Design forming tooling for manufacturing parts from sheet blanks using digital technologies

Tatiana Dolgova[1], *Dmitry* Durov[1], *Andrey* Smolyaninov[2*], and *Nickolay* Linkov[3]

[1]Moscow Aviation Institute (National Research University), 4, Volokolamskoe shosse, 125993, Moscow, Russia
[2]Voronezh State Technical University, 20-letiya Oktyabrya Street, 84, 394006, Voronezh, Russia
[3]Moscow State University of Civil Engineering", 129337, Yaroslavskoe shosse, 26, Moscow, Russia

Abstract. The paper considers the possibilities of using modern information technologies to solve the problems of ensuring the quality, accuracy of tooling, reducing the time and labor intensity of manufacturing, improving its design processes through the use of an electronic model of a part and a technological electronic model of tooling in technological processes of shaping parts on equipment with numerical control.

1 Introduction

As is known, the proportion of airframe parts of a modern passenger aircraft, obtained by shaping from sheet blanks and profiles, is about 60-70%. This category of parts is characterized by low rigidity, large dimensions, the complexity of their geometric contours and high requirements for the accuracy of their manufacture, as one of the key quality indicators. These circumstances lead to an increase in the terms of technological preparation of production - as a stage in the development of the production of an aircraft, and the scope of its work at the same time is quite extensive [1].

Technological processes for the manufacture of the above parts in aircraft construction are usually implemented from sheets, profiles and pipes using stamping methods, but it is far from always possible to immediately design tooling that makes it possible to obtain products of the required quality and with the necessary performance characteristics. Often it requires revision, which involves changing the geometry of the shaping surfaces of the die tooling, types of operations and modes of the shaping process, and sometimes changing the selected production technology, which sometimes requires significant time and economic resources [2].

At the same time, the preliminary design stage is closely related to solving the problems of designing surfaces of complex shapes, and designing technologies for their manufacture presents certain difficulties, since it requires solving a number of optimization problems for linking procurement and assembly equipment, which is used later for the production and control of parts, assemblies, compartments and aircraft units [3].

* Corresponding author: u00781@vgasu.vrn.ru

https://doi.org/10.1051/e3sconf/202337601095

2 Model and method

The design of surfaces of complex shapes of parts, assemblies and assemblies of aircraft was traditionally carried out by graphical methods using the plaza linking of contours and its inherent use of templates for the manufacture and control of technological equipment and parts, which, compared with the main production, accounted for a significant part of the cost of materials and the volume of production of equipment - about 55-75% [4].

Modern production methods and the main tasks of its technological preparation involve the rapid design and high-quality manufacturing of technological equipment, which predetermines the introduction and widespread use of digital technologies that contribute to the creation of a single information space of the enterprise. This will improve the efficiency and productivity of production processes through the introduction of modern methods of information interaction while ensuring the life cycle of the product [5].

The use of technological equipment that uses the capabilities of modern CAD / CAM / CAE systems will solve a number of related problems that will improve the accuracy of tooling and reduce the time it takes to make it, improve and automate its design processes, increase the economic efficiency of manufacturing stamping tooling through the use of an electronic model of the part (EMD) in technological processes, as well as to reduce the amount of manual finishing work [6].

3 Research and results

Let us consider the process of designing a tooling for a typical part of a transverse set of a bearing or control surface (Fig. 1) made of a sheet with a wall and a curved flange bent at a right angle to the wall. The part is made of aluminum alloy 1163AM OST 1 90246-77 with a thickness of 1 mm; The bending radius between the walls and the flange of the part is 3 mm, two pin holes (sh.o.) with a diameter of 2.7 mm are made in its wall for fixing the workpiece on the mold block during the workpiece bending operation or for fixing it on the die in the die during the bead drawing operation.

For parts of this kind, a tooling manufacturing scheme (Fig. 2) can be used, which consists of five main stages[7-8].

At the first stage, taking into account the geometry of the theoretical contour of the product and its electronic model, an electronic model of the part is created using 3-D design tools, for example, the NX system [9-11]. The accuracy of the model at this stage is ±0.001 mm. In this case, the NX system is used as a means of mechanizing the design process.

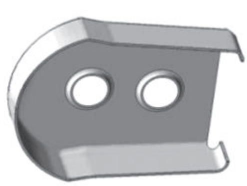

Fig. 1. Electronic model of the par.

