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FEATURE MODELS IN VIRTUEL PRODUCT DEVELOPMENT

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Abstract. *Development of new products requires the use of modern tools for design, which enable evasion of errors and reduction of the number of iterations as soon as in the early phases of development. In the concept of simultaneous development of products and technologies, the feature-based design enables creation of product models suitable for various engineering applications. The paper provides an outline of the favourable effects of the feature-based design during the development of the virtual product in digital factory ambiance. What is emphasized is manufacturability analysis, which enables adoption of the product to manufacturing conditions and reduction of the cost of manufacturing.*

Key words: *Feature-based Design, Manufacturability Analysis, Design for Manufacturing, Intelligent CAD Systems, Simultaneous Design*

1. INTRODUCTION

The basic precondition for the development of every country is its maintaining the existing market and, if possible, expanding it. In order to do so, it is necessary to meet the demands of the market over a number of years. The market permanently sets even more complex demands with respect to the manufacturability, quality, and speed of development of new products. Therefore, what is required is knowledge, learning, which create receptiveness to innovations, new economic and technical solutions, and readiness to meet the individual demands of purchasers in a highly competitive market.

Nowadays, the situation in the world market is characterized by two salient tendencies:

- domination of purchasers' demands, and
- globalization of the market,

Domination of purchasers' demands means that modern products must satisfy the purchasers' expectations and demands, down to the level of their individual requirements, which gives rise to product differentiation and their permanent innovation.

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Globalization of the market increases competition, so that it is of high importance to launch quickly various quality products. The demands which modern manufacturing meets can best be seen in an analysis of changes in companies, performed between 1990 and 2000. The time of product delivery was reduced by 60%, demands regarding product quality and functionality were increased by 50%, with a parallel increase of competition in the market (by cca. 50%), which in some cases radically reduced product cost. Within this period, the lifetime of products was reduced by about 20%.

Increased demands regarding product quality, having to do primarily with its most important features, render the development and launching of successful products very difficult. As a consequence, development of high-quality complex products is performed within a short period of time, and they are launched into a highly competitive market.

2. DIGITAL FACTORY

The representation of products and processes in integrated models is not today's main idea. As the concept of computer-integrated manufacturing (CIM) failed, isolated applications for different tasks in production management emerged, such as production planning and control (PPC) systems. Nowadays major enterprises try to revive the vision of integrated product and process modeling, supported by powerful information technology, especially in the automotive and electronics industry. These attempts are summarized by the term of the digital factory (fig.1).

In contrast to the CIM concept the idea of the digital factory consists of developing methods, models and tools to allow access to existing enterprise data via standardized interfaces.

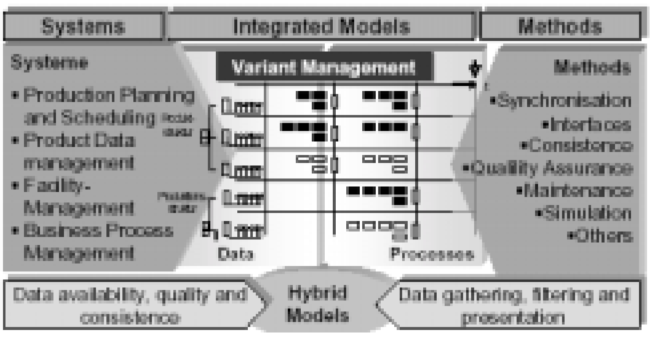


Fig. 1. The Vision of the Digital Factory.

The digital factory integrates the generation, storage and delivery of all relevant product and process data across the entire life cycle - from early planning production. A digital factory is much more than just a virtual 3D factory tour it brings together product/process simulation with product data management and organization/workflow management. Mastering those techniques is vital and ensures competitive advantage.

