Algorithm and Flowchart for Geometric Modeling of Microcomponents Based on the CAD System "MICROSYS 25"

Desislava Petrova
Department "Management"
Technical university of Gabrovo
Gabrovo, Bulgaria
des_petrova@abv.bg

Tsanka Zlateva-Petkova
Department "Management"
Technical university of Gabrovo)
Gabrovo, Bulgaria
tszlateva@abv.bg

Angel Lengerov
Department Mechanical engineering
and technologies
Technical university of Sofia, Branch
Plovdiv
CoC – "Smart-Mechatronics, Eco-
and Energy Saving Systems and
Technologies"
Plovdiv, Bulgaria
anlengerov@abv.bg

Abstract—**The article presents the general system of sets of connections of the design of the product and the production process. An algorithm and a flowchart for geometric modeling of the automated system "MICROSYS 25" for microsystems equipment products and a flowchart of an algorithm for selecting a technological process (TP) of the automated system have been developed.**

Keywords— automated system, microsystems engineering, technological design.

I. INTRODUCTION

The main task of automated structural design is the implementation of a principle structural scheme of the designed object and preparation of documentation. The tasks solved in this process can be divided into two groups [1, 2]. One - structural design solves the determination of the geometric parameters of the structure, and these are the tasks of geometric design. The second group of tasks - to synthesize the structure (typology) of the structure, taking into account the functional characteristics of the object, and these are the tasks of topological design. In addition to them, the tasks of structural design also include checking (analysis) of the qualities of the resulting structural solution. Geometric design includes the tasks of geometric modeling, geometric synthesis and design documentation, topological design includes the tasks of layout, placement and routing.

The object of the specialized automated design system "MICROSYS 25" is the development of the database of the modules "structural design" and "technological design", as well as the relationship between them in. The product is considered not as a mechanical connection of different types of objects (elements and components) or as a random community of heterogeneous and independent phenomena occurring in it, but as something holistic, representing a single organic whole of interconnected objects, ensuring the manifestation of numerous mutually conditioned relationships between different phenomena [3].

Thanks to this type of connectivity and conditioning of objects and phenomena, a specific product is formed, which functions in a characteristic and unique way. Thus, the issue of connections and their mutual conditioning becomes important both in the process of designing the product (MMC, MME, MC, etc.), and in the process of its production, because it is the structure and properties of the connections that determine the quality and value of the product, the level of production intensity and its efficiency.

The creation or construction of the product is reduced to the construction of a system of two mutually conditioned sets of connections - material and geometric [4, 5].

For the materialization of each construction, an appropriate PP must be created, representing a new system of five mutually conditioned sets of connections of:

- material properties;
- geometry (topology);
- information;
- time and

◻ economic sets of connections

The mutual dependence between the sets of material properties and dimensional relationships is necessary in the production process in order to create an analogous system of relationships in the product and to define its quality [6]. The set of information relationships is necessary for the management of the production process, and it is carried out in time and at the expense of living and material labor (a set of economic relationships).

The creation of each product (MMC, MME, MC, sensor, etc.) is reduced to the construction of two systems of relationships, relating to: the design of the product (MMC) and the production process of its manufacture.

It is necessary that the relationships in the PP be constructed in strict accordance with the system of relationships contained in the design of the product, i.e. TP inherits the system of sets of the two types of relationships characteristic of the design, which must be included in the new more complex system (Fig. 1).
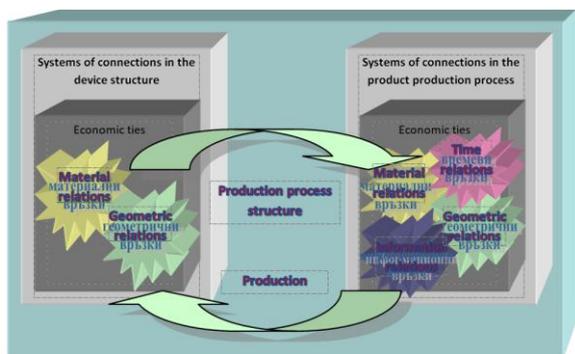

Fig. 1. General system of the sets of connections of the product design (MMK) and the production process

The system of connections constituting the product (micromechanical components - MMC) can be considered strictly deterministic, while the production process is a complex probabilistic system belonging to the category of cybernetic control systems [7].

