Integrated approach to process design of manufacturing of high-precision products

A Nazaryev*, P Bochkarev and E Reshetnikova
Yuri Gagarin State Technical University of Saratov, 410054, 77 Politechnicheskaya street, Saratov, Russia

*alex121989@mail.ru

Abstract. In the present paper considers the structure of the complex design procedures (integrated approach) of the system for taking into account the requirements for the assembly of high-precision products in the design of manufacturing methods of machining, which is based on the establishment of a link between the process design of machining and assembly plants, is considered. Also, the paper considers mathematical models and approaches to system ware implementation.

1. Introduction
Assembly of products is the final and most crucial stage of the production cycle. This is especially true for high-precision products. Achieving the specified operational characteristics of this products causes considerable difficulties. The elimination of these difficulties is associated with costly methods in the form of numerous finishing work, reassemblies and configuration refinement. Also, the existing methods of the achievement of the assembling precision are not multipurpose and they depend on the nature of the manufacture and the design features of the products [1,2].

It should be noted that the traditional design of manufacturing methods of machining and assembly is subjective. The process planner is not able to consider all possible options for the manufacture of parts and assembly of products and choose from them the most rational. As well as with the traditional design of technological processes, it is impossible to take into account the real state of the manufacturing system. When designing manufacturing methods of machining, there is no consideration for subsequent assembly requirements. Issues related to the accuracy of the assembled product are solved during the design of manufacturing methods of assembly.

That is why it is necessary to develop approaches for the intellectualization of process design, allowing to design rational manufacturing methods of machining that take into account the requirements of subsequent assembly and the current manufacturing situation.

2. Formatting the title, authors and affiliations
The structure of the complex of design procedures of the system of accounting requirements for the assembly in the design of manufacturing methods of machining is proposed [3]. This system will allow to take into account the really developing manufacturing situation and to choose rational manufacturing methods of machining taking into account the requirements of the assembly. This will reduce manufacturing content of assembling high-precision products, the number of sets of parts required for assembling, improve the quality and accuracy of high-precision products, and also reduce time and labour intensity of the process design. The structure of the system in general form is
presented in figure 1. The analysis of the initial data and the development of rational manufacturing methods in the system of automated sequencing of manufacturing methods [4,5] includes several steps:

- The analysis of a high-precision assembly unit and its assembly requirements;
- The analysis of possible options of manufacturing methods of machining;
- The selection of rational manufacturing methods of machining.

**Figure 1.** The structure of the system in general form.

The initial data for the first step are the design documentation and the resulting databases.

The design dimensional analysis consists in the construction of graphs of dimensional analysis of assembly units (graphs of conjugations) \( G_C = (A,B) \) and graphs of dimensional analysis of parts (graphs of sizes) \( G_{SJ} = (C,D) \) (j index denotes the number of the part in the assembly). Then is followed by the calculation of the closing links.

The graph of sizes can be interpreted as the result of resultant of the graph of conjugation to the level of geometric contours then forming the elements of the product [6].

As a result, we obtain the union of the graphs (the graphs of sizes are elements of the graph of conjugation):

\[
G_{S1}, G_{S2}, \ldots, G_{Sn} \in G_C = G_{CS}
\]

In figure 2 shows a fragment of the union of the graph of conjugation and the graph of sizes of a high-precision product.

On the basis of the result of the union of the graphs are constructed the systems of equations for calculating the required links.

The initial data for the second step are many variants of manufacturing methods of manufacturing parts.

The technological dimensional analysis consists in the construction of the graphs of possible variants of manufacturing methods of manufacturing parts:

\[
G_{Tjk} = (B_T, C_T)
\]

where \( k \) is the number of the option of the manufacturing methods of manufacturing part.
As a result of the implementation of the procedure, variants of systems of equations of nominal sizes and envelopes of metal were generated for each part.

The graph of the manufacturing method and the dimension chains are the source data for the approach used for the automatisation of the designing of the manufacturing dimension chains [7,8].

At the final step, the variants of generalized graphs are compiled (the graphs of sizes, the graph of conjugation, and graphs of technological dimensional analysis of variants of manufacturing methods): $G_T^{i_1}, G_T^{j_2}, ..., G_T^{m_0} \in G_{CS}$

An example of compiling of the generalized graphs is shown in figure 3.