Today, the parameters for producing companies are determined by ever shorter innovation cycles which results in shorter product life cycles and an increased diversity of variants. This calls for a reduced time-to-market and places higher demands on the quality of production planning and the ramp up of mass production. The rapid development in information and communication technologies offers new possibilities to meet these challenges. A variety of software tools is available to support individual tasks from product engineering and production planning to final manufacturing and operation. To satisfy the vision of a Digital Factory which is primarily pushed by the automotive industry, good isolated applications alone are not sufficient. For product development, detail planning and the operation of the manufacturing facilities, the required tools (e.g. office software for spreadsheets or project planning, simulation software, check lists) are mostly available next to sophisticated methods (e.g. DFA - design for assembly, DFM - design for manufacturing, value assessment, manufacturing assessment). It is, however, very rare that they are integrated in a universal system of design planning processes. Systematic DP aided procedures are lacking mainly in the sector of traditional manufacturing planning.

3. PRODUCT DEVELOPMENT USING FEATURE-BASED DESIGN

The design process describes a product in detail, from the initial idea to gaining grounds for its manufacturing. To meet all demands, changes in design are frequently required. E.g. results of FEM or BEM calculations may require change to the object of design. Such changes can be supported by applying feature-based design, where geometry is modelled through changeable parameters.

It is in the blueprint phase, when the geometry has not yet been worked out in detail, that translation of functional dependences into geometrical measures is performed. This is why contours and surface elements are defined through changeable parameters, and are interconnected by means of a number of relations.

Procedures of design, i.e. modelling, are most frequently based on composing geometrical primitives. Such an approach frequently provides only a sketchy account of the structure. It is often the case that the designer needs to think about the product's function and to predict its manufacturing procedures. Upconstruction and extending of geometrical primitives by structural and technological forms is known as feature-based design, which enables more flexible work on product development.

Features help computer-based elaboration of the designing task. The information which they contain is used in all phases of product development, so that they represent the basis for a methodological approach to product development. A feature consists of the semantic and the geometrical part. A f*orm-feature* represents a set of geometrical features. Such a geometrical object can be composed of a group of features relating to contours, surfaces, volumes, or parts, combined according to demands. This can be examplified by the shaft-wheel centre constraint, where there is an adequate combination of grooves and openings. These objects contain the requred geometrical information. As opposed to this, *semantics* contains non-geometrical information, e.g. data having to do with the structure or technological data. Feature sematic information can be described through three types of attribute:

- Static, technological attributes, such as e.g. tolerances of shape and position, machining attachments,
- Parameters for corresponding geometrical values, such as e.g. length of openings, standard screw diameter, and,

- Functional and technological boundary conditions, such as e.g. rules information about the complete feature structure of parts or assemblies.

In this way, a feature can contain semantic information having to do with shape, which also provides a description of the application's purpose. Distinction should be made between features relating to structure, manufacturing, or quality. The designer has the option to work with structural features, whose informational content also includes the following processes, e.g. those having to do with NC-programming.

In contrast with conventional design technology, which frequently deals solely with geometrical parameters, here the designer also has semantic contents of the design object at his disposal. At any moment, he can re-define or change the structure, e.g. if the object's manufacturing procedure changes, which affects e.g. the quality of surfaces. In this case, a special feature-library is avaliable; the user can access it at all times.

With the introduction of the feature as a semantic object in the system of product development, information surpassing the product's geometrical description can be processed. A feature's informational contents are oriented towards semantic parameters, which are of high importance to the user (Fig. 2).

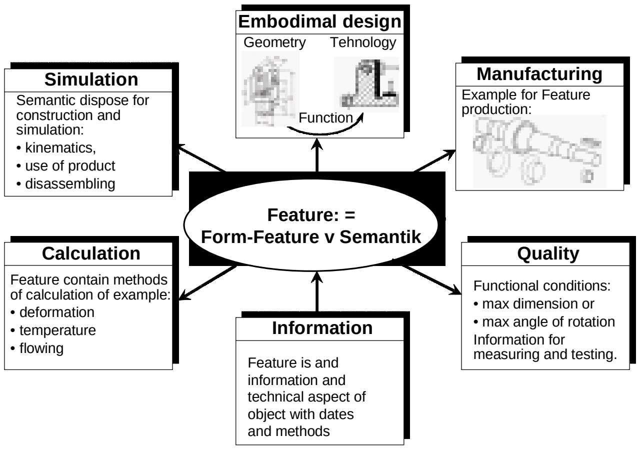


Fig. 2. User aspect of a feature

According to the way in which they are obtained, feature-based models can be divided in three groups:

- Interactive feature definition,
- Automatic feature recognition
- Design by features.

