MODEL OF MODERN TECHNOLOGICAL PRODUCTION PREPARATION

Dejan LUKIĆ[1], Velimir TODIĆ [2], Mijodrag MILOŠEVIĆ[3]

Abstract *Production system will work well, achieve growth and development if it satisfies requirements of the market, or if its products are functional, economical, have high quality and good design, if they are environmentally suitable, competitive and market acceptable products. Product development consists of two basic steps, or functions. The first step is product design based on functional, aesthetic and other requirements. The second step relates to the production process planning, whose activities are implemented within the technological production preparation.Technological production preparation tasks are solved in many different interrelated phases, starting from the global production planning and preliminary process planning, through the detailed process planning and to the generation of NC programs and necessary technological documentation. This paper will show a model of modern technological production preparation with appropriate activities, or phased in accordance with the requirements of modern business and engineering capabilities of new techniques and information technology.*

Key words: *technological production preparation, process planning, CAPP, CAM, CAPP-CAx.*

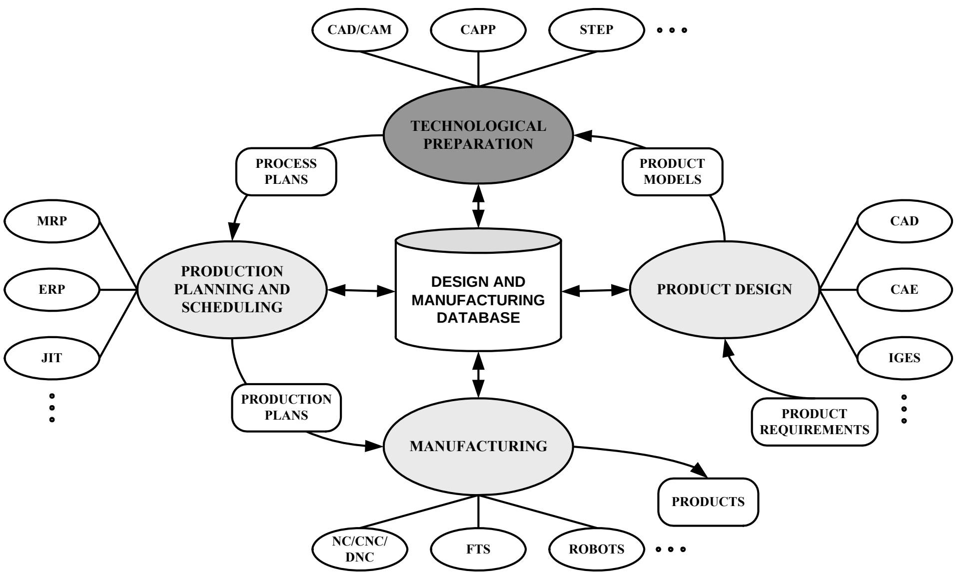

Fig. 1. Production preparation phase in the CIM environment.

1. INTRODUCTION

Dynamic development of market oriented production sets high and complex requirements. This primarily relates to product quality, price, variety, complexity and delivery deadlines. These requirements have to be addressed in the production preparation phase.

Production preparation encompasses not only technical-technological documentation preparation, but it also follows product's life cycle, linking all activities from product idea and product design, to production planning and manufacturing (Fig. 1) [1, 2].

There are two phases of production preparation: technical and operational preparation. Technical preparation consists of two main functions. The first relates to product design and the second one relates to the production (manufacturing) process planning, also known as technological production preparation or just technological preparation [3]. Workload and complexity of technological preparation, as well as its importance and reflection to the product quality, required systematical approach in its organization accompanied with modern engineering, production and information technologies.

