2. Мухин Ю.И. Антиаполлон. Лунная афера США.— М.: Эксмо, 2005.
3. http://ru.wikipedia.org/wiki/Список_космических_запусков_Рос-сии(проверено 08.04.2011)
4. http://ru.wikipedia.org/wiki/Хронология_пилотируемых_космических_полётов.
5. Viasat drops Ariane-5 for Lower-Cost Proton Launch, Space News, 16.03.2009
6. UCS Satellite Database. UCSUSA -<http://www.ucsusa.org>
7. Архипов И. - Россия прощается с космосом -<http://www.inright.ru/articles/>

Kudryashov V.A., Arazveliev B.T., Seltsov E.V., Zhukova Y.V.
**On the problem of the variability of processes in improving the technological
preparation of aircraft components production**

*Ulyanovsk State Technical University
(Russia, Ulyanovsk)*

doi: 10.18411/lj-04-2021-40

Аннотация

В работе отражены процессы, направленные на оптимизацию технологической подготовки производства (ТПП) с учетом наиболее успешных результатов в условиях автоматизации процессов. Рассмотрены мероприятия по оптимизации цикла работ, по повышению качества сборки на существующем этапе развития.

Ключевые слова: средства технологического оснащения, алюминиевые сплавы, аддитивные технологии, точность сборки, клепально-сборочные работы, формообразование деталей, взаимозаменяемость, листовой материал

Abstract

The paper reflects the processes aimed at optimizing the technological preparation of production (TPP), taking into account the most successful results in the conditions of process automation. Measures to optimize the work cycle, to improve the quality of the assembly at the current stage of development are considered.

Keywords: technological equipment, aluminum alloys, additive technologies, assembly accuracy, riveting and assembly work, forming of parts, interchangeability, sheet material

The intensive development of aviation requires the design of new processes and improvement of existing ones for the assembly of aircraft components in the highly competitive global conditions. Minimization of the human factor, achievement of the required repeatability, improvement of quality when performing riveting and assembly work are closely related to the applied means of technological equipment, riveting equipment and tools.

The fuselage panels of the long-range aircraft with modern approaches to design usually have a double curvature and dimensions along the length in the average range of up to eight meters. In hard-to-reach places, the riveting of the panels, the application of the sealant is carried out manually. There may be losses of the design parameters set by the developer on the skins, stringers, compensators after manual operations. These operations along with others are the least accurate in the assembly of components.

The optimal assembly of the panel structure with skin in terms of labor intensity and cycle directly depends on the accuracy of the resulting shapes of the parts at the stage of their manufacture. The process of designing means of technological equipment is constantly being improved and takes into account the requirements for the accuracy of electronic design and technological documentation based on the use of computer-aided design (CAD).

Using of new materials in the design of equipment, automation of the processes of design and technological preparation of production is aimed at reducing the final cost when assembling large-sized panels of aircraft. Currently, the division of technological operations is used between the equipment of the frame type with an individual set of beds for panels for the transition to production line.

When analyzing the existing technological processes of panel assembly, numerous movements of the technological unit between the slipways and the frame of the riveting equipment were established. In this case, there is a variable displacement of the parts relative to each other. There are additional displacements, structural distortions. There is also a need to optimize the cycle of riveting and assembly work when interacting with riveting equipment.

When analyzing the processes associated with the narrow space of riveting equipment, it is necessary to show the directions of optimization of losses:

- setting up the equipment according to numerical control (CNC) for each panel;
- readjustment of pallet-type frame technological device beds for each panel;
- development of CNC programs in order to optimize the machine movements when riveting zones with technological fasteners;
- technological losses when riveting small-sized panels due to the relatively small amount of fasteners.

The quality of cutting holes, assembling the technological package of long panels can be improved by using of riveting machines. In the pre-assembly equipment, the panel skin is laid. Then, such elements of the power set as stringers and expansion joints are installed on the technological fasteners. Sufficient rigidity of the assembled structure is provided by manual operations. This structure is moved to a special technological device of the pallet type in order to ensure the process of cutting holes, riveting on riveting equipment. After performing a cycle of drilling and riveting work, the assembled panel is moved to the equipment for the remaining riveting and assembly work performing control operations.