At the second stage, using the electronic model of the product, sections and development are performed using NX tools. Then comes the design of a technological model of the base of the mold block (Fig. 3), which is necessary for writing a control program (CP) on a milling machine with numerical program control (NPC). The accuracy of these works is within ±0.001 mm.

Based on the obtained sections and development, further design of the templates used to create and control the tooling of this part is underway. In this case, this is an internal contour template (ICP) (Fig. 4, a), which is used to manufacture the mold block overlay, control the

 https://doi.org/10.1051/e3sconf/202337601095

base of the mold block, control the manufacture of the part in the blanking and stamping shop, and it also serves as a source for the manufacture of the part sweep template (PST) (Fig. 4, b), which, in turn, is used to control the manufacture of the mold block, markup and control the development of parts, cutting the workpiece. The design accuracy of these templates is within ±0.1 mm.

At the third stage, the CP is being prepared for the NPC machine for manufacturing the base of the mold block. CP preparation can be implemented in the NX system using the NX-CAM module [12-14]. The accuracy of these works is within ±0.03 mm. Also at this stage, the preparation of the CP for cutting templates and the manufacture of templates on a laser cutting machine is performed. The accuracy of these works is within ±0.1 mm.

After that, the manufactured templates are transferred to the locksmith site for their control, if necessary, the template contour is cut in accordance with the constructive plaza, and all the necessary information is applied to the templates using a ruler, stamp, hammer and scriber. Template manufacturing accuracy: ICP = -0.2 mm; PST = +0.2 mm.

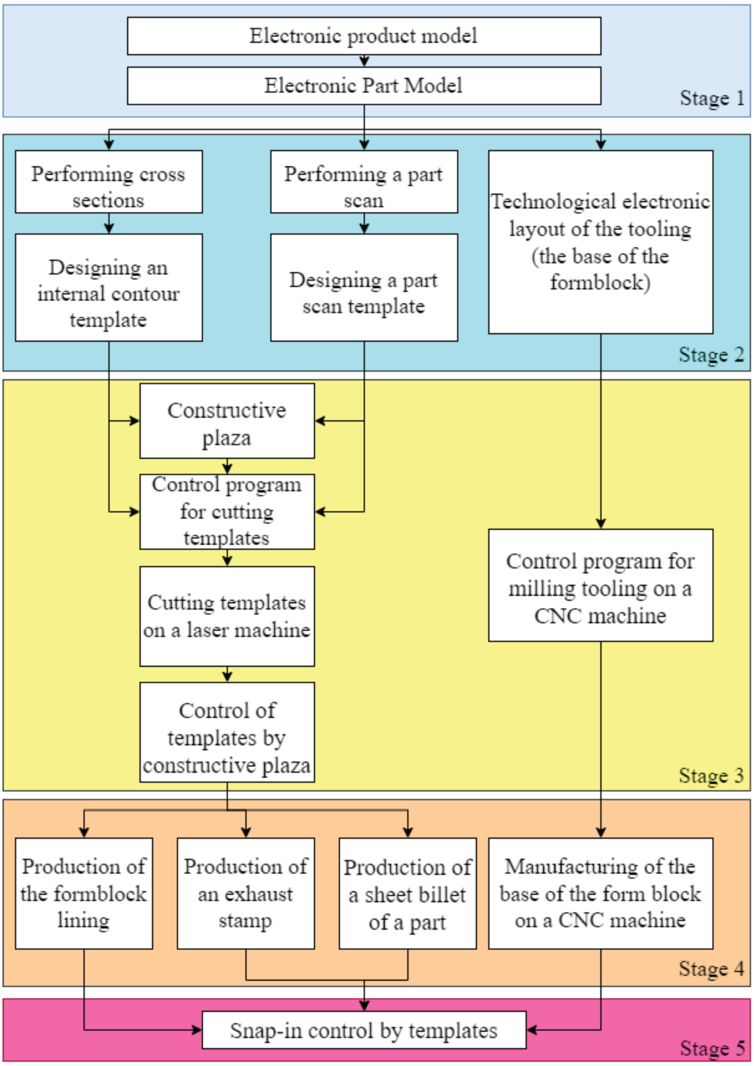

Fig. 2. Scheme for the manufacture of tooling for the part.

 https://doi.org/10.1051/e3sconf/202337601095

At the fourth stage, the templates are delivered to the carpentry for the manufacture of tooling according to the list of plaza-template tooling (PTT). In this case, an overlay is made for the mold block and the stamp for drawing the sides. Tooling is controlled by templates [14-15]. The accuracy of the equipment obtained by this method is within ± 0.2 mm.

