to the load, the total reactive power of the consumer will be $Q-Q_c$ (current I_x-I_c). The angle φ will decrease and the power factor will rise from $\cos \varphi_1$ to $\cos \varphi_2$. The total power consumption at the same active power will decrease from S_1 (current I_n) to S_2 (current

I_2). Therefore, with the same cross-section, it is possible to increase the throughput of the line in terms of active power.

Ideally, it is necessary to carry out full compensation when $Q = Q_c$, but in reality such a situation is unattainable due to the constantly changing network configuration, changes in the operating mode of receivers, etc.

When compensating for reactive power, voltage losses in power transmissions are also reduced. If before compensation the voltage loss was determined by expression (2), then in the presence of compensation we will have:

$$\Delta U_k = \frac{PR + (Q - Q_c)X}{U_n} \quad (4)$$

As already noted, reactive power compensation is carried out using capacitor banks, which are most widely used. The widespread use of capacitor banks is explained by their advantages: insignificant specific losses of active power, absence of rotating parts, ease of installation, relatively low weight and size and cost indicators,

absence of noise during operation, etc. However, there are also disadvantages: fire hazard, residual charge that must be removed, sensitivity to overvoltage, the need for special conditions for the disposal of used batteries.

In networks with a sharply variable shock load, as well as for smooth adjustment of the compensation level, it is recommended to use combined high-speed reactive power sources (Fig. 2). In this case, inductance regulation is carried out by VS thyristors.

Figure 2. Schematic diagram of a fast-acting compensating device

Another technical means of reactive power compensation, which has become widespread, is a synchronous compensator. It is a synchronous motor with no shaft load. It can operate both in the reactive power generation mode and in the mode of its consumption. The change in the generated or consumed reactive power of the compensator is carried out by regulating its excitation.

The advantage of the synchronous compensator as a source of reactive power is the possibility of smooth regulation of the generated reactive power and high resistance in short-circuit and overvoltage modes.

The main difference between a synchronous motor and an asynchronous motor is that the magnetic field required for the operation of the motor is created mainly from a separate direct current source (exciter). As a result, in normal mode, the synchronous motor almost

does not consume reactive power from the network, which is necessary to create the main magnetic flux, and in overexcitation mode (with a leading power factor) it can generate reactive power into the network.

Synchronous motors can generate reactive power at voltage U_{nom} :

$$Q = 0,5P_{nom} \quad (5)$$

One of the disadvantages of synchronous motors is the additional active losses in the winding caused by the generated reactive power:

$$\Delta P = \frac{Q_{nom}^2 r}{U_{nom}^2} \quad (6)$$

Where Q_{nom} is the rated reactive power, r is the resistance of one phase of the motor winding.

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REACTIVE POWER COMPENSATION IN POWER GRIDS**Zuhriddin Hamidjonov**

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КОМПЕНСАЦИЯ РЕАКТИВНОЙ МОЩНОСТИ В ЭЛЕКТРИЧЕСКИХ СЕТЯХ**Хамиджонов Зухриддин Маъруфжонугли**

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ABSTRACT

Reactive power compensation in power grids is a problem that needs to be analyzed on several criteria. Reactive power must be constantly monitored in different operating modes of the power grid. Of course, maintaining reactive power at normal values ensures the stability of the energy system. Finding a solution to this problem will allow us to improve voltage modes, minimize power losses, increase line power, improve voltage stability and power factor.

АННОТАЦИЯ

Компенсация реактивной мощности в электрических сетях - проблема, которую необходимо анализировать по нескольким критериям. Реактивную мощность необходимо постоянно контролировать в разных режимах работы электросети. Конечно, поддержание реактивной мощности на нормальных значениях обеспечивает стабильность энергосистемы. Решение этой проблемы позволит нам улучшить режимы напряжения, минимизировать потери мощности, увеличить мощность в сети, улучшить стабильность напряжения и коэффициент мощности.

Keywords: power, reactive power, compensation, voltage, power grid

Ключевые слова: мощность, реактивная мощность, компенсация, напряжение, электросеть.

Almost all consumers of electrical energy not only require active power for operation but also reactive power.

In most cases, this is an inductive reactive power required for creating magnetic fields, which are required in all electrical drives, for example. Like active power, this reactive power must be generated by generators and transmitted to the consumers. Due to the fact that the transmission of reactive power also causes active power

losses at the ohmic resistances of the transmission system; the electricity companies try to keep the power factor $\cos\varphi$ of the consumers as high, as possible (i. e. in the vicinity of the value 1). Even a $\cos\varphi$ value less than 0.9 leads to a noticeable rise in the apparent current and, thus, in the active power losses [1].

There are several ways to compensate for power grids. We will now explore some of them.

Figure 1. Reactive power compensation by means of parallel capacitors and corresponding vector diagram

Parallel compensation: By means of parallel connection of a capacitance, the power factor of a mixed ohmic – inductive consumer can be improved. The capacitive reactive current of the capacitor compensates the inductive component of the consumer current.

The principle of this parallel compensation, frequently used in practice, is depicted in the following figure for reasons of simplification; the operational capacitance of the line has not been taken into consideration:

The capacitive reactive power Q_c of the capacitor partially or totally compensates the reactive component I_b of the load current, depending on the value of C . For reasons having to do with tariff scales, complete compensation is not of use to the electricity utilities. Compensation is only carried out to a residual reactive power Q'_r , at which point a power factor $\cos\varphi_2$ is just reached, for which no reactive energy need be paid for.

For power values which are uncompensated or partially compensated, the following vector diagrams are valid (P , Q , S = active, reactive, and apparent power of the consumer, $\cos\varphi'_2$ = power factor of the consumer without compensation and the $\cos\varphi_2$ = power factor with compensation):

The compensation power Q_c required for improving the power factor from the angle φ_2 to the angle φ'_2 can be deduced from the vector diagram above [2]:

$$Q_c = P(\tan\varphi_2 - \tan\varphi'_2)$$

From this the required capacitance of the three individual capacitances of a compensation system in star connection can be deduced :

$$C = \frac{Q_c}{\omega \cdot U_N^2}$$

Figure 2. Power relationships with uncompensated and partially compensated operation

Parallel compensation is dependent on load. In practice, therefore, capacitors are connected or disconnected depending on the load condition. In the determination of the capacitance required in compensation for long overhead lines and cables, half the operational capacitance should be taken into consideration if necessary.