Taking into account the variability of the drilling process, countersinking of holes, riveting of the technological package, the equipment is adapted including the design features of the components, different standards between the applied fasteners and the design features of the equipment, and the technological properties of the system.

Figure 1 shows a general view of the typical supports for the panel assembly production line. The design of the beds (technological equipment) considers the design features of the equipment, the design features of the higher-level assemblies the compartments of the aircraft containing panels in their structure. The beds of technological equipment are in contact with the inner surface of the skin.

Fig. 1 General view of the standard supports for the production line of panel assembly

When analyzing the accuracy of panel assembly, the error of the assembly device is determined as follows [7]:

$$\delta_{pr} = \Delta_{\Sigma} + \delta_{\Sigma}, \quad (1)$$

where Δ_{Σ} – is the coordinates of the center of grouping of assembly errors; δ_{Σ} – is the standard deviation or half of the tolerance field.

The linking error is determined as follows [7]:

$$\delta_{\text{link}} = \Delta_{\Sigma} + \delta_{\Sigma}, \quad (2)$$

The accuracy of the assembly is determined as follows [7]:

$$0,6\delta_{\text{sb}} = \delta_{\text{pr}} + \delta_{\text{con}} \times K_{\text{pr}}, \quad (3)$$

where δ_{sb} – the accuracy of the assembly of the finished unit, mm; δ_{pr} – the error of the assembly device, mm; δ_{con} – the error of installing the aircraft part on the base element of the tooling, mm; K_{pr} – the clamping rate.

The calculated accuracy was compared with the specified permissible accuracy values. The accuracy of the calculation does not exceed the permissible deviations specified for the product in question. Numerical simulation and optimization of the workflow parameters were performed using the NX Nastran solver. Figure 2 shows a fragment of the section of the in-line assembly of panels, the section of other riveting and assembly work, and the execution of control operations.

Fig. 2 Fragment of the section of the in-line assembly of panels. The site of other riveting and assembly works and performing control operations

In order to improve the quality of panel assembly, a finite element analysis of the design of devices with structural changes in the material of the beds was carried out using additive technologies (Figure 3). It was found that when using a modified bed design, the variability of values during assembly of aggregates is optimized.

Fig. 3 Fragment of the finite element analysis of the device element design

Taking into account the analysis of simulation processes and CAD approaches including TeMP with statistical variation analysis using the Monte Carlo method, the use of the Pareto diagram, approaches to automating the processes of cutting holes, feeding the

fastener, applying the sealant are formed. Figure 4 shows a causal diagram of the assembly process using panels as an example.

Fig. 4 Causal scheme of the assembly process on the example of panels[4]

Using of a variable method for analyzing CNC programs and optimizing the moves of automatic equipment will increase its productivity. Automation of assembly processes allows increasing the level of accuracy taking into account the requirements of design documentation.

1. Kudryashov, V. A., Lapyshov A. A. Development of additive technologies in terms of fatigue behavior in aviation engineering // Izvestia of Samara Scientific Center of the Russian Academy of Sciences, vol. 20, № 4(3), 2018, pp. 406-413.
2. Leskov D. M., Guseva, R. I., Maintaining the cycle of performing riveted joints using Brotje company's riveting machines when assembling the fuselage panels – Youth and science: actual problems of fundamental and applied research FSBEI HE «KnASU», 2020. – p.24-26
3. Guseva R. I. On the issue of the calculation of assembling accuracy for units and components of the frame of an aircraft Scholarly Notes of Komsomolsk-na-Amure State Technical University – 2011 – Issue I – 1(5) p. 16-22
4. Xia Liu , Lulin An , Zhiguo Wang, Changbai Tang, Xiaoping Wang, and Shouxin Yu Assembly Variation Analysis of Aircraft Panels under Part-to-part Locating Scheme – International Journal of Aerospace Engineering – 2019(36), p.1-15 [Электронный ресурс] – URL: <https://www.hindawi.com/journals/ijae/2019/9563596/> (дата обращения: 02.04.2021)
5. PI 249-2000 Riveting of metal structures M.: NIAT