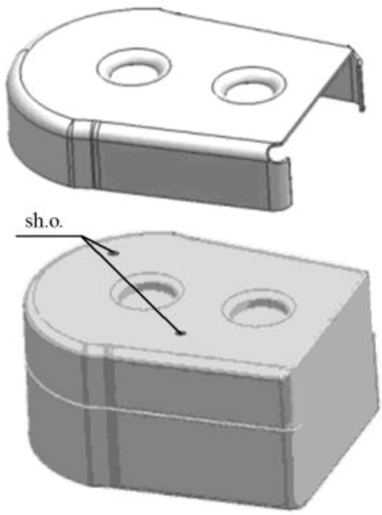

Fig. 3. Equipment - the base of the form block.

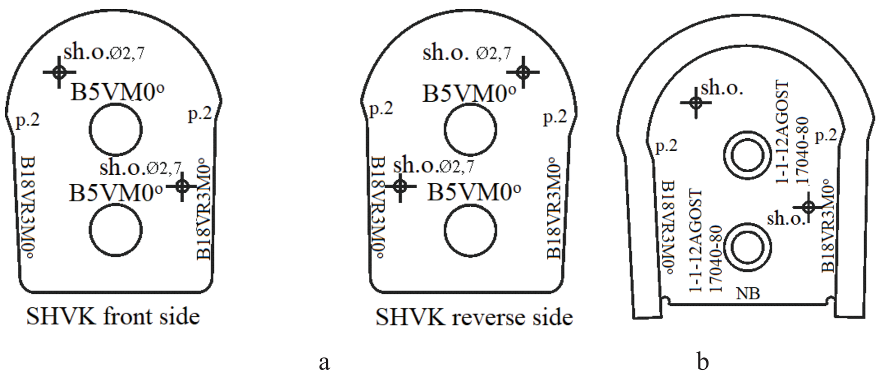

Fig. 4. Templates: a - ICP; b – PST.

At the same stage, according to the CP on a NPC machine, the base of the mold block is manufactured, after which the tooling is transferred to the locksmith site for sawing, linking and controlling the tooling contour with templates. The manufacturing accuracy of the base in this case is within ±0.2 mm.

This method of manufacturing the base of the mold block requires a large number of operations, since this equipment has a complex surface configuration, machine tools and the NPC system do not meet modern requirements, primarily in terms of accuracy and productivity [16,17].

Also at this stage, the manufacture of a flat blank for the part according to the PST on a copy-milling machine is performed manually. Control takes place according to the PST template. The accuracy of this operation is within ±0.2 mm.

The fifth stage is the control and linkage of the manufactured equipment with each other according to templates along two tool holes and along the contour of the part. For this option, information technology is used as a means of mechanization. All coordination is carried out according to the constructive plaza, and control takes place according to templates [18,19].

In the manufacture of tooling for parts of the considered type, certain disadvantages can be noted that reduce the efficiency of the production process. Here, EPM are used, as a rule, only for writing CP for tooling manufacturing, and the use of manual finishing methods and traditional equipment do not provide high precision tooling. The tooling produced by this method has a high labor intensity and a long production cycle, and if changes are made to the design documentation of the manufactured part, a long process of modification of the used tooling follows [20].

The noted problems can be solved by using new NPC machines, as well as the use of control and measuring machines to improve the accuracy of work.

4 Conclusion

The use of electronic models of parts and assembly units of the considered type can provide spatial linkage of parts with each other in the context of the assembly, which will make it possible to quickly make decisions on issues that arise during the subsequent assembly of the aircraft.

Technological electronic mock-up (TEL) of the designed equipment according to EPM can be used in the development of CP for a NPC machine and its manufacture on it, which will allow you to link the configuration of the equipment in models before the process of its manufacture on the machine. In most cases, tooling surfaces are surfaces of double curvature, and the use of electronic models makes it possible to develop CP according to the linked TEL with marking and applying assembly, pin, tool and other holes on it. When making structural changes, the manufacture or refinement of equipment occurs in a short time.