If each consumer is individually compensated, then we refer to individual compensation. If a common capacitor system is used for the compensation of a series of consumers - for example, for all drives of an industrial user - then we refer to central or group compensation. Once again, it must be possible to connect and disconnect individual capacitors, in order to adapt the compensation system to varying load conditions.

Series compensation: Another task is fulfilled by the so-called series capacitors. They are used to compensate the inductance of longer lines and thus reduce the voltage drop on the transmission line. However, the transmission losses occurring cannot be reduced using this type of compensation.

To illustrate this principle, it suffices again to study a line without its operating capacitance:

The voltage drop ΔU between U_1 at the beginning of the line and U_2 at the end of the line can be split into a direct-axis component ΔU , and a quadrature component ΔU_q , as shown in Fig. 4; the quadrature component is always much smaller than the quadrature component [2]:

Figure 3. Reactive power compensation using series capacitor and the corresponding vector diagram

The aim of compensation is to achieve a direct-axis voltage drop which is as small as possible. For the capacitance of the series capacitor the following applies when neglecting ΔU_q and under the condition $\Delta U_1 = 0$: [3]

$$C = \frac{1}{\omega(\omega L + R \cdot \cot \varphi_2)}$$

The effect of the series capacitors is independent on the level of the load, but is dependent on its $\cos \varphi_2$. Because; in the case of consumers of the same type, this does not change very much, a series capacitor, unlike a parallel capacitor, need not be controlled.

The capacitor must be protected against overvoltages, which could appear as a result of high short circuit current caused by a short circuit at the end of the line. For this, elaborate measures – a protective series gap for example - are required, which often make the use of series capacitors uneconomical.

Other types of compensation: A third type of compensation is the possibility of reducing the effect of the operating capacitance of long no load lines, or lines operated with light load, by connecting so-called shunt reactors in parallel in this manner, the danger of a voltage increase by the Ferranti effect is prevented [3].

Figure 4. Division of the voltage drop on a line into a direct-axis and quadrature-axis component

In conclusion, take note that the favorable influencing on transmission losses and reduction in voltage increase of no-load lines can be caused not only by capacitors and reactors (so-called static compensation). For this, synchronous machines are also well suited, which are operated at no-load in the mains and, due to their exciter state, only generate inductive or capacitive reactive power. Since, in this case, the phase angle of the mains can be effected, synchronous machines (normally generators of pumping power stations) are described as rotating phase shifters in this operating mode.

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ELEMENTS OF POWER GRID DESIGN*Hamidjonov Zuhridin*

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ЭЛЕМЕНТЫ ПРОЕКТИРОВАНИЯ ЭЛЕКТРОСЕТЕЙ*Хамиджонов Зухриддин Маъруфжонугли*

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ABSTRACT

Designing a new power grid is a complex task that requires solving many technical and economic issues. At the technical issues that given for designing, piece of consumer loads with reliability of energy supply is provided. It also provides opportunities for further development of the network, such as daily schedules of loads, operating time per year with maximum load, secondary voltage of substations, relative position to each other, and availability of supply sources.

АННОТАЦИЯ

Проектирование новой электрической сети это комплексная задача, требующая решения многих технико-экономических вопросов. В технических заданиях для проектирования, приводятся мощности нагрузок потребителей по категориям надежности электроснабжения. Кроме того, для дальнейшего развития сети приводятся точные графики нагрузок, время работы в год с наибольшей нагрузкой, вторичное напряжение подстанции, взаимное расположение и доступность источников питания.

Keywords: rated voltage, economic current density, overhead line, substation, transformer.

Ключевые слова: номинальное напряжение, экономическая плотность тока, воздушная линия, подстанция, трансформатор.

In the terms of reference for the design, the composition of consumers according to the reliability category of the power supply with load capacity is given. It also provides opportunities for further development of the network, such as daily schedules of loads, operating time per year with maximum load, secondary voltage of substations, relative position to each other, and availability of supply sources [4].

During the design process, the nominal voltage, the rational scheme of the network, the cross-section of the conductor and cable lines are selected on the basis of the initial data in the available terms of reference; the number and capacity of transformers or autotransformers in substations are determined; their electrical wiring diagrams are developed; the need to install reactive power sources at substations will be assessed; the means of adjusting the voltage are determined [1, p 180].

Currently, in practice, the method of mutual comparison of costs is used in the design of power grids. The proposed options differ in the rated voltage of the installed network, the configuration of the circuit, the reliability of the power supply to consumers. But all of these options must meet the required requirements. Exactly

such options of the power grid are then carried out by economic analysis and selection of the most rational. If the cost of the compared variants is based on the initial data in the task, then the final choice is selected according to the additional characteristics of the options, ie network operating conditions, its subsequent expansion, high rated voltage, the possibility of easily adding additional automation tools.

The cross-sectional area of line wires of power lines with a nominal voltage higher than 220 kV is selected from the economically normalized current density.

A section of conductor that is economically feasible

$$F_{\text{ЭК}} = \frac{I_{N.b}}{I_{\text{ЭК}}},$$

where, $I_{N.b}$ – is the current flowing through the line wires in the normal mode with the largest load, A.

The next step in determining the cross-section of the conductor wires is to determine the whole value close to the standard values, to check the conditions of general coagulation and heating of the conductors in the post-accident mode, as well as to change the selected sections if the conditions are not met.

In power transmission above 330 kV, the economic current density is not normalized, and the determination of the economic cross-section is carried out by the method of economic intervals.

