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INTEGRATION CAD/CAPP/CAM SYSTEMS IN DESIGN PROCESS OF INNOVATIVE PRODUCTS

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Abstract: *Development of innovative products requires companies a lot of effort. The creation of an appropriate strategy development, climate, protection of resources and preparing a launch system (innovation diamond) [4] are a major challenge. Uncertainty and risks associated with innovation require the use of appropriate methods and tools for precise design innovation which will guarantee a success. Establish appropriate procedures and tools in this area are very important. This paper presents the use of integration methods for design and planning of technology as a solution to support the development of innovative products. This method also includes estimating the cost product which is one of the most important criteria for deciding on the implementation and commercialization of innovative solutions.*
Keywords: *CAD, CAM integration, product innovation, features method*

1. INTRODUCTION

The enterprises must decide to introduce new and unique products to achieve success in the current market conditions. This requires to follow the path of innovation. According to the idea presented by Drucker, those activities should be continuous (Continuous Innovation) [5]. For this purpose, it is necessary to continuous monitoring of the processes carried out in the company, quality control of products, to observe the competitive market and research needs. The proper response to perceived shortcomings is an important part of business operations. Rapid correction of ongoing processes or changes in manufactured products will influence future benefits. It is therefore important to develop appropriate procedures, methods and tools to respond flexibly to market needs. Integration the CAx systems in the area of production preparation is one of the solutions that allow to quickly modify and develop products, defined as product innovations. Solution presented in this article concerns the integration of CAD/CAPP/CAM, which was developed for a company producing industrial valves in aim of rapid implementation and modification of manufactured products.

Among the many CAD systems currently developed, the majority, even those in which the design is based on the so-called features, does not conform to the requirements for systems supporting the production planning CAPP. Models generated by CAD systems contain mainly information about the geometrical shape and do not contain information concerning the future of the manufacturing process. This makes the data are not fully usefull for production planning systems. Production planning support systems usually have a specific data format. Many CAPP system does not have an interface between them and CAD systems. CAPP system has a key role in the integration of CAD/CAM as it is responsible for transforming the constructional informations into technological informations. Therefore, to the CAD model must be assigned not only informations about geometrical dimensions, but also guidance for the process performance associated with accuracy, surface quality and the relationship occurring between the surfaces. For such a detailed description of the CAD model is well suited features method, which allows a full description of the product model and in the appropriate system of identification of the elementary objects facilitates to prepare process planning. For these reasons, it is reasonable to develop work on building interfaces that integrate CAPP systems with CAD systems based on the features method [7, 8].

2. PRODUCT MODEL BASED ON FEATURES

In the features method, which is the basis for integration of CAD/CAPP/CAM, product models are represented by a set of features. In the process of modeling the product features are closely related to the stage of design and manufacturing. Description of objects made at the design stage allows the use of full information on facilities for the preparation of the manufacturing process and production planning. Features are extracted from pre-produced parts [3]. Decomposition of the product should be carried out by a thorough analysis of design and technological documentation. Decomposition of the element is shown in the example of the valve stem (Fig. 1).

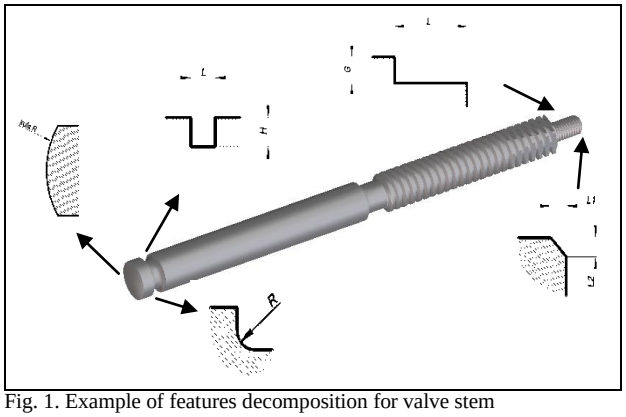
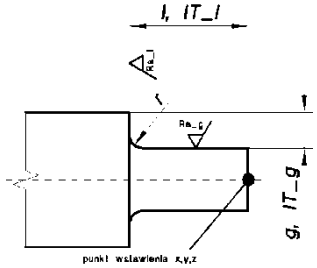
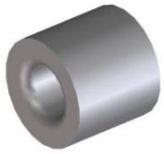


Fig. 1. Example of features decomposition for valve stem

Each of the elementary objects is described parametrically due to its geometric shape. Example of one of parameterized feature is shown in Tab. 1.

