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Wear Resistance of Repair Composite Materials with Ceramic Fillers

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ABSTRACT

This article highlights importance of application of protective coatings on working areas of industrial equipment. The most suitable composite materials with ceramic fillers are determined. The required laboratory facilities and experimental procedures are selected. A set of studies has been performed to confirm their main specifications and to forecast operation lifetime of reconditioned equipment.

Key words: wear resistance, composite materials, ceramic fillers, friction testing machine, reconditioning.

1. INTRODUCTION

Engineering and auxiliary equipment, used in housing services, during operation is exerted to various types of wear, these types are illustrated in Fig. 1.

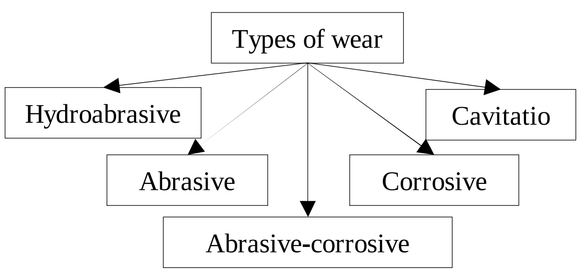

Figure 1: Types of wear

Higher wear extents are characteristic for water and heat supply systems. The destroying action of abrasives, corrosion and cavitation impairs the state of internal cavities of centrifugal pumps, impellers, gates, joints of pipelines and some other elements [1].

Development of industrial services in various industries is based on application of advanced materials and challenging technologies including coating [2].

Protective coatings allow to obtain not only new properties of items due to formed compositions combining high lifetime (wear resistance, specific properties) with sufficient reliability, but to increase operation durability, to recover worn surfaces and, hence, to reduce demand for spare parts [3]. Application of coating makes it possible to achieve specific properties of operating areas of equipment exposed to various types of wear. The most important property of coatings in this case is wear resistance.

2. METHODS

Analysis of specifications of marketable repair composite materials, supplied by such companies as Loctite, Durmetal, Belzona, Diamant, and Chester Molecular, demonstrated that the consequences of wear of metal surfaces of industrial equipment could be eliminated by application of protective coatings, the most preferable among them were the composite materials with ceramic fillers [4]. In the terms of price/quality, the most acceptable are the composite materials fabricated by Chester Molecular, namely: Metal Ceramic T of pasty consistency; and Metal Ceramic F of liquid consistency [5]. These materials are characterized by superior physicomechanical and chemical properties allowing to decrease significantly the prime cost and labor intensity of repair, as well as to reduce the consumption of required energy and materials [6].

The recommendations to use these materials for repair and recovery of critical parts and units of industrial equipment should be based on appropriate experimental results aimed at determination of their wear resistance. For the considered problem, that is, wear of equipment in water and heat supply systems, the most acceptable method is weighing of samples with applied coating before and after tests in a friction testing machine.

Samples for these tests are made of aluminum angles with the edge size of 35×15 mm (Fig. 2). A notch was cut out in the center of each side for fixation in the holder of a 77 MT-1 friction testing machine [7].

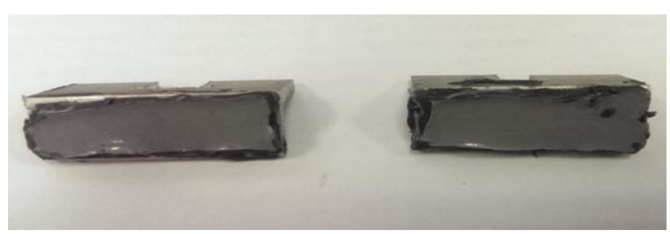

Figure 2: Sample (angle) with applied material for wearing tests

Prior to application of composite material, all samples were prepared according to standard procedure (similar to shear and tear tests):

• mechanical cleaning of joint surface to roughness of Rz= 175 μm;

• degreasing of cleaned surface by Chester Molecular F7 cleanser.

After the surface preparation, the tested composite material was applied to one angle side. The thickness of composite layer was 2 mm. Aiming at formation of even (solid) composite layer of certain thickness on surface and prevention of material draining from the surface, a rectangular contour of putty (a compartment for filling with material) was formed [8].

In order to produce a layer of certain thickness, the same amount of compound as other samples was poured into the formed compartment.