The cross-section of the conductors of local networks is determined by the allowable voltage loss under additional conditions. If, as an additional condition, the equality of the cross-sections of the conductors in all parts of the line is taken, then,

$$F = \frac{\rho}{\Delta U_{\alpha \text{ add.}} U_{N.Ohm}} \sum_{i=1}^n P_i l_i,$$

where, ρ is the specific resistance of the conductor, $\text{Ohm} \cdot \text{mm}^2/\text{km}$; $\Delta U_{\alpha \text{ add.}}$ - allowable voltage drop across the active resistance of the line; $P_i l_i$ - active power and the length of the i -st part of the line [1, p.182]

If the voltage drop in the line is within the $\Delta U_{\text{add.}}$ allowable magnitude,

$$\Delta U_{\alpha \text{ add.}} = \Delta U_{\text{add.}} - \Delta U_r(F);$$

$$\Delta U_r(F) = \frac{x_{03}}{U_{N.Ohm}} \sum_{i=1}^n Q_i l_i,$$

where, x_{03} - is the inductive resistance along the length of the line, set the same for each part of the line;

Q_i - reactive power of the i st part of the line .

If the equality of the current density in all parts of the line meets the additional conditional requirements, it is calculate from the following formula

$$j = \frac{\Delta U_{\alpha \text{ add.}}}{\sqrt{3} \rho \sum_{i=1}^n l_i \cos \varphi_i}$$

where, $l_i \cos \varphi_i$ is the length of the network and the power factor of the i st part , respectively .

To eliminate the uncertainty in determining the cross section of the conductors, one of the additional conditions is to achieve the minimum material consumption during the line installation process. In this case, the cross section of the last section of the line is from the following formula

$$F_n = \frac{\rho \sqrt{P_n}}{\Delta U_{\alpha \text{ add.}} U_{N.Ohm}} \sum_{i=1}^n l_i \sqrt{P_i}$$

The cross section of the remaining parts is determined from the following relation

$$\frac{F_1^2}{P_1} = \frac{F_2^2}{P_2} = \dots = \frac{F_i^2}{P_i} = \dots = \frac{F_n^2}{P_n}$$

In the considered cases, the determined quantities are rounded up to the nearest standard values and the compliance of the actual and allowable values of the voltage loss is checked. Inductive resistance $x_0 = 0$, cable-sectional direct line voltage loss $\Delta U_{\text{add.}}$ is selected magnitude. Power lines are designed to be tested for heat, as are conductors. Under such test conditions, the maximum operating currents of the $I_{\text{max.p}}$ lines $I_{\text{д}}$ are

compared with the allowable heating currents to the conductors, in terms of previously abandoned cost-effectiveness or allowable voltage loss . If the $I_{\text{max.p}} \leq I_{\text{д}}$ condition is met, then the selected cut is considered to satisfy the heating conditions in the set mode. In this case, the allowable heating current for cables is determined by making a correction to the number of cables operating close to the ground, the temperature of the ground and the overload at the time of emergency response.

The operating and starting currents of the line, which are characterized by a n-load, m coefficient of uniformity, are determined from the following formula

$$I_{\text{max.p}} = m \sum_{i=1}^n I_{\text{max.p}}(i)$$

$$I_{\text{пуск}} = I_{\text{пуск}(n)} + m \sum_{i=1}^{n-1} I_{\text{max.p}}(i)$$

As can be seen from the last equation, with a maximum starting current, one motor is started, while the rest of the loads operate in the set mode. The rated operating current of motors, their nominal power $P_{N.Ohm}$, efficiency coefficient η , power factor $\cos \varphi$ and load factor k_3 are determined [5]:

$$I_p = \frac{P_{N.Ohm} k_3}{\sqrt{3} U_{N.Ohm} \eta \cos \varphi}$$

If the $I_{\text{max.p}} < I_{N.Ohm}$ condition is met, the $I_{N.Ohm}$ fusible inserts of the rated current savers ensure the normal uninterrupted operation of the line being protected.

The second criterion for selecting soluble inserts for storage is the engine start condition, which corresponds to the following inequality:

run under normal conditions

$$I_{N.Ohm} \geq \frac{I_{\text{пуск}}}{2,5}$$

In severe start-up conditions $I_{N.Ohm} \geq \frac{I_{\text{пуск}}}{1,6 \div 2,0}$

Mechanical accounting of overhead lines is an integral part of network design. There are issues with the choice of the capacity of the step-down transformer with or without a moving reserve in the system. In accordance with these recommendations, the total power of the additional reactive power sources $Q_{\text{к}\Sigma}$ is equal to the value of the reactive power imbalance in the network [2].

If reactive power sources are connected at n-substations, then

$$Q_{\text{к}\Sigma} = m \sum_{i=1}^n Q_{\text{ки}}$$

where, is a m-time coefficient.

In order to determine the cost-effective placement of reactive power sources of substations in the network, it is necessary to determine the minimum costs associated with the connection of these sources to the network.

When applied to radial networks with a single load at the end of each line, the minimum cost specified shall meet the following condition

$$\frac{\partial Z_1}{\partial Q_{k1}} = \frac{\partial Z_2}{\partial Q_{k2}} = \dots = \frac{\partial Z_i}{\partial Q_{ki}} = \dots = \frac{\partial Z_j}{\partial Q_{kj}} = \dots = \frac{\partial Z_n}{\partial Q_{kn}}$$

In this case, the economically feasible size of the j -substation reactive power sources is as follows [2, p.288]

where, r_i - i is the active resistance of the supply line of the substation; Q_i , τ_i - the reactive power of the substation and the time of maximum losses, respectively; r_j , Q_j , τ_j - similar to the above quantities, only a j -for the substation

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ISSUES OF EFFECTIVE SELECTION OF COMPENSATING DEVICES OF REACTIVE POWER**Mirsoli Uzbekov**

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**ВОПРОСЫ ЭФФЕКТИВНОГО ВЫБОРА КОМПЕНСИРУЮЩИХ УСТРОЙСТВ
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ABSTRACT

In the electrical circuit, the generated reactive energy is equal to the consumed one. Most industrial installations consume reactive energy, usually exceeding the coverage capacity of power plant generators. The article considers the necessary additional devices for the supply of reactive power to the power system - reactive power compensators: capacitor banks. A large number of aspects are considered both from the standpoint of economic benefits for the energy supplying organization and for the consumer of electricity.