Feature	**External undercut**

2D model and parametric dimensions		
3D model		
Properties of feature	*Geometrical*	
	The insertion point	x, y, z
	length	l
	depth	g
	fillet	r
	Qualitative	
	The surface roughness determined by dimension l	Ra_l
	The surface roughness determined by dimension g	Ra_g
	The accuracy - dimension l	IT_l
	The accuracy - dimension g	IT_g
	Determining the direction of treatment	
	Machining direction	L – left or R - right

Tab. 1. Example of feature – model and parameters

To prepare a system allowing the use of the features method in the design process, it is necessary to develop a method of classification and identification. For this purpose, defined four classes determining the level of complexity (Fig. 2):

- product,
- assembly,
- part,
- feature.

The objects were defined in each class. Their membership to the class is determined by the complexity of the manufacturing process. Features belonging to the lowest class are the simplest elements and are associated with a single technological operation. Objects belonging to the higher classes require several technological operations or the full manufacturing process.

Drawing on existing classification systems for products and machine parts have been prepared system for classification and identification based on distinctive properties of individual elements, and determining the complexity of these elements for each of products. The method of classifying and identifying elements of the valve includes characteristics of their design and exploitation parameters. Prepared classification system has allowed the design of the database necessary for object-oriented design using the features method.

Class: **Product**

Classification symbol	*218.080.00.01*
Name	*Globe valve*
Type	*218*
Nominal diameter	*80*
Design variant	*00*
Type of ends	*01*
List of components	*A01, A12, A14, …*

Class: **Assembly**

Classification symbol	*A01.218.080.00.01*
Name	*Zespół kadłuba*
Type	*218*
Nominal diameter	*80*
Design variant	*00*
Type of ends	*01*
Main dimensions	*L=320, H=200, W=240*
Material	*20HGM*
Belongs to	*218.080.00.01*
List of components	B01, B12, …

Class: **Part**

Classification symbol	*B52.218.080.00.01*
Name	*Valve stem*
Type	*218*
Nominal diameter	*80*
Design variant	*00*
Type of ends	*01*
Main dimensions	*L=315, D=24*
Material	*2H13*
Belongs to	*218.080.00.01*
List of components	C01, C02, …

Class: **Feature**

Classification symbol	D01
Name	Undercut
Position	0,0,0
Dimensions	L=50, g=3
Belongs to	B01
Tolerance	
Fit	d11
Roughness	2,5

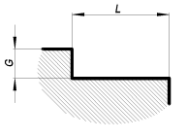


Fig. 2. Classification system for valves structure

Defined and parameterized objects and prepared database allow for execution of the valve element models. Fig. 3 presents a model of the valve bonnet using the method features. The design process is based on inserting the following features, which resembles the realization of the manufacturing process. Sequence of used features is stored in the structure of the element, as shown on the left side of the screen (Fig. 3).

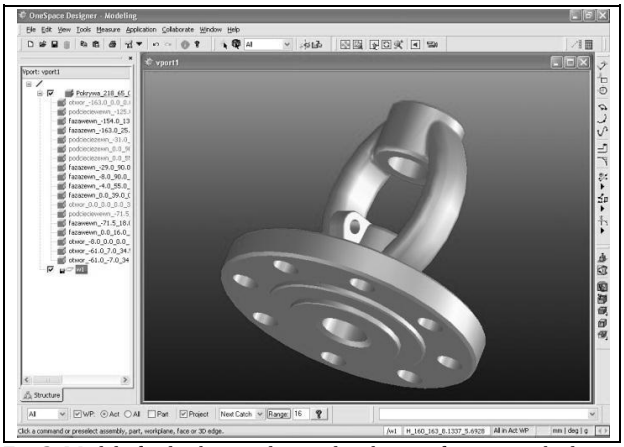


Fig. 3. Model of valve bonnet designed with using features method

The product structure is defined at the design stage. It involves the presentation of the product by the elements

and interactions between them. Elements and relations have certain attributes such as dimensions, material type, etc. General scheme is based on four characteristics of the product cost control and the basic structure. Bearing in mind the possibility of cost estimating the only solution is to assign costs to each part. The four characteristics (geometric features, material, type of production process and production planning) are attributes of the part and determine the cost of his production. They are only linked to the physical elements of the product, not relations. The physical elements of the product include: assembly, parts, modules and features. If the relationship that occurs between elements (eg, tolerance) has specific implications of cost, they are associated with higher levels of aggregation.