4. Design by Features

Design by features implements features in the designing process, where the product's model itself contains geometrical, topological, and semantic information (Fig. 3). Apart from determining the geometry and the topology, flexible structural models also give the designer more freedom regarding the shaping of the structure. Through feature-related semantics, information, regulations and functional dependencies can be processed and stored by a computer, so that they can be used in later develoment of the system.

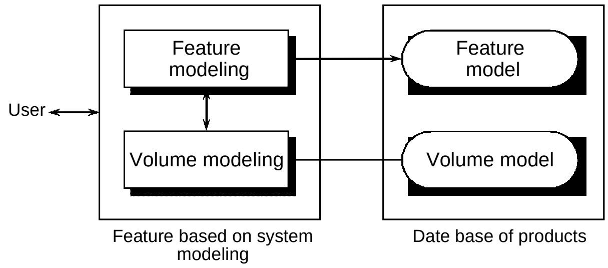


Fig. 3. Design with feature

Design by features consists of three parts:

- design, supported by a pre-defined, programmed feature,
- design with an implicit feature, and,
- design through the use of feature, memorized explicitly in the model and implicitly in the manufacturing procedure.

5. DESIGN BY COMBINING TECHNICAL FEATURES

The technique of model design by combining technical features is to a large extent adapted to the engineer's logic. Within this technique, structural or technological features modeled through blueprints or ready-made are added to a usually simple base feature (Fig. 3). Apart from definition of geometry and constraints, description of features also contains definition of the behavior of geometry through rules and attributes. They represent some of the structural and technological geometrical shapes which are most frequently met in practice. The design shapes have positive volume and are obtained by some of the described techniques: on the basis of 2D contours or by combining

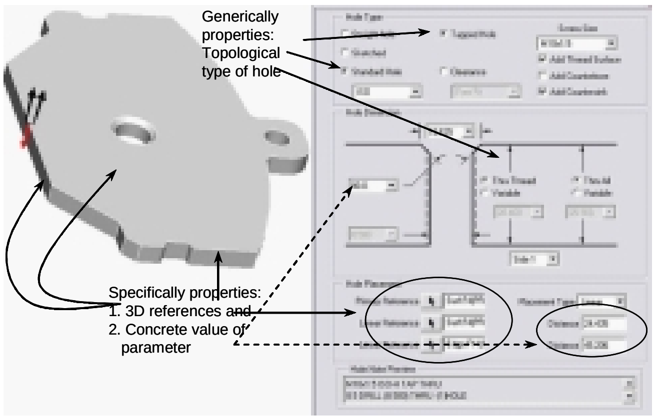
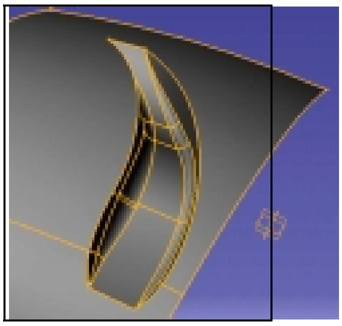


Fig. 4 Technical element hole with his properties

primitives, whereas technological shapes have negative volume; these are openings, rounded and chamfered edges, grooves, ribs, etc. Dimensional parameters of the features themselves and dimensional parameters of their position in relation to the 3D model are changeable.

From the standpoint of the engineer's logic, what is of special importance is the fact that features have certain 'intelligence' which enables them to maintain their interrelationships under change. In designing programs, it is usually also possible to define own, **user-defined features**, the so-called. **UDF** ***(User Defined Features)***. A UDF could be e.g. a hole with a thread or a complex groove. Once created, a UDF can be used in further work as a unique feature. Figure 5 shows the generic UDF of the lateral groove at the tire tread pattern with constraints and referenced technology.