АННОТАЦИЯ

Электрической цепи генерируемая реактивная энергия равна потребляемой. Большая часть промышленных установок потребляет реактивную энергию, обычно превышающую возможности покрытия ее генераторами электростанций. Статье рассмотрены необходимые дополнительные устройства для поставки в энергетическую систему реактивной мощности - компенсаторы реактивной мощности: батареи конденсаторов. Рассмотрены большие количество аспектов как с позиций экономической выгоды для энергоснабжающей организации, так и для потребителя электроэнергии.

Keywords: energy, electricity, power supply, components of electrical energy, power, active power, reactive power, compensation of electrical energy, compensating devices, capacitor bank.

Ключевые слова: энергия, электроэнергия, электроснабжение, составляющие электрической энергии, мощность, активная мощность, реактивная мощность, компенсация электрической энергии, компенсирующие устройства, конденсаторная батарея.

When choosing a compensating device, the main issue is the choice of the capacity of the compensating device. When choosing the power of the compensating device, they strive for the correct distribution of reactive power sources and the most economical loading of the network.

The required power of the compensating device is selected taking into account the highest reactive power Q_e ,

which can be transferred from the power system networks. The condition must be met:

$$Q_p - Q_k \leq Q_e \quad (1)$$

where Q_p is the calculated reactive power consumed by the enterprise, Q_k is the reactive power that must be compensated for at the enterprise.

The enterprise sets the mode of consumption of reactive power, taking into account its maximum loads. This requirement consists in the fact that the values of Q_{e1} are set - the reactive power provided by the power system to the enterprise during half an hour during the period of maximum active loads of the system, and Q_{e2} - the average reactive power transmitted from the power system network or generated to the network during the period of its lowest load.

Therefore, we can write:

$$Q_{k\max} = Q_{p\max} - Q_{e1} \quad (2)$$

$$Q_{k\min} = Q_{p\min} - Q_{e2}, \quad (3)$$

where $Q_{k\max}$, $Q_{k\min}$ are the required powers of the compensating device in the mode of maximum and minimum loads, $Q_{p\max}$, $Q_{p\min}$ are the calculated reactive power of the enterprise in the mode of maximum and minimum loads.

Thus, the lack of reactive energy in the power system to cover the reactive loads of the enterprise is eliminated due to the compensating devices of the enterprise.

In order to stimulate the enterprise to implement measures to compensate for reactive power, a system of payment for electricity and consumed reactive power has been introduced.

The choice of the capacity of compensating devices and their distribution over the networks of the enterprise are made on the basis of technical and economic costs. Reduced costs for reactive power compensation:

$$Z_k = Z_{0k} + Z_{u,k1} Q_k + Z_{u,k2} Q_k^2, \quad (4)$$

where Q_k is the reactive power of the compensating device, Z_{0k} is a constant component of costs that does not depend on the power Q_k , $Z_{u,k1}$ are the unit costs per 1 kvar of reactive power, $Z_{u,k2}$ are the unit costs per 1 kvar² of reactive power.

Constant component of costs:

$$Z_{0k} = E_n K_0, \quad (5)$$

where E_n is the standard coefficient of the efficiency of capital investments, K_0 is the cost of switching equipment, control devices, etc.

On the basis of a technical and economic comparison of options, it is necessary to additionally consider the option when the compensating device is not installed at all and the enterprise will have to pay for the consumption of reactive power.

Reactive power sources with a voltage of 6-10 kV are more economical compared to voltages up to 1 kV. However, the transfer of reactive power from a 6-10 kV network to a network up to 1 kV can lead to an increase in the number of transformers at a transformer substation, due to their additional load, transmitted reactive power, and, accordingly, to an increase in electricity losses in lines and transformers.

The capacity of the compensating device in networks with a voltage of up to 1 kV is determined at a minimum

cost by choosing the optimal number of transformers of the workshop TP and determining the additional power of compensating devices below 1 kV in order to optimally reduce losses in transformers and in the 6-10 kV network that supplies these transformers.

The compensation power calculated in this way is distributed among all transformers of the shop in proportion to their reactive loads.

The approximate number of required transformers of the same optimal economic power to cover all electrical loads of the workshop with an uneven distribution of these loads over the area of the workshop is chosen by the expression:

$$n_{tr} = \frac{S_{sm}}{\beta \lambda S_{nom.t}} \quad (6)$$

where S_{sm} is the total average power of the workshop for the maximum loaded shift, $S_{nom.t}$ is the optimal economic rated power of the transformer, β is the recommended load factor of the transformers, $\lambda = \cos\varphi_2 / \cos\varphi_1$ is the ratio of the power factors on the secondary voltage side of the transformer, respectively, after and before compensation of reactive loads.

The highest reactive power that can be transferred from a 6-10 kV network to a network with a voltage of up to 1 kV to cover the remaining uncompensated reactive power in the network up to 1 kV without increasing the number of installed transformers is determined by:

$$Q_v = \sqrt{(n\beta S_n)^2 - P_{sm}^2} \quad (7)$$

where P_{sm}^2 is the active average load for the maximum busy shift.

After the approximate determination of the required power of the compensating device, the problem arises of their optimal location in the power supply system of the enterprise. The greatest effect is achieved when installing a compensating device near an electrical receiver with the highest reactive power consumption, since this leads to the maximum reduction in electricity losses. The choice of the place of installation of the compensating device determines its cost and power losses. Static capacitor banks for a voltage of 6-10 kV have the lowest cost, but when installed, the greatest losses of active power will be in the elements of the power supply system that are outside the compensation zone.

Therefore, the problem of placing compensating devices in power supply systems is multifactorial. Their optimal placement corresponds to a technically acceptable option, which ensures the lowest estimated costs. The presence of complex branching systems with a heterogeneous load leads to the need to consider a large number of options.

For power supply of large enterprises, characterized by the presence of an extensive power supply system, the following method is recommended:

- 1) The center of consumption of reactive loads (x_0 , y_0) on the territory of the enterprise is determined;
- 2) On the basis of technical and economic calculations, the appropriate capacity of the compensating device Q_k is determined. In this case, there may be options:

there are no compensating devices at all on the territory of the enterprise, or compensating devices are installed at the enterprise and they must be supplemented with new ones. In the first case, the installation site should be closer to the center of consumption of reactive loads. In the second one should find a center for generating reactive power for compensating devices already at the enterprise. Further, by the method of successive approximations, the coordinates of the installation of the additional compensating device are determined so that the new center for generating reactive power is located near the center of its consumption (x_r , y_r).