Considering the production process of manufacturing the product (micromechanical components - MMC) as a manifestation of the overall system of sets, technology and studies these connections in order to solve the problem of ensuring the required quality at a given productivity and minimal expenditure of time, labor, energy and materials [8, 9, 10].

II. MATERIALS AND METHODS

A. Algorithm for geometric modeling of micromechanical elements (MME) for the system for automated design of components of microsystems technology

For geometric modeling of MME included in the construction of microcomponents, two main methods of structural design are used:

◻ Variant geometric modeling - its use is determined by the fact that the system will design variants of geometrically similar MME. This requires the components and the MMEs that make them up to be classified into groups according to structural and technological features. The concept of variant geometric modeling consists in the development of groups of geometrically similar MME. For each group, a geometric parametric model is developed, which contains all the features of the elements of the corresponding group. Each designed MME is coded and refers to a microcomponent, in the construction of which the designed MME is included. Microcomponents are also divided into groups and a structural parametric model is created for each of them. Each designed microcomponent (MC) is coded. In variant geometric modeling, there are two possible solutions. If there is a geometric model in the DB that completely matches that of the designed MME, only the dimensions of the specified parameters of the element are entered and they are saved in the DB as a ready-made solution. If the geometry of the designed MME does not match any geometric model from the DB, the closest model is selected. The necessary corrections are entered and it is saved in the DB as a new geometric model of the MME. The dimensions are entered for the specific designed MME and it is saved in the DB as a ready-made solution [11, 12, 13, 14].

◻ Generative geometric modeling – if there is no geometric model in the DB that fully or partially matches the designed MME, then its geometry is designed, the parameters of this model are determined and it is saved in the DB as a new solution of a group of designed MMEs. The dimensions of the specific designed element are entered and the data are saved in the DB as a ready-made solution [15, 16].

Algorithm of a submodule for geometric modeling of a structural design module of the "MICROSYS 25" system:

1. In the table "Ready-made solutions of MME" from the database, a ready-made solution of MME is searched. If such a solution is found, go to item 15. If no ready-made solution is found, go to item 2.

2. From the table "Microcomponents" (MC) from the database, a component is selected in the construction of which the designed MME is included.

3. From the table "Micromechanical elements" (MME) from the database, the type of the designed MME is selected.

4. In the table "Geometric models of MME" from the database, a ready-made geometric model of the designed MME is searched. If a ready-made geometric model is found, go to item 5. If no such MME model is found, go to item 8.

5. Generation of a unique variant number with values for the parameters of the designed MME.

6. Entering the variant with values for the geometric parameters of the designed MME.

7. Recording the values in the table "Variants with values for MME parameters" from the database. Proceed to item 15.

8. Creating the geometric model of the designed MME.

9. Defining and entering the parameters describing the designed MME.

10. Generating a unique number for the geometric model of the designed MME.

11. Recording the created model in the table "Geometric models of MME" of the database.

12. Generating a unique number for the variant with values for the MME parameters.

13. Entering the variant with values for the geometric parameters of the designed MME.

14. Recording the values in the table "Variants with values for MME parameters" of the database.

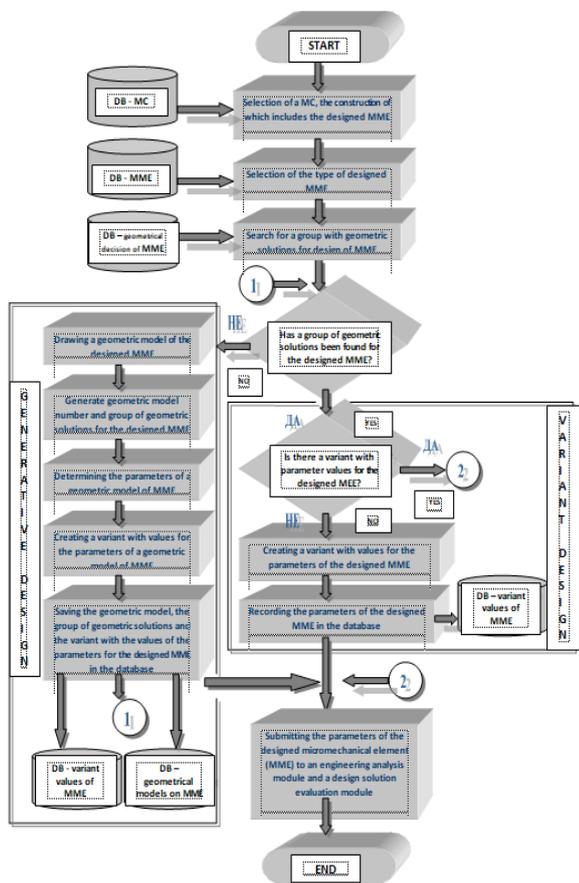15. Proceeding to the submodule "Engineering analysis".