NC Sequence Parameters

TOOL_ID	T0008
NCL_FILE	-
PRE_MACHINING_FILE	-
POST_MACHINING_FILE	-
ROUGH_OPTION	ROUGH_ONLY
SCAN_TYPE	**CONSTANT_LOAD**
CUT_TYPE	CLIMB
STEPOVER_ADJUST	YES
RETRACT_OPTION	SMART
RETRACT_TRANSITION	
CORNER_TRANSITION	
TRIM_TO_WORKPIECE	NO
CUT_DIRECTION	STANDARD
CORNER_FINISH_TYPE	FILLET ...

Fig. 5. The topology of lateral groove at tire tread and referenced manuacturing information

By using Feature Based Design together with library forms and UDF, a product model can be created and then, through various CA techniques, analyzed so that it becomes the virtual prototype.

6. Manufacturability analysis by using feature-based design

Manufacturability analysis has become an important part of modern CAD/CAPP/CAM systems. Unintentional errors, such as omission of rounding-off of the edges or unreasonably high demands with respect to the quality of certain surfaces, which would otherwise emerge from the design phase, can be evaded by the implementation of tools of design for manufacturing.

The most frequent problems considered in relation with virtual prototype manufacturability analysis comprise the following three analyses:

1. Determining whether a virtual prototype (shape, dimensions, tolerances, surface quality) is manufacturable or not,
2. if a virtual prototype is manufacturable, determining the degree of manufacturability, and,
3. if a virtual prototype is not manufacturable, recognizing the properties which create problems during manufacture.

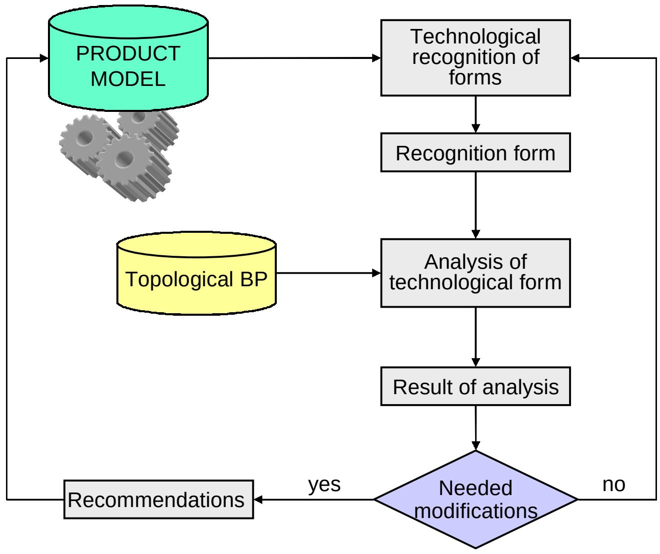


Fig .6. Analysis of technologically in product development

In manufacturability analysis, there are three primary characteristics according to which systems are classified; these are: approach to consideration of manufacturability, measures for determining the degree of manufacturability, and the degree of automation.

Approaches to the analysis of structure manufacturability can be roughly classified in the following way: first comes the **direct approach**, or the approach based on the use of rules which directly inspect the geometrical model, i.e. features. This is convenient with parts having one-step machining, such as casting, forging, etc. The second is the **indirect approach**, based on the use of the manufacturing procedure. In the first step, the manufacturing procedure is defined, which is then analyzed and reduced so as to cut the expenses. If there are several alternatives, the most optimal one is selected. These systems have wider appliance.

Measures for determining the degree of manufacturability are as follows. **Binary assessment**, i.e. whether something can be done or not. **Qualitative assessment** of a virtual prototype within a manufacturing procedure, assesses the degree of manufacturability as low, average, good, highly manufacturable. **Abstract-qualitative** assessment of the degree of manufacturability is performed by attributing numerical values to a procedure from a selected range of the numerical scale. As a measure of manufacturability, there also appear **time** and **expenses** required for the manufacture of a certain type of construction, which can be combined into a total of manufacturability.

The degree of automation of the system for manufacturability analysis is expressed in the way in which the designer interacts with the system. It is measured by the quantity and type of the designer's interactions with the system, and by the quantity and type of feedback from the system.

