Development the engineering analysis system of mechanical processing technology and assembly for the parts like axially symmetrical bodies

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Abstract. The problem of developing an engineering analysis system for modeling technological processes of machining and assembly and carrying out dimensional analysis has been considered. The purpose of creating the system, the tasks was formulated, the objects was selected. The general principles of the system design, the data structure, the software, and functioning of the engineering analysis system of mechanical processing technology and assembly has been proposed. Software modules allow you to perform modeling procedures for technological processes of machining and assembly, dimensional analysis of structures and technological processes of machining, products visualization, parts, workpiece, technological processes of machining and assembly. The system functioning is possible in the analysis modes of existing technological processes and synthesis of new technological processes of machining and assembly. A set of techniques, mathematical models, algorithms underlie of system building has been listed. It is noted that the developed system of engineering analysis provides an increase the efficiency of products design and technological processes of machining and assembly in terms of ensuring accuracy. The possible directions of further development of the system has been indicated.

1. Introduction
At present, integrated systems of computer-aided design of products and process planning of their manufacturing are widely used, which makes it possible to significantly increase the labor productivity of designers and process planers, by automating routine operations of design and preparation documentation for a particular adopted design and technological process \cite{1}. The problem of obtaining an optimal product design with the use of CAE-systems for the engineering analysis of structures has been solved, but the problem of obtaining the optimal version of the technological process of machining and assembly for actual manufacturing conditions remains has been unresolved. This is due to the fact that the design of technological processes of machining and assembly remains a time-consuming creative task, largely based on the use of experience and intuition of the designer, and the use of the scientific foundations of engineering technology with a full range of methods for solving problems of designing mechanical processing technology and assembly. At the same time, formalized methods has been developed for solving separate tasks based on the use of a formalized language, coding system, graph theory, mathematical logic and other models and a method of combining all
tasks into an integrated system has been proposed. However, the problem of creating an engineering analysis system for technological processes based on the pass-through formalization and algorithmization for the processes of generating and transformation the design-engineering information using various mathematical models remains has been unsolved.

An important task in the design of products and technological processes is to ensure accuracy. This problem has been solving based on the dimensional analysis methods [2-4]. Dimensional analysis includes a large number of calculation and analytical actions and it is a labor intensive procedure. Automation equipment of dimensional analysis has been developed, but they solving problems of either dimensional analysis of structures [5] or dimensional analysis of technological processes [6]. The results of dimensional analysis of structures are the initial data for the technological processes of machining and assembly design, as well as carrying out dimensional analysis of technological processes of machining. Therefore, the dimensional analysis of structures, the technological processes of machining and assembly design, and the dimensional analysis of technological processes of machining should be rationally carried out in a complex, that is, within a single system of engineering analysis. This will allow evaluating the effect of decisions, were established during dimensional analysis of structures on the manufacturing process of the product and increase their validity.

2. Problem statement

The purpose of development the engineering analysis system is to ensure the possibility of carrying out analysis, synthesis, and technological processes modeling, with the purpose of substantiate design decisions while ensuring accuracy based on dimensional analysis. In developing an engineering analysis system, it will be necessary to:

1. Formulate the basic principles for building a system.
2. Develop a framework and software.
3. Develop the functioning of the system.
4. Develop a set of techniques, mathematical models, algorithms for solving problems of dimensional analysis and modeling technological processes of machining and assembly.

Due to the complexity and diversity of the tasks being solved, the development of an engineering analysis system should be carried out for details of type-defined. Among engineering products, a high proportion of products are axially symmetrical bodies: pumps, gas turbine engines, etc. Details of such products have the shape of revolution bodies limited by cylindrical, flat, conical, spherical and other surfaces of rotation. We take the details and products of this type as objects of the engineering analysis system being developed.

3. Description of the study

The following general principles for constructing an engineering analysis system are proposed.

1. The use of special data elements structure of the system - approximated geometric and information models that retain not all, but only the basic properties of objects - a simplified geometric shape, including only flat and cylindrical surfaces, design-technology features of parts surfaces, data on dimensions, surface quality, accuracy parameters.
2. Ensuring data connection of all models.
3. The possibility of increasing the calculated, analytical and other models and software modules.
4. The continuity of the applied models and software modules in their refinement and improvement.

In accordance with the purpose and general principles of building an engineering analysis system, the following models should be included in the data structure:

1. Geometric models parts, products, workpieces of the technological process of machining (TPM).
2. Information models of part, technological process of machining, product, of the technological process of assembly based on the problem-oriented languages (POL) [7].

The following modules should be included in the software engineering analysis software structure:
1. The simulation modules for modeling technological processes of machining and assembly.
2. The dimensional analysis modules of constructions and technological processes of machining.
3. The visualization modules of the products, parts, workpieces, technological processes of machining and assembly [8].

The structure of the engineering analysis system is presented in Figure 1.

Figure 1. The structure of the engineering analysis system in mechanical engineering.

Depending on the tasks have being solved, the engineering analysis system is operational in the modes of analysis and synthesis. The order of the system operation in the analysis mode includes the following steps.

1. Preparation the initial data:
   - generation the part model, the workpiece model and the technological process of machining, according to the technological documentation.
   - generation all parts models and product models according to the drawing, and generation a model of the assembly technological process according to the technological documentation.
2. Visualization of the initial data in order to check the adequacy of the generated models.
3. Dimensional analysis of the constructions and the technological process of machining.

The order of the system operation in the synthesis mode includes the following steps.

1. Preparation of base initial data:
   - generation the part model;
   - generation the product model.
2. Visualization of the initial data in order to check the adequacy of the generated models.
3. Generation models of the parts and the products in a POL and synthesis of technological processes of machining and assembly.
4. Analysis of the obtained technological processes of machining and assembly with visualization, dimensional analysis of the construction and technological process of machining.

Building the system of engineering analysis is possible in the presence of a set of techniques, mathematical models, algorithms. Developing the system depends on the following components:

- the baseline technique of calculating the linear technological dimensions using the graph adjacency matrix;
- information-related models of parts and technological process with the general designations of the size boundary, allowing to significantly simplify the preparation of initial data for dimensional calculations by completely eliminating the labor intensive step of manually constructing dimensional diagrams;
- algorithms for preliminary verification of the initial data for adequacy, ensuring the complete identification of random errors made during the development of geometric models and the input of information into the computer;
- visualization technique that provides fully automatic imaging of objects of dimensional analysis;
- edged model of parts such as bodies of revolution with theoretical and measurable edge parameters, edges equations and distances between edges, and a corresponding apparatus for converting theoretical parameters enabling to combine the calculation of linear, diametric dimensions, parameters of deviations from the location of surfaces, to take into account their reciprocal influence;
- automated technique of dimensional analysis of constructions;
- technique of automation the design of technological processes of machining and assembly based on coding algorithms for design and technological information.

Recommended application areas of developed system: analysis of design and technological documentation in order to verify the provision of a given accuracy; the appointment of accuracy parameters in the design of products and technological processes of assembly and machining.

Further improvement areas of developed system: providing adaptive calculation of technological dimensions, improvement of simulation modules for technological processes of machining and assembly, improving the visualization module in order to obtain images of dimensional diagrams and graphs of design and technological dimensional chains.

4. Conclusions
The developed system of engineering analysis provides an increase the efficiency of products design and technological processes of machining and assembly in terms of ensuring accuracy.

Prospects for the further development of engineering analysis systems for dimensional analysis of structures and technological processes of machining is to expand the number and types of tasks, to expand the types of parts, to increase the adequacy of the results.

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