Fig. 2. Block diagram of the geometric modeling algorithm from the automated system "MICROSYS 25"

B. *Algorithm for selecting a technological process of the "MICROSYS 25" system*

Two design approaches are used in Automated process design on Technological Process (APTP) – variant and generative. The basis of the variant design method is the unification of objects and processes, by using the methods of typical TP and group processing. The generative

method provides automated synthesis of an individual TP [17, 18, 19]. The revised algorithm for automated technological design of MME includes the variant design approach. This choice is determined by the specifics of production in microtechnics – mass production using group technology [20]. Variant design is based on the fact that for each group of micromechanical elements, typical technological processes (TTP) are developed for different processing methods. The choice of a specific type of TP is determined by the degree of suitability of this TP for the specifically designed MME.
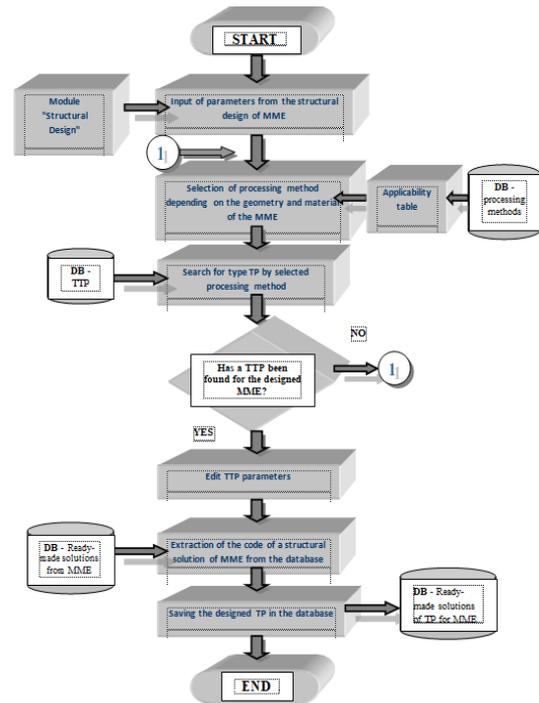

Fig. 3. Flowchart of the algorithm for selecting a technological process (TP) of the automated system "MICROSYS 25"

The algorithm of the module for selecting a technological process of the "MICROSIS" system works in the following sequence:

1. In the table "Ready-made solutions of TP" from the DB, a ready-made project of TP for the designed MME is searched. If such a solution is found, go to item 8. If no ready-made solution is found, go to item 2.

2. From the "Constructive design" module, the parameters of the designed MME are transferred - geometric description, dimensions, technical requirements, material.

3. Selection of a processing method from those possible for the specific MME according to the criteria of geometric features and material.

4. In the table "Typical TP" of the DB, a search is made to see if there is a TTP for the specific MME. If such a solution does not exist, go to item 3. to select a new processing method.

5. Editing the TTP parameters for the specific MME.

6. From the table "Ready-made solutions of MME" of the DB, the code of the MME for which the TP is being designed is extracted.

7. In the table "Ready-made solutions of TP" of the DB, the data for the designed TP are recorded.

8. Transition to the submodule "TP Evaluation".

9. Economic efficiency of the technological process [21, 22, 23].

The block diagram of the algorithm for selecting TP is shown in Fig. 3.

III. RESULTS AND DISCUSSION

Figure 2 shows the optimized block diagram of the geometric modeling algorithm. To create the geometric model of a designed MME, it is necessary to use a software product that must have the following characteristics:

- Ability for 3D modeling of objects.
- Ability to enter dimensions as parameters.
- Ability to correct an already designed object.
- Ability to automatically generate drawings.
- Ability to exchange data with other systems through standardized graphic file formats.
- The models must be directly used for structural analysis or other applications.