3) The calculation of voltage levels during the hours of maximum and minimum loads.

Compliance with the permissible voltage deviations at the terminals of the receivers is, as a rule, the main limitation when choosing the power and location of the compensating device. To fulfill this condition, in some cases, it is necessary to use adjustable compensating devices.

If synchronous motors are the means of compensation, then this problem is solved simply by regulating the excitation. If static capacitors are used for compensation, then the adjustment can only be made stepwise, by dividing the batteries into parts. Of course, such regulation has serious drawbacks: the ability to work for some time with insufficient or excessive compensation, as well as the cost of installing additional switching equipment. But nowadays, combined compensating devices

have become widespread, which combine the advantages of modulating control and low cost.

Longitudinal compensation of the inductance of the lines is called, which is realized by connecting a capacitive resistance in series in the line. This resistance compensates for the inductive resistance of the line, as a result of which voltage losses in the line are reduced.

Consider the case of a line with a load (Fig. 1). The longitudinal and transverse components of the voltage drop for the line under consideration are determined by the expressions:

$$U_{\text{prod. } \phi} = I(R \cos \phi + X \sin \phi),$$

$$U_{\text{non. } \phi} = I(X \cos \phi - R \sin \phi). \quad (8)$$

With a given vector of phase voltage at the consumer U_{2f} , the voltage at the power source is determined by the vector U_{1f} (point A). If capacitors with reactance X_c are connected in series in the line, then the voltage drop in the reactance will be $I(X - X_c)$ and the components of the voltage drop will be equal to:

$$U'_{\text{prod. } \phi} = I(R \cos \phi + (X - X_c) \sin \phi),$$

$$U'_{\text{non. } \phi} = I((X - X_c) \cos \phi - R \sin \phi). \quad (9)$$

Figure 1. Network diagram and vector diagram with the use of longitudinal compensation of reactive power of the line

The required voltage at the power supply will now be equal to the vector U'_{1f} , determined at $X_c < X$ by point A'. Its value in comparison with the original has decreased, since $U_{\text{prod. } f}$ and $U_{\text{non. } f}$ decreased due to a decrease in the reactance of the line.

With full compensation ($X_c = X$), the voltage drop will be determined only by the active resistance of the line R .

With overcompensation ($X_c > X$), the voltage loss will be close to zero and $U_{1f} = U_{2f}$. In this case, the value of X_c will be:

$$X_c = X + R \operatorname{ctg} \varphi \quad (10)$$

The reactance of the capacitors in this case compensates not only the inductive resistance of the line, but also the voltage drop across the active resistance.

Capacitor power is determined by:

$$Q_c^2 = 3I^2 X_c, \quad (11)$$

where I is the maximum line current.

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POWER, METALLURGICAL AND CHEMICAL ENGINEERING**PROBLEMS OF DETECTING SINGLE-PHASE GROUNDING IN LOW VOLTAGE NETWORKS****Mirodil Kobilov***assistant,
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E-mail: qobilov.mirodil1995@gmail.com***ПРОБЛЕМЫ ОБНАРУЖЕНИЯ ОДНОФАЗНОГО ЗАЗЕМЛЕНИЯ
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В статье рассмотрены основные режимы работы нейтралей в электрических сетях Узбекистана. Краткое описание каждого режима с точки зрения аварийных режимов. В частности, рассмотрены режимы заземления в фазах электрических сетей, вызванные токами короткого замыкания.

ABSTRACT

The article considers the main operating modes of neutrals in the power grids of Uzbekistan. A brief description of each mode in terms of emergency modes. In particular, the grounding modes in the phases of power grids caused by short-circuit currents are considered.

Keywords: neutrals, capacity, fault currents, overcurrent, line voltages, complex branched networks, higher harmonic components.

Ключевые слова: нейтралы, емкость, токи короткого замыкания, перегрузки по току, линейные напряжения, сложные разветвленные сети, высшие гармонические составляющие.

In our country, the following modes of operation of neutrals are traditionally used:

Neutrals are not grounded - they are connected directly to the grounding device. These networks include power lines up to 1 kV and above 110 kV.

Effectively connected to neutral ground - networks with grounding factor not exceeding 1.4. In three-phase networks, the grounding factor is the difference between the undamaged phase and the potentials between the ground and phase at the grounding point, or the potential difference between the ground and the other two phases before the short circuit at this point. As a rule, such networks are used at voltages of 110 kV and above, with the help of a disconnector it is possible to connect and

disconnect the neutrals to limit the zero-sequence currents. Neutrally grounded networks - a generator or transformer is isolated from neutral ground or connected to the network using a measuring or signaling device with high resistance. Such networks include networks insulated from neutral ground on 6-35kV lines. Neutral ground compensated networks - networks connected by means of arc quenching reactors in order to limit the neutral grounding current [1, pp.13]. It is related to the phase capacity and the inductance of the arc quenching reactor, which is isolated or compensated from the neutral ground and separated from the ground. The networks are characterized by very small grounding currents.

Thus, in 6-35 kV networks, the fault currents do not exceed 30–10 A, respectively [3,pp,28].

Single-phase ground fault protection is a typical type of damage to 6-35 kV networks. They account for 70-80% of line damage. It should be noted that currently the total length of 6-35 kV distribution networks in the country exceeds 100 thousand km. Almost 65% of the total length of 0.4-110 kV power transmission lines. Therefore, the issue of locating, diagnosing and timely disconnection of single-phase grounding is especially relevant. With a phase-to-earth fault, the line voltages do not change.

The currents in the phases change very insignificantly (by 10–30 A) and the consumer in these conditions maintains a normal operating mode, there are no strict requirements for the immediate disconnection of the damaged line. Also, the absence of requirements for disconnecting the line is explained by the fact that the sensitivity of the existing protections is not enough to ensure selective operation, and, as a rule, undamaged elements are subject to disconnection. However, the voltages of the undamaged phases with respect to earth increase [6,pp,86-88].