It becomes possible to perform an analysis of the detachability of a part from a tooling, which at this design stage may reveal the need for a partial change or complete replacement of the design of the designed tooling. On the basis of electronic models of parts and assembly units, it is possible to implement cross-sections and reamers for subsequent cutting on a laser cutting machine, while ensuring the alignment of flat and three-dimensional PTT, cutting sheet material is more optimally performed.

References

1. A. Korchagin, Y. Deniskin, I. Pocebneva, O. Vasilyeva, Transportation Research Procedia **63**, 1521-1533 (2022) doi: 10.1016/j.trpro.2022.06.164
2. M. Akhmatova, A. Deniskina, D. Akhmatova, L. Prykina, Transportation Research Procedia **63**, 1512-1520 (2022) doi: 10.1016/j.trpro.2022.06.163
3. D. Yurin, A. Deniskina, B. Boytsov, M. Karpovich, E3S Web of Conferences **244** (2021) doi: 10.1051/e3sconf/202124411010
4. I. Pocebneva, Y. Deniskin, A. Yerokhin, V. Artiukh, V. Vershinin, E3S Web of Conferences **110** (2019) doi: 10.1051/e3sconf/201911001074
5. A. Kolosov, A. Smolyaninov, D. Kargashilov, D. Spitsov, Transportation Research Procedia **63**, 1621-1630 (2022) doi: 10.1016/j.trpro.2022.06.176
6. G.N. Kravchenko, K.G. Kravchenko, A.V. Smolyaninov, Determining patterns of distribution of random loading load cycles in typical aircraft chassis elements (2021) doi:10.1007/978-3-030-54814-8_39
7. V.I. Butenko, O.S. Dolgov, D.S. Durov, B.B. Safoklov, Russian Engineering Research **42(5)**, 464-467 (2022) doi:10.3103/S1068798X22050082

8. B. Safoklov, D. Prokopenko, Y. Deniskin, M. Kostyshak, Transportation Research Procedia **63**, 1534-1543 (2022) doi:10.1016/j.trpro.2022.06.165
9. S. Salimbeni, A. Redchuk, The impact of intelligent objects on quality 4.0 (2023) doi:10.1007/978-3-031-16281-7_28
10. V.I. Bekhmetyev, V.A. Tereshonkov, V. Lepeshkin, VERTICAL CAD in the design of efficient technologies for making aircraft glider parts (2022) doi:10.1007/978-3-030-94202-1_28
11. O. Dolgov, D. Prokopenko, A. Kolosov, I. Abrosimova, Transportation Research Procedia **63**, 1639-1659 (2022) doi: 10.1016/j.trpro.2022.06.178
12. Y. Li, Z. Tao, L. Wang et al, Robotics and Computer-Integrated Manufacturing **79** (2023) doi: 10.1016/j.rcim.2022.102443
13. H. Yu, D. Yu, C. Wang, Y. Hu, Y. Li, Robotics and Computer-Integrated Manufacturing **79** (2023) doi: 10.1016/j.rcim.2022.102418
14. P. Calvo-Bascones, A. Voisin, P. Do, M.A. Sanz-Bobi, Computers in Industry **144** (2023) doi: 10.1016/j.compind.2022.103767
15. F. Franchi, V. Gattulli, F. Graziosi, F. Potenza, Structural health monitoring systems operating in a 5G-based network (2023) doi:10.1007/978-3-031-07254-3_10
16. D. Milanoski, G. Galanopoulos, D. Zarouchas, T. Loutas, Damage diagnostics on Post-buckled stiffened panels utilizing the Digital-twin concept (2023) doi:10.1007/978-3-031-07254-3_21
17. W. Kim, S. Kim, J. Jeong et al, Mechanical Systems and Signal Processing **181** (2022) doi:10.1016/j.ymssp.2022.109471
18. J. Jiang, H. Li, Z. Mao et al, Scientific Reports **12(1)** (2022) doi:10.1038/s41598-021-04545-5
19. J. Liu, X. Wen, H. Zhou et al, Advanced Engineering Informatics **54** (2022) doi: 10.1016/j.aei.2022.101737
20. K. Chen, C. Liu, C. Chen, Mathematics **10(14)** (2022) doi:10.3390/math10142514