In microtechnology, repeated operations are used to structure layers, which implement the main processes (basic technologies) and are presented in Figure 4 and Figure 5, but can also be classified as follows:

A) Deposition of layers on a substrate or a previous layer:

- Physical methods for manufacturing elements by applying thin layers using the methods of vacuum evaporation and sputtering;
- Chemical methods for gas-phase deposition of polycrystalline silicon and amorphous layers;
- Epitaxy - deposition of a single-crystal layer;
- Electrodeposition of galvanic and chemical coatings;
- Methods for applying thick layers.

B) Modification of the surface layer of the substrate, as well as of an already finished layer, so that a new layer with other physical properties, different from the initial state, is formed:

- Thermal oxidation;
- Diffusion;
- Ion implantation.

C) Structuring of a protective layer – production of a protective layer by lithography as a mask for the next etching operation and LIGA (combined lithographic - galvanic) method [24, 25].

D) Methods for microstructuring by mechanical micromachining [26].

E) Removal of layers by etching the areas of the substrate free from the mask, respectively the areas of the layer.

F) Methods for processing by high-energy sources:

- Electron beam processing;
- Laser beam processing;
- Plasma jet processing.

The technological processes and methods of shaping and shaping, as well as surface (layer) shaping and shaping are illustrated below in Fig.4 and Fig. 5.
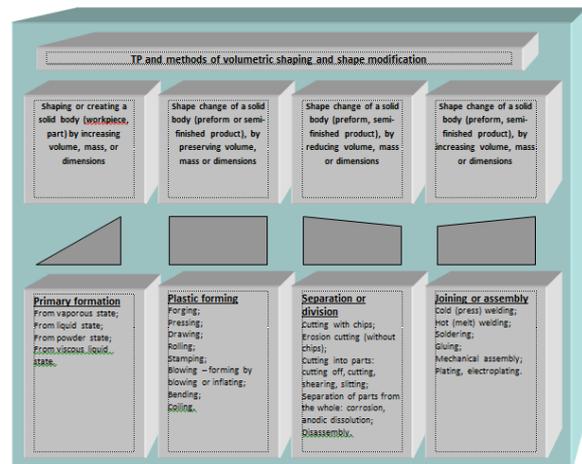

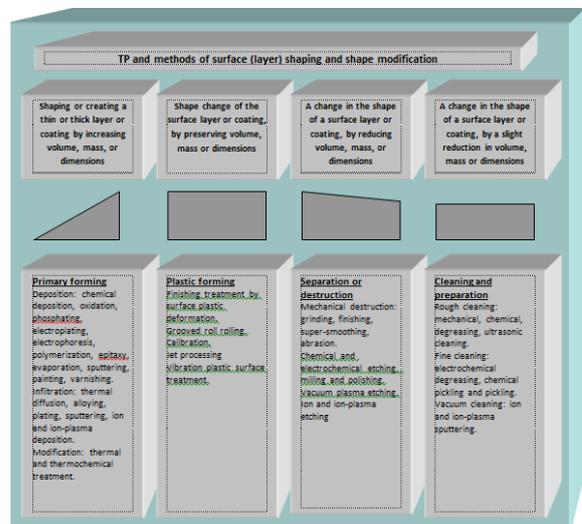Fig. 4. TP and volumetric forming methods

Fig. 5. TP and methods of surface (layer) forming

IV. CONCLUSIONS

An algorithm has been developed for the modules for "Geometric Modeling" and "Constructive Design" of the CAD system "MICROSYS 25", according to which the geometric modeling of MME from MT is best performed using a variant or generative method.

The "Choice of a technological process" from the module "Technological Design" of the specialized

automated system "MICROSYS 25" has been implemented using a variant method of designing technological processes.

Classifications of microcomponents – microsensors, executive micromechanisms and MME, using the facet method, have been further developed, summarized and presented in tabular form (convenient for further work and processing). The tables serve to build the design database of the CAD system "MICROSYS 25".

The design of the design and technological database of the CAD system "MICROSYS 25" has been implemented, and their relational models have been presented.

The automated system for the design of MMK for products from MT "MICROSYS 25" has not completed the design cycle, since computational software is required, therefore the CAD/CAM system is not completed, but is open for further development.

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