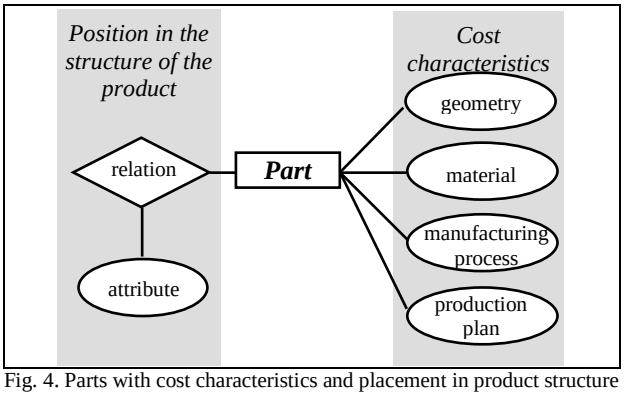


Fig. 4. Parts with cost characteristics and placement in product structure

3. MODULE AIDED PROCESS PLANNING

Establishment a variant of the manufacturing process is based on the technological features (Fig. 5) which are associated with the corresponding geometric features.

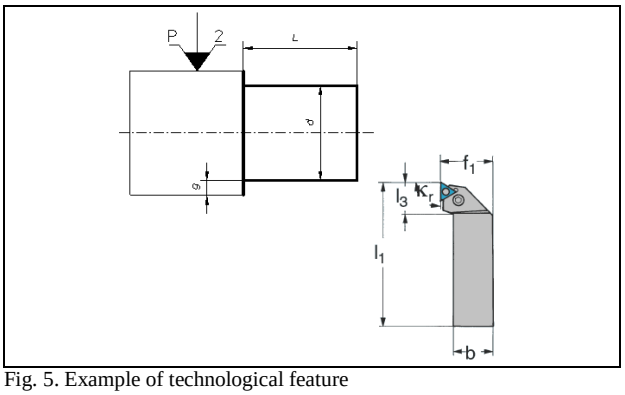


Fig. 5. Example of technological feature

Because of variability the existing manufacturing processes, each of geometric feature can be allocate to a few technological features. The selection of suitable matching of geometric and technological features and thus determining the optimum variant of the manufacturing process takes place due to the costs incurred as a result of its implementation. In order to determine which of the existing variants is the best in terms of cost will be applied cluster analysis (cluster detection) [6], ie the search for clusters in multidimensional data space. Selection criterion, while complying with quality requirements, for variant of the manufacturing process is the cost and execution time. The study shows that each element has the attributes with a significant impact on the cost of its production. These may be its geometrical dimensions, accuracy, quality, etc. In the case of a group of elements with high structural similarity, and here the example can be a study group of valves. Their cost of production is related with the main decisive geometrical dimensions.

For the automatically generate manufacturing process was necessary to create a computer program performing two functions: CAPP system to prepare the manufacturing process and estimating the cost of this process. The tasks carried out under this program include:

- import data from a CAD model,
- analysis of the CAD model,
- combination of geometric features with the technological features and to determine the optimal manufacturing process based on cluster analysis guided by the criterion of minimum cost,
- estimate the cost of the manufacturing process,
- generating of technical documentation,
- generating the machining program for CAM system.

Deciding on the implementation of the manufacturing process the lowest cost is not always most important criterion. Therefore, the program allows also to manually select a variant of the manufacturing process. The program will automatically create this process as a suggestion the best solution. Model of this system is shown in fig. 6.

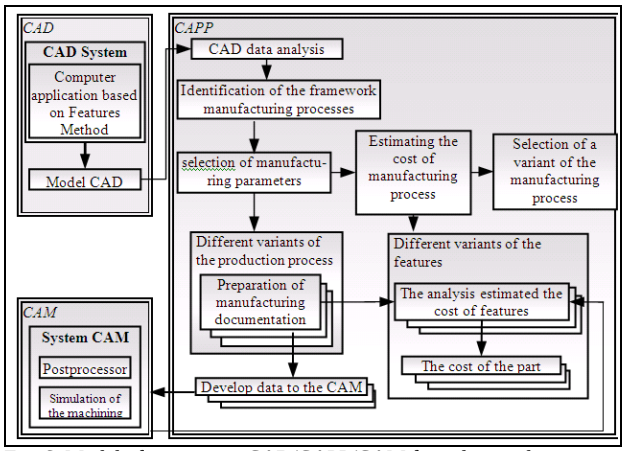


Fig. 6. Model of integration CAD/CAPP/CAM for valve production

4. COST ESTIMATING OF THE MANUFACTURING PROCESS

Estimating the cost of product is due to the aggregation the cost of all features, analyzing them in the order of operations and procedures laid down in the generated manufacturing process. Key role in determining these costs is cluster analysis, which selects the variant of the manufacturing process characterized by the lowest cost of its realization [2]. As a result of this choice, it is possible to associate technological features to geometrical features by identifying areas where is expected the lowest cost. The choice of this method was due to the large number of possible solutions in the selection the tools of production and machining parameters. Cluster analysis, in this part of the cost estimation, allows to narrow the search for solutions to the nearest cluster. This action allows to determine the

direct costs. By contrast, indirect costs shall be charged based on the cost sheet made for the previous billing period using standard calculation methods used for series production [1]. In this way we obtain the cost of product, which can be compared with the costs of products produced in the past. The model of cost estimating is shown in Fig. 7.