Figure 2. The fragment of the union of the graph of conjugation and the graph of sizes of a high-precision product.

As a result, generalized systems of equations of graphs are obtained.

On the basis of their chosen set of manufacturing methods of manufacturing parts that satisfy the requirements of the assembly. The selection criterion is to obtain the maximum possible number of assembly kits $W_{AK} = \max \{d_j\}$.

The variant of a rational manufacturing method is determined from manufacturing methods that meet the requirements of the assembly. Selecting manufacturing method carried out by the following criteria:

- The number of operations of manufacturing methods of manufacturing parts ($N_{op}$);
- The number of operations of manufacturing methods of manufacturing parts ($N_{op}$);
The homogeneity of processing equipment ($K_{h.m.e}$).

It is necessary to choose the optimal value of the weighting factors $\zeta$ for each of the criteria of rationality. It is necessary to observe the following conditions:

$$\zeta_{op} > \zeta_t > \zeta_{h.m.e}$$

The choice of a rational manufacturing method is carried out by the method of multi-criteria optimization according to the Pareto criterion. The genetic algorithm is applied to determine the weighting factors of each of the criteria [9,10].

3. Conclusion

The application of the system of accounting requirements for the assembly in the design of manufacturing methods of machining is an urgent task, since this system will allow to take into account the actual developing production situation and to choose rational manufacturing methods of machining, taking into account the restrictions imposed by the assembly requirements. The application of the system of accounting requirements for the assembly in the design of manufacturing methods of machining is an urgent task, since this system will allow to take into account the really developing manufacturing situation and to choose rational technological processes for the processing of parts, taking into account the restrictions imposed by the assembly requirements. As a result of that it should be possible to reduce labour inputs, production time and working cost, to improve quality and precision of the high precision products. And also it should be possible to reduce labour inputs and production time during the process design.

References

[1] Suslov A G and Dal'skij A M 2002 Scientific fundamentals of technology of mechanical engineering (Moscow: Mashinostroenie Publ.)
[2] Bazrov B M 2005 Fundamentals of technology of mechanical engineering (Moscow: Mashinostroenie Publ.)
[3] Nazaryev A V, Bochkarev P Yu and Bokova L G 2019 Handbook. An Engineering journal vol 3 (264) Complex approach to implementation of technological preparation of multiproduct machining productions by taking into account specifics of assembly of high-precision product (Moscow: Publishing house “SPEKTR”) pp 35–42
[4] Mitin S G, Razmanov I A and Bochkarev P Yu 2017 Handbook. An Engineering journal vol 5 (242) Design procedures formation in the synthesis of the complex structured manufacturing operations (Moscow: Publishing house “SPEKTR”) pp 33–39
[5] Bochkarev P Yu, Shalunov V V and Bokova L. G 2009 Vestnik Saratovskogo gosudarstvennoho tekhnicheskogo universiteta vol 3 (1) The design of technological operations of machining in the planning system of technological processes (Saratov: Yuri Gagarin State Technical University of Saratov Publ.) pp 46–54
[6] Grechnikov F V. and Tlustenko S F 2011 Vestnik Samarskogo gosudarstvennogo aerokosmicheskogo universiteta im. akademika S. P. Koroleva vol 3-4 The design of technological operations of machining in the planning system of technological processes (Samara) pp 38–43
[7] Thimm G, Britton G A and Fok S C 2004 International Journal of Advanced Manufacturing Technology A graph theoretic approach linking design dimensioning and process planning. Part 1: Designing to process planning (London: Springer-Verlag) pp 261–271
[8] Muholzoev A V 2015 Vestnik YuUrGU. Ser. Mechanical Engineering Industry vol 3 Algorithm of the module for automated calculation of technological dimensional chains (Chelyabinsk: YuUrGU Publ.)
[9] Li W D, Ong S K and Nee A Y C 2002 International Journal of Production Research vol 40 (8) Hybrid genetic algorithm and simulated annealing approach for the optimization of process plans for prismatic parts (London: Taylor & Francis) pp 1899-1922
[10] Bierwirth C and Mattfield D C 1999 Evolutionary Computation vol 7 Production Scheduling and Rescheduling with Genetic Algorithms (Cambridge, Massachusetts: MIT Press) pp 1-17