Qualitative technological analyses usually make use of features, together with the technological database. They usually consider the following questions:

- Which machining processes are required for the manufacture of a designed prototype?
- Are all the required manufacturing resources (material, machines, tools, fixtures etc.) available, and on which conditions?
- Is it physically possible to apply all the required machining processes?
- Are all the determined technological parameters in accordance with the acquired and established manufacturing experiences?

Qualitative analyses contain rules based on technological knowledge and experience. The most frequently, production rules of IF-THEN type are used. For example, the following rule determines the manufacturability of an opening in relation to the selection of tools.

IF *feature R is an opening with diameter D*
and the depth of opening L is bigger than the diameter and the quality of the machined surface is smaller than N7
and there is tolerance T1 of the diameter
and there is no tool in the base with that diameter D and which guarantees tolerance T1

THEN *the opening is not manufacturable*

7. Features in CAM applications – technological features

For applications dealing with designing the manufacturing process, features must be defined in a form which enables planning and performing various types of manufacturing (technological) processes on product model.

A technological feature is usually defined as a set of related geometrical elements, which as a whole correspond to the concrete technological process required for their manufacturing, or which can be used in the process of determining which technological process is required for their manufacturing. The connection between features and technological information is usually realized through the *model of the technological process*. In typical cases of machining, models of technological processes can be organized as a set of elementary machining processes such as milling, drilling, turning etc. Models of the technological process are expressed within the informational model of *manufacturing resources,* which can be used to conduct machining processes (machine tools, tools, clamping devices, accessory materials). *Technological process parameters* have to do with the possibilities of these resources, whereas information about the so-called *remaining* attributes determine the selection of a concrete process (cost, time etc.).

To implement the connection between technical and technological features, technological features are represented by sets of possible models of technological processes which can be applied to manufacture a technical feature. For example, if we need to manufacture a feature with *prismatic machining volume* (the first figure in Table 1), this feature is connected with models of alternative applicable technological milling methods. In this case, the term 'method' is used to mark NC sequence of the process for manufacturing the feature. As shown in Table 1 (Figures 1, 2 i 3), methods can contain knowledge about planning the technological procedure, such as e.g. costs (time).

Table 1. Technical elements in CAM aplication

<table>
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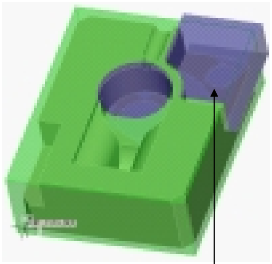
<td>
technological technical element:
volume MILL_VOL1 number 133

Fig.1</td>
<td>|**|
| **Manufacturing Related Information** |
|**|
Feature ID : 133
Feature Number : 10
Operation Name : OP020
Workcell Name : DMU50E01
Workcell Type : Mill
Sequence Type : Volume Milling
Cut Mtn Feat : 139
Axis Type : 3 Axis
Fixture Setup : FSETP1
Mill Volume : MILL_VOL1
Tool ID : T0008
Cutting time : 13.2963 min
Retract Plane : ADTM4
START POINT : N/A
END POINT : N/A
NCL File Name : SEQ0001
MACH CSYS : PRT_CSYS_DEF (Reference Part)
NCSEQ CSYS : PRT_CSYS_DEF (Reference Part)
Tool Travel Envelope:
X_MIN : 23
X_MAX : 35.6544
Y_MIN : 28
Y_MAX : 45.4989
Z_MIN : 7.5
Z_MAX : 21.5</td>
</tr>
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<table>
<tr>
<td>
method of gnawing
With constant load on tool