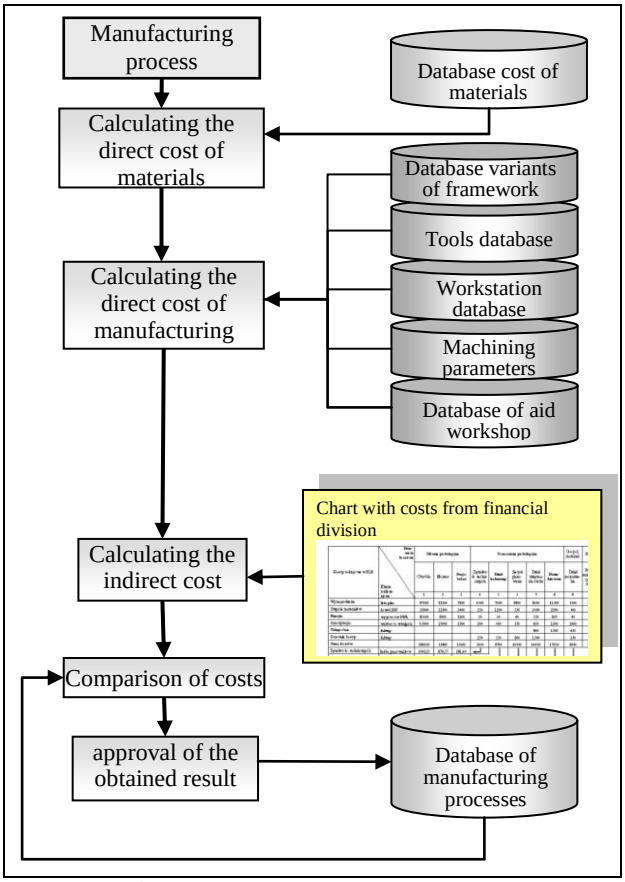


Fig. 7. Model of costs estimating in the CAPP module

5. APPLICATION OF INTEGRATION OF CAD/CAPP/CAM IN THE DESIGN OF INNOVATIVE SOLUTIONS

The company, for which this solution of integrating the processes of production preparation have been developed, often perform modification of products. It is caused by strong competition in the market. To maintain the leading position in the domestic market it is necessary to continually improve the products. The changes are often unique and therefore can be regarded in terms of innovation. These are product innovations with incremental nature. The proposed changes in product design requires analysis of the profitability of production, the evaluation of the cost of the modified product. Presented in article solution serves as a perfect tool to help in the preparation of the manufacturing process such innovative products. It also allows to estimate the cost of production of new product and compare them with the cost of production the products manufactured in the past. The introduction of changes in product design requires only a change in the parameters stored in the database of features or create a new features. Making changes to your features is not labor intensive and can very quickly assess the profitability of future production. As an example is a modification of the valve stem. The aim was to achieve rapid closure of the valve, which was necessary in the event of an emergency requiring a rapid cut-off flow. It was decided to shorten the thread and change its pitch, which made it possible to shorten the time for opening and closing the valve.To achieve this goal it was necessary to take the following action: make the appropriate changes to the database of features, prepare a model of the product, generate the manufacturing process and estimate of costs. Changes were made in only one feature. His exchange has caused automatically changes to the manufacturing process and the calculation of the expected costs.Time of this operation was only few minutes. This allowed for a rapid decision about start of production.

6. CONCLUSION

Innovation processes are highly desirable element in the functioning of enterprises on the market where is the intense competition. Innovative activity is a very difficult task and requires the involvement of many efforts and financial resources. Because of this an important element in innovation process is rapid assessment of the proposed solutions. Having the right tool for the rapid preparation of innovation design and evaluation of its benefits, is possible to quickly decide about start the implementation process. In terms of product innovations, such a task can perform integrated CAD/CAM system. Solution presented in this paper shows that the CAPP program supplemented with a module of cost estimation is very useful tool for the analysis of proposed product innovation solutions. In presented solution, the assessment is based on the criterion of cost. This is not always a decisive criterion. Innovative solutions may be evaluated in view of the other criteria that do not have to be non-deterministic. Therefore it was decided that the decision-making module will be added to presented system of integration CAD/CAM in the course of further research. It will allow to assessment of product innovation solutions based on multiple criteria and expert knowledge. The cost, due to its importance, will be only one of these criteria.

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