An intermittent arc is an open electric arc that periodically fades and reappears. In this case, over voltages up to 2.5-3 rated phase voltages occur on undamaged phases and lines of the network.

$$U_{per} = (2.5 \dots 3)U_{nom} \quad (1.1)$$

The duration of such a high voltage is several tens of minutes, as there are no strict requirements for immediate shutdown of the damaged network through relay protection. In this case, there is a high probability of damage to the insulation of the undamaged phases and the occurrence of two-way grounding.

Therefore, it is necessary to identify the damaged element in the shortest possible time and notify the

personnel on duty about the presence of an accident with the help of an alarm, so that they can find and eliminate the damage within a reasonable time (no more than two hours) [4,pp,107-108]. Otherwise, the line must be disconnected.

The function of detecting the ground fault and the point of damage is carried out by means of special protection and by signaling to the duty officer. In some cases, protection can be provided by immediate disconnection in networks. According to Technical Operation Rules (TOR) requirements, such networks include 6-10 kV networks designed to supply peat and oil refining equipment as well as portable construction machinery. In the case of switching from a single-phase directional ground connection to a two-phase directional grounding, which may occur in such networks, there is a high probability of a step voltage that is dangerous to the human factor. In addition, the appearance of periodic arcs can cause fires, which can have serious consequences, especially in oil fields and peat mining areas. Therefore, the problem of creating high-frequency and selective protection devices that detect single-phase grounding is one of the main problems today [7,pp,75].

Types of ground protection

Below, we review the main types of protection used in networks with small grounding currents and highlight their main advantages and disadvantages. The non-selective general signaling device is installed on the busbars of 6-35 kV substations or generator busbars of power plants. This device is connected to voltage transformers of NAMI-10 type (voltage transformer is designed for anisotropic, oily, measuring) in an open triangular circuit (pic.1). Normally the voltage at neutral is $\Delta U = 0V$, while at single-phase grounding $\Delta U = U_A + U_B + U_C = 3U_0$. Uses RV-53 / 60 D voltage relay as protection relay. However, this type of protection is widely used due to its simplicity [9,pp,34-36] and high sensitivity.

Picture 1. Scheme of non-selective signaling device connection

Disadvantages: This protection is not selective, it is impossible to determine the point of single-phase grounding in a network of 6-35 kV.

Residual overcurrent protection, non-directional

Depending on the distribution of the zero-sequence currents in the complex network, it is possible to determine the currents in the line short circuit and the external ground line.

Currents flow through intact lines due to the capacitances of the phases of these lines relative to the ground:

$$3I_{0 \text{ undamaged}}^{(1)} = 3I_{0L}^{(1)} = j \cdot \omega \cdot C_{0L} \cdot U_{\text{phase}} \quad (1)$$

If the line is damaged, then a current will flow through it, which is the sum of the capacitive currents of all intact lines, depending on the total capacitance of these lines:

$$3I_{0 \text{ undamaged}}^{(1)} = 3I_{oL}^{(1)} = j \cdot \omega \cdot C_{oL} \cdot U_{\text{phase}} \quad (2)$$

here- $C_{0 \text{ ekv}} = \sum_{i=1}^n C_{oL}$ is the equivalent phase capacitance relative to earth of all intact lines.

In this regard, the residual current protection, which responds to steady-state currents, must be offset by the operation current from the capacitive currents of the protected line:

$$I_{pr} = K_{re} \cdot 3I_0^{(1)} \quad (3)$$

In this case, there must be a sufficient number of outgoing lines providing the necessary sensitivity, so that the condition:

$$\begin{aligned} C_{0 \text{ ekv}} &\gg C_0; \\ I_{0 \text{ ekv}}^{(1)} &\gg I_o^{(1)} \end{aligned} \quad (4)$$

The fact is that in order to tune away from the transient inrush of capacitive current arising during various commutations, a detuning factor is introduced into formula (3), equal for protection without time delay $K = 4-5$ and for protection with time delay $K = 2-2.5$. Then, in the worst case, the sensitivity coefficient calculated by the formula,

$$K_{sen} = \frac{I_0^{(1)}}{K_{cap} \cdot I_o^{(1)}} \quad (5)$$

may be less than the required value of $K_{cap} \geq 1.5$, since it is known that the equivalent capacity and the equivalent capacitive current of the system are related to the capacity and capacitive current of the protected connection by the ratio.

$$\begin{aligned} C_{0 \text{ ekv}} &\gg (6 \dots 6.5) \cdot C_0; \\ I_{0 \text{ ekv}}^{(1)} &\gg (6 \dots 6.5) \cdot I_o^{(1)} \end{aligned} \quad (6)$$

Therefore, in practice, there should be at least 8-10 outgoing lines powered by busbars to provide the required sensitivity. In addition, zero sequence current

protection cannot provide selectivity in networks with a variable primary circuit, in which there is a periodic change in the capacitance of the phases relative to the ground [8, pp.135].

These networks include power supply systems for mobile construction sites, the length of which varies over time.

Picture 2. Scheme of zero sequence protection circuit

The relay, which responds to the zero sequence current, is connected to the single-transformer zero sequence current filter TTNP type TLMZ-1. Most often, the current relay RT-40 / 0.2 or more modern RTZ-51 acts as a KA relay.

To exclude false triggering from capacitive currents passing through the sheath of an undamaged cable at an external short circuit, the funnel of the cable is isolated from the ground, and the ground wire is passed through the hole of the TTNP. In this regard, the use of such current transformers is difficult in overhead lines due to the need to use cable inserts. In addition, the values of capacitive currents in air networks are small and certain difficulties arise with the stability of the operation of the RT-40 current relay at low currents [5, pp.24].

Directional residual overcurrent protection

Directional overcurrent protections that react to steady-state currents are used in cases where the number of outgoing lines is small and the required sensitivity cannot be provided. In directional protections, a power direction relay is additionally used, which is switched on for voltages and currents of zero sequence. This relay operates only in the positive direction of power from the busbars into the line, so there is no need to tune away from the current $3I_{oL}^{(1)}$ according to condition (3), it flows in the other direction. In this case, it is enough to tune only from the unbalance current of the zero sequence filter.