The collected samples were held at ambient temperature for 24 h to provide polymerization of the composite material [9]. Immediately before installation into the holder of friction testing machine, the samples were weighed on electronic scales (Fig. 3). This value was recorded for subsequent computations: measuring weight losses of applied material on sample during friction tests [10].

Figure 3: Sample weighing on electronic scales

Then, the sample was installed directly into the holder of laboratory facility and the load of 5 kg was applied by means of external weights. The experiment duration was 9 h. The sample was weighted after each hour of tests. After termination of friction cycle, the samples were weighted again using electronic scales, the weight loss of composite material was detected, all results were recorded.

3. RESULTS

The initial experimental results of samples are presented in the coordinates: weight loss g_{exp} vs wear duration τ (Fig. 4). Average weight loss g_{exp} , g is determined by weighting prior and after wear of all samples tested at certain speed, particle diameter and wear duration:

$$g_{\exp} = \frac{1}{n}\sum_{i=q}^{n} g_{\exp.i}$$

where g_{exp} is the weight loss for certain tested samples, g; n is the number of tested samples according to [11].

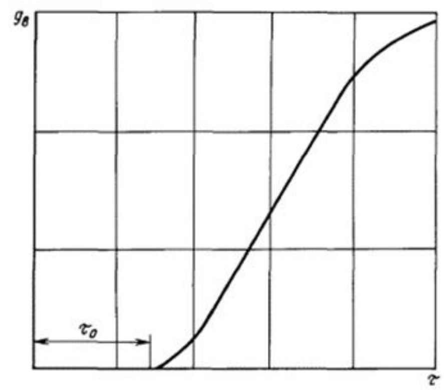

Figure 4: Weight loss of tested sample as a function of wear duration.

Materials during friction with reciprocating motion of moving sample (wear tests) were tested using a 77 MT-1 friction testing machine, its general view is illustrated in Fig. 5.

Figure 5: 77 MT-1 friction testing machine.

A 77 MT-1 friction testing machine is comprised of three units: electric motor, reducer, and friction testing machine itself [12]. Kinematic flowchart is illustrated in Fig. 6.

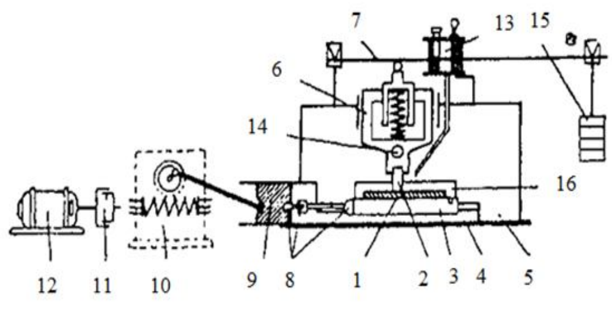

Figure 6: 77 MT-1 friction testing machine: 1 –cylinder sample; 2 – piston ring sample; 3 –crosshead; 4 – guide; 5 – machine body; 6 – rod; 7 – load lever; 8 – pivots; 9 –sliding block; 10 – reducer; 11 – coupling; 12 – electromotor; 13 – oiler; 14 –heater; 15 – weight; 16 – oiling tank.

Specifications of 77 MT-1 friction testing machine are as follows:
Drive: 1 kW;
Dimensions: 1300×350×250;
Weight: 90 kg;
Load on lever: 20 kg max.;
Number of double strokes of crosshead: 108 min.
It is possible to vary oiling conditions, loads, as well as temperature and working medium in this machine [13]. Figure 7 illustrates flowchart of wear tests.

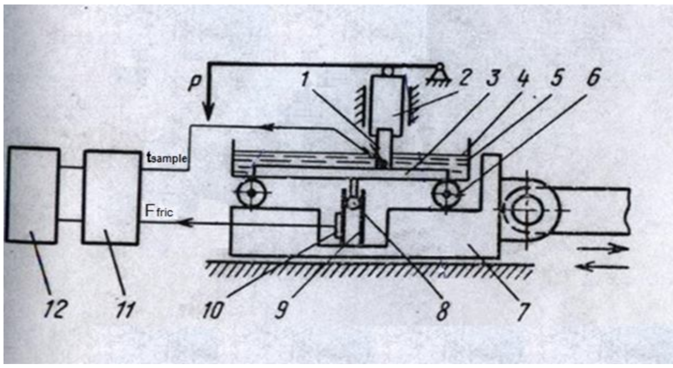

Figure 7: Tests on 77 MT-1 friction testing machine.