Fig. 2</td>
<td>**FEATURE NUMBER 10**
NC SEQUENCE NUMBER 1
INTERNAL FEATURE ID 133
FEATURE WAS CREATED IN ASSEMBLY EOS_MFG1
PARENTS = 1(#1) 12(#5) 129(#7) 130(#8) 136(#9)
CHILDREN = 139(#11) 138(#12)
TYPE = MILLING
|------------------------------------|
| **NC Sequence Parameters**|
|------------------------------------|
TOOL_ID T0008
NCL_FILE -
PRE_MACHINING_FILE -
POST_MACHINING_FILE -
ROUGH_OPTION ROUGH_ONLY
SCAN_TYPE CONSTANT_LOAD
CUT_TYPE CLIMB
STEPOVER_ADJUST YES
RETRACT_OPTION SMART
RETRACT_TRANSITION CORNER_TRANSITION
TRIM_TO_WORKPIECE NO
CUT_DIRECTION STANDARD
CORNER_FINISH_TYPE FILLET
CUSTOMIZE_AUTO_RETRACT YES
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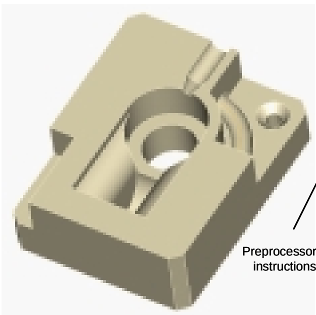
<td>
Preprocessor instructions

Fig 3</td>
<td>...
|------------------------------------|
| **CL data file** |
|------------------------------------|
$$-> MFGNO / EOS_MFG1
PARTNO / EOS_MFG1
$$-> FEATNO / 133
MACHIN / UNCX01, 1
$$-> CUTCOM_GEOMETRY_TYPE / OUTPUT_ON_CENTER
UNITS / MM
LOADTL / 4
$$-> CUTTER / 4.000000
$$-> CSYS / 1.0000000000, 0.0000000000, 0.0000000000, 0.0000000000, $
0.0000000000, 1.0000000000, 0.0000000000, 0.0000000000, $
0.0000000000, 0.0000000000, 1.0000000000, 0.0000000000
SPINDL / RPM, 7000.000000, CLW
RAPID
FROM / 30.3373635520, 39.5163459705, 21.5000000000
$$-> SETSTART / 30.3373635520, 39.5163459705, 21.5000000000
RAPID
GOTO / 30.3373635520, 39.5163459705, 20.0000000000
FEDRAT / 215.000000, MMPM
GOTO / 30.3373635520, 39.5163459705, 18.0000000000</td>
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8. Conclusion

The following conclusions can be made on the basis of this discussion:

- A consequence of globalization of the market is manifold increase in competition. In order for companies to survive in the market under such conditions, reduction of the time required for product development, improvement of product quality, and reduction of the product's price are imperatives. The solution lies in finding and applying a global strategy of product development.
- One of the global development strategies, which has yielded good results in practice, is integral product development. The efficiency of applying this strategy is primarily based on simultaneous management of phases in the process of product development, application of an integral organization model, as well as on application of an all-encompassing and forced computer support of all activities in product development.
- Modern product development requires making manufacturing decisions as early as in the phase of product design. A successful solution of these problems is achieved by using features during product design and analysis, bearing in mind that, by their definition, they can be technologically recognized and analyzed. In the intelligent CAD system concept, design for manufacturing is implemented by applying automated manufacturability analyses on the basis of technological knowledge incorporated in the system. The presented methodology enables realization of simultaneous design and development of a product within integrated CAD/CAPP/ CAM systems.

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FEATURE MODELI U VIRTUELNOM RAZVOJU PROIZVODA

Miodrag Manić, Vojislav Miltenović, Miloš Stojković

Razvoj novih proizvoda zahteva korišćenje modernih alata za konstruisanje koji u velikoj meri smanjuju mogućnost greške i broj iterecija već u ranoj fazi procesa razvoja. Koncept simultanog razvoja proizvoda i tehnologije, odnosno, feature- zasnovano konstruisanje, omogućuje izradu modela prozvoda pogodnih za različite tehničke aplikacije. U radu su razmatrane mogućnosti koje pruža feature- zasnovano konstruisanje pri razvoju virtualnog proizvoda u digitalnom okruženju. Posebno je naglašena analiza proizvoda sa aspekta proizvodnje a u cilju svrsishodne redukcije troškova proizvodnje.