The disadvantage of this type of protection is the need to use cable inserts, which significantly limits its use, as well as excessive operation of protection when an intermittent arc occurs and the lack of a clear method for determining the operation settings. Such protections are used in cases where the neutral is compensated and currents earth fault less than 5 A. In this case, the protection operation current is selected according to the condition of detuning from the transient earth fault current [5, pp. 26].

Protections responsive to the transient current value of zero sequences

The most widespread are autonomous devices of directional wave protection and carbon dioxide charging station.

$$I_{pr}^{(1)tr} = K_{re} \cdot 3I_{0L}^{(1)tr} \quad (7)$$

The device for single-phase ground faults consists of a starting element that responds to the appearance of zero sequence voltages, a current direction element, a power supply and an indicator relay. A feature of such protections is the short duration of the appearance of the transient earth fault current. This time is 0.1–0.2 seconds, therefore protections reacting to transient currents must have a trip latching device.

The disadvantage of such protections is the complexity of the implementation and detection of the fact of excessive operation with intermittent arc faults, and the advantage is the ability to fix even a short circuit, which provides a preventive check of insulation and allows you to identify the places of its weakening in order to make timely repairs and prevent subsequent short circuits [7,pp,104].

Using high frequency superimposed current

This method assumes the presence of an high frequencies signal generator, which is usually connected to the phases of the monitored line through a capacitive divider. The generator sends a high frequency signal in phases and monitors the return time of the reflected signal. If there is no signal return, then one phase to ground has occurred, and the protection is triggered. In this case, the distance to the place of breakdown is fixed according to the resistance of the loop to which the generator is turned on - from the point of connection to the point of short circuit and again through the ground to the generator.

The application of this principle is difficult in complex branched networks that create a strong signal dissipation and require a high power generator.

Fixation of harmonic components in zero sequence current

When a phase is closed to ground, the signals, zero sequence currents are non-sinusoidal and in transient modes contain higher harmonic components: 100 Hz and above. By separating these components through frequency filters, it is possible to fix the earth fault with a very high sensitivity, which is especially important in networks with compensated neutral.

The disadvantage of such protections is excessive operation, which is a consequence of the wrong choice of protection settings, depending on a number of factors that change during operation. In addition, the process of finding a damaged connection takes a lot of time, therefore, according to [1,pp,102], it should be automated. Currently, devices have been developed that respond to harmonic components in the zero sequence current. These are devices of the USZ-2/2 (alarm devices) type - an individual device connected to a cable-type zero sequence current transformer and USZ-3M (alarm device) - a group device, alternately connected to a zero sequence current transformer of each connection.

The operation of the USZ-3M device is based on measuring the sum of the higher harmonic components in the earth fault current (from 150 to 650 Hz) [7,pp,64]. However, more than forty years of experience using this device has revealed a number of significant disadvantages:

1. non-selective operation in arc earth fault;
2. unsuitability of the USZ-3M device for use in complex networks with parallel lines;
3. impossibility of fixing short-term earth fault;
4. The need for personnel to go to the substation to carry out a large number of measurements in order to determine the damaged connection;

Picture 3. Diagram of the signaling device for single-phase ground faults, type USZ-3M

Currently used microprocessor devices SPAC 801-013, SPAC 801-113, LLC ABB Relay-Cheboksary [5,pp,30], Sirius, produced by NPF Radius [5,pp,32] and their foreign counterparts - SEPAM by Schneider Electric. These devices perform a relative measurement of higher harmonics, on the basis of which they are able to operate not only with a ground fault, but also with

phase-to-phase faults. At the same time, all microprocessor devices of both domestic and foreign production have the following disadvantages:

- a) high cost of devices;
- b) complexity, with the choice of response settings due to the lack of an unambiguous methodology;

c) Thus, the indicated disadvantages of protections reacting to harmonic components in the zero sequence current create obstacles for their widespread use.

General summary

Thus, analyzing the available types of earth fault protection devices in networks with low earth fault currents, the following types of disadvantages inherent in these devices can be distinguished. This is nonselective protection work, difficulties in finding a damaged connection in branched networks, excessive triggering in the event of arc earth fault outside the

protection zone, the complexity of the implementation of some types of protection, the lack of unambiguous methods for determining the response settings and the high cost of microprocessor terminals. Therefore, the most urgent in the current situation is the development of a device that is not associated with the use of transformer filters of zero sequence currents. A promising direction is the use of wavelet analysis algorithms for the selection of harmonic components of the current and voltage of the network, allowing it to be used to protect networks with both isolated and compensated neutrals, as well as to protect high-voltage electric motors.

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ANALYSIS OF REACTIVE POWER COMPENSATION IN INDUSTRIAL ENTERPRISES, ITS IMPORTANCE AND PRODUCTION METHODS

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АНАЛИЗ КОМПЕНСАЦИИ РЕАКТИВНОЙ МОЩНОСТИ НА ПРОМЫШЛЕННЫХ ПРЕДПРИЯТИЯХ, ЕЕ ЗНАЧЕНИЕ И МЕТОДЫ ПРОИЗВОДСТВА

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ABSTRACT

The article examines information about the consumption of reactive power at industrial enterprises, the processes of its generation and compensation of reactive power. One of the main issues at the design stages of industrial power supply systems and during their operation is the issue of reactive power replenishment (compensation). This problem is related to the task of generating a sufficient amount of energy for the consumer of reactive power, also known as compensation, and includes the selection of appropriate sources, their calculation and power regulation, the placement of sources in the power supply system.

АННОТАЦИЯ

В статье исследуются сведения о потреблении реактивной мощности на промышленных предприятиях, процессах ее генерации и компенсации реактивной мощности. Одним из основных вопросов на этапах проектирования промышленных систем электроснабжения и при их эксплуатации является вопрос восполнения (компенсации) реактивной мощности. Эта проблема связана с задачей выработки достаточного количества энергии для потребителя реактивной мощности, также известной как компенсация, и включает в себя выбор подходящих источников, их расчет и регулирование мощности, размещение источников в системе электроснабжения.