The tested samples (Fig. 6) 1 and 3 are placed into the tank 5 filled with the oil 4. The tank on ball bearings 6 can move with respect to the crosshead 7 with minimum friction losses. The tank motions are restricted by the plates 9, between which the rack 8 is placed rigidly connected with the tank. The crosshead moves to and fro, the sample 3 moves with it. During application of load onto samples via the rod 2, the friction force appears in the contact preventing motion of the sample 3 and the tank where the sample is fixed. Herewith, the plates 9 will be deformed, and the deformation in the elasticity range will be proportional to the friction force. The strain gauges 10 are adhered to the plate, the signal from the gauges via the amplifier 11 is transferred to the recorder 12. The temperature of fixed sample is recorded simultaneously by the same device [14].
This flowchart allows to detect friction force during the tests with high accuracy. The crosshead moves at the frequency of 60 double strokes per minute. The stroke distance is 0.06 m. Hence, the average speed during the tests is 0.12 m/s. The surface area of friction of upper sample during the tests is 50×10-5 m. The lower and upper samples are made of grade 45 steel (HRC, Ra 1.6). Figure 8 illustrates a sample with applied composite material in holder.

Figure 8: Sample in holder for wear tests.

In comparison with other designs of friction testing machines with reciprocating motion, the use of crosshead with high degrees of freedom makes it possible to accelerate alignment of samples with flat or concave surface in the case of samples cut out of engine cylinder and piston ring. Moreover, removal and repeated installation of samples into the machine is performed without additional alignment [15].
During the wear tests, the following results were obtained:

Table 1: Experimental results for sample coated with Chester Metal Ceramic F, T (initial weight m0 = 8.9 g)

No.	Sample weight prior to testing, g		Test duration, h
	Ceramic F	Ceramic T	
1	8.8	8.8	1
2	8.7	8.8	2
3	8.6	8.7	3
4	8.6	8.7	4
5	8.6	8.7	5
6	8.5	8.6	6
7	8.5	8.5	7
8	8.5	8.5	8
9	8.5	8.5	9
10	8.4	8.4	10

The experimental results are illustrated in Figs. 9, 10.

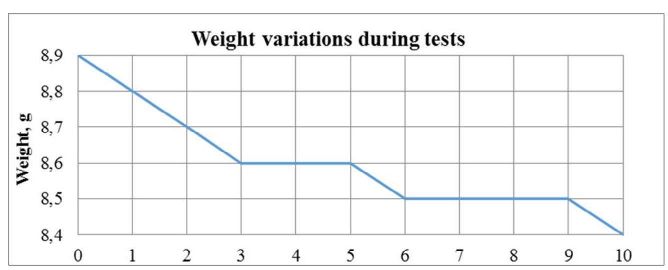

Figure 9: Weight loss of sample coated with Ceramic F in 10 h.

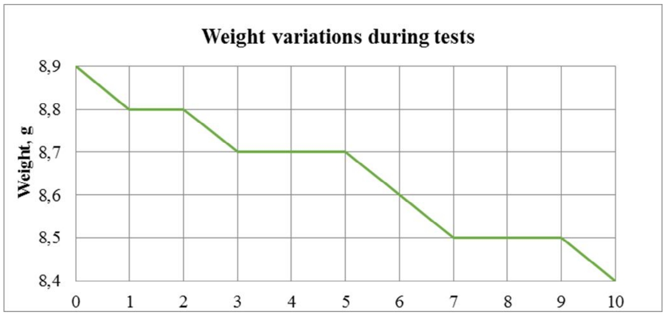

Figure 10: Weight loss of sample coated with Ceramic T in 10 h.

4. DISCUSSION

Analysis of international experience in studying the issues related with wear resistance of coatings has demonstrated that the values of weight wear of two conjugated samples made of the same material under steady testing conditions depend on their friction surfaces [13]. The wear of sample with higher friction surface area is higher than that of sample with lower surface area [11]. Therefore, it has been established that the weigh wear ratio is one of simulation criteria upon testing materials on laboratory facilities. This phenomenon has been detected due to good reproducibility of results upon wear tests of materials on a 77 MT-1 friction testing machine.

5. CONCLUSION

Weight wear best characterizes capability of composite materials to withstand wearing of working areas. Therefore, on the basis of this property, it is possible to conclude that the considered composite materials would allow to increase significantly operation lifetime of equipment reconditioned with these materials.

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