Keywords: reactive power, electrical networks, dissipated power, reliability, quality indicators, electricity.

Ключевые слова: реактивная мощность, электрические сети, рассеиваемая мощность, надежность, качественные показатели, электроэнергия.

The appearance of the name "reactive" power is related with the need to allot power consumed by the load, a component that originates electromagnetic fields and provides the motor torque. This element happens when the load is inductive. For instance, when connecting electric motors. Nearly, whole household loads, not allude to industrial commodity, are inductive to single degree or other. Electrical apparatus consumes energy while operation. In this case, the whole power consists two components: active and reactive. Reactive power does no useful work, but make known extra losses into the circuit. Consequently, they strive to decrease it, for which they come to different technical solutions for compensating reactive power in electrical settings [1, p. 85].

The whole electrical power consists of active and reactive energy:

$$S = Q + P \quad (1)$$

here: Q – reactive power, P – active power.

In electrical networks, when the load has an active character, the flowing current is in phase from the voltage. Unless the load is inductive (motors, transformers at no load), the current lags beyond the voltage. When the load is capacitive (capacitors), the current conducts the voltage [2, p. 43-48].

Reactive power happens in magnetic and electric fields, which are characteristic of inductive and capacitive loads when working in AC circuits. When a resistive load is operating, the voltage and current phases are the same and coincide. When an inductive load is connected, the voltage lags behind the current, and when a capacitive load is connected, it leads. In a single-phase power system, reactive power comes from the interaction of generator windings and any inductive loads on the system, and it's bad because then you have this energy exchange between the load and source going through the whole transmission system, overloading lines and resulting in losses [3, p. 33-37].

Picture 1. Phasor diagram represents the relationship of powers

In order to reduce the reagent, reactive power compensation equipment are used, they are constantly used as a power compensator:

a) Synchronous motors;

b) capacitor banks;

Since the amount of reactive power can change over time, it means that compensators

Picture 2. Several scenarios of current phase displacement relative to voltage and what that means for the position of the power waveform.

can be:

1. Automatic - compensation steps change depending on the state of the network
2. Dynamic - compensate when the load quickly changes its character.
3. Unregulated - a capacitor banks without the possibility of disconnecting individual capacitors to change the capacity

The circuit uses, depending on the amount of reactive energy, from one to a whole bank of capacitors that can be input and output from the circuit. Then the control can be:

manual (circuit breakers);

- semi-automatic (push-button posts with contactors);
- uncontrolled, then they are connected directly to the load, turn on and off with it.

Capacitor batteries can be installed both at substations and directly near consumers, then the device is connected to their cables or power buses. In the latter case, they are usually calculated for individual compensation of the reagent of a specific motor or other device - it is often found on equipment in 0.4 kV electrical networks. [4, p. 33-37].

Picture 3. Circuit diagram of reactive power static compensator and the schemes of connection and control of reactive power series compensation devices SCB

Centralized compensation is done either at the border of the balance section of the networks, or at the substation, and it can be done in 35 kV high-voltage settings. The good thing is that it unloads high-voltage lines, but the bad thing is that the 0.4 kV lines and the transformer itself are not unloaded. This method is cheaper than the others. At the same time, it is possible to centrally unload the low side of 0.4 kV, then the UKRM is connected to the buses to which the secondary winding of the transformer is connected, and accordingly it is also unloaded. [5, p. 11]

There may also be a group compensation option. It is an intermediate type between centralized and individual. Another way is compensation with synchronous motors, which can compensate for reactive power. It appears when the engine is in overexcitation mode. Такое решение используется в сетях 6 кВ и 10 кВ, также встречается и до 1000В. The advantage of this method over the installation of capacitor banks is the possibility of using a compensator to perform useful work (rotation of powerful compressors and pumps, for example). [5, p. 1019-1023]

Picture 4. Inside a power compensation enclosure

Power factor correction is one of the best investments to reduce energy costs with a short payback. In a large number of cases, the design and dimensioning work has been made more difficult by the fact that, in a company's internal low-voltage installation, and also in the medium-voltage supplying it, the proportion of network harmonics has grown increasingly over the last few years. Power converters, electronically controlled

drives, static frequency converters, televisions and computers feed harmonic currents into the supply network. These harmonics might be amplified by the network impedances and capacitors installed. The freedom from harmonics also minimizes interference with other devices being powered from the same source. [6, p. 18-24].

Picture 5. The characteristics of the change in driving current of the motors

The graph shows the U-shaped characteristic of a synchronous motor, which reflects the dependence of the stator current on the field current. Below it, you see what the cosine ϕ is. When it is greater than zero, the motor has a capacitive character, and when the cosine is less than zero, the load is capacitive and compensates for the reactive power of the rest of the inductive consumers.

Conclusion

The importance of reactive power compensation is beyond doubt. The stability of the energy system and the voltage value at consumers are associated with the reactive power mode and the solution to the problem of its compensation. The use of the power of generators and

transformers, the cross-sections of cables and wires depends on the solution of the compensation problem. The amount of electricity losses in the elements of electrical networks also depends on the mode of reactive loads and their compensation.

The main reactive load in power systems is created by industrial enterprises. Hence, it is clear how important it is to carry out measures to compensate for reactive power at industrial enterprises. As mentioned above, first of all, under all conditions, enterprises should take measures to reduce the reactive power of the electricity receivers themselves. However, these measures alone are insufficient.

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Научный журнал

**UNIVERSUM:
ТЕХНИЧЕСКИЕ НАУКИ**

№ 11(92)
Ноябрь 2021

Часть 6

Свидетельство о регистрации СМИ: ЭЛ № ФС 77 – 54434 от 17.06.2013

Издательство «МЦНО»
123098, г. Москва, улица Маршала Василевского, дом 5, корпус 1, к. 74
E-mail: mail@7universum.com
www.7universum.com

Отпечатано в полном соответствии с качеством предоставленного
оригинал-макета в типографии «Allprint»

630004, г. Новосибирск, Вокзальная магистраль, 3

16+