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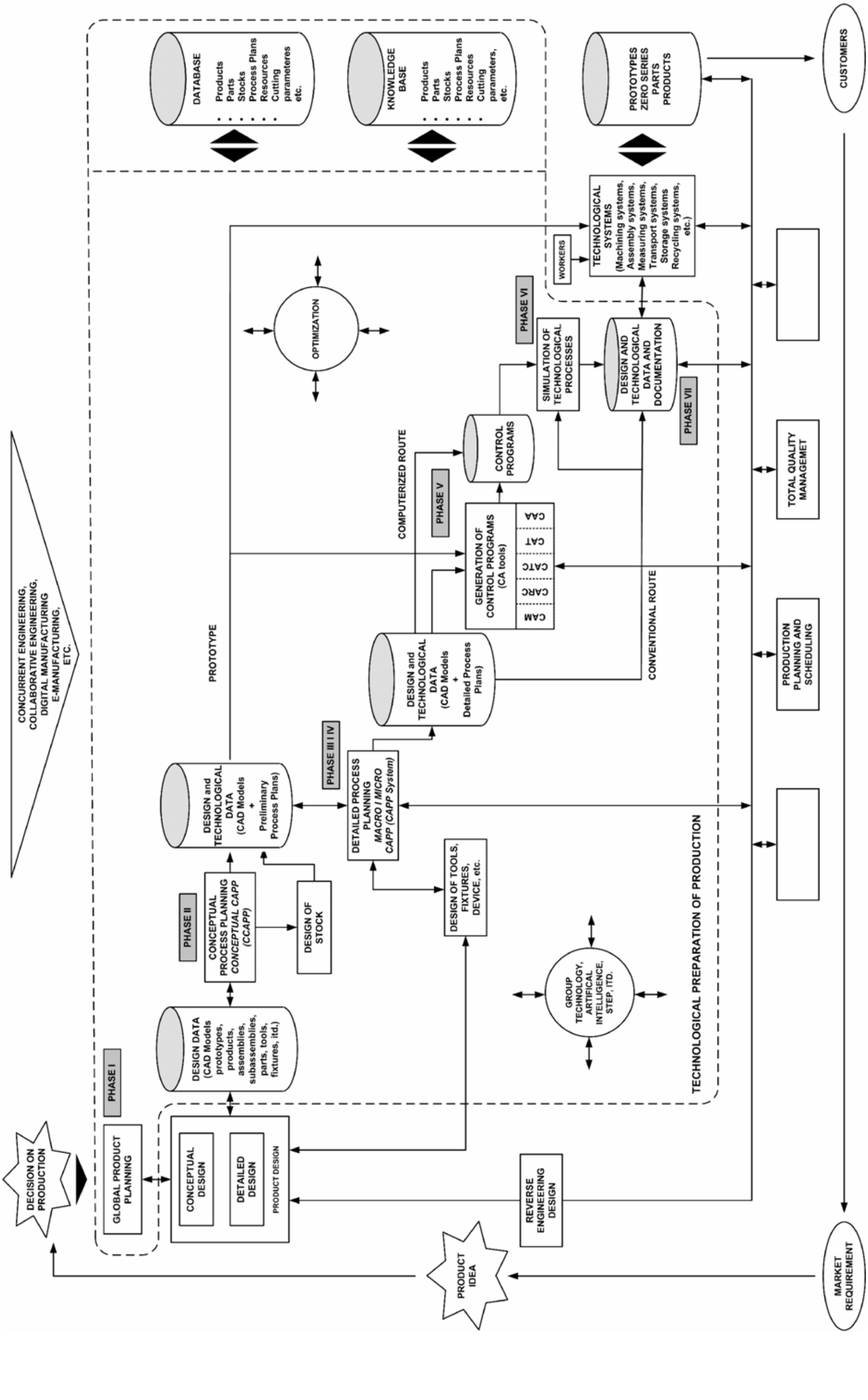

Fig. 2. General model of technological production preparation.

Modern manufacturing environment does not necessarily recognize strictly defined action areas. Instead, it can be said that higher and higher levels of product development integration are done. These modern engineering techniques are being used: concurrent engineering, collaborative engineering, digital manufacturing, e-manufacturing, etc. [4, 5].

The main goal of this paper is to explain general model of modern technological preparation, as well as to define basic tasks and model's phase targets. These will indicate importance and role of the technological preparation in the product's life cycle and in the manufacturing environment of actual production systems.

2. TECHNOLOGICAL PRODUCTION PREPARATION - GENERAL MODEL

A lot of literature, various developed models, CAPP, CAD/CAPP/CAM and other systems were analyzed, with the technological production preparation general model development in mind.

Suggested model of technological preparation of production with basic phases and related activities is presented in Fig. 2.

Suggested model comprises the following phases:

- Phase I – Global production planning;
- Phase II – Conceptual process planning (Conceptual CAPP);
- Phase III and IV – Detailed process planning (Macro and Micro CAPP);
- Phase V – Generation of control programs/information;
- Phase VI – Production processes simulation;
- Phase VII – Production documentation and data verification.

Technological production preparation activities, including manufacturing, assembling, measuring, transport, storing, recycling are integrated in the presented model. They are realized through various conventional and computerized manufacturing systems. Also, production processes for the product or the prototype, series zero, sets, subsets and assembly parts are integrated in the model.

3. TECHNOLOGICAL PREPARATION - MODEL BASIC PHASES

Phase I – Global production planning

During product's life cycle, the first period is marked with research activities as well as decision-making process linked with product development and production. Good quality data about production potentials and effects are needed in the early stage of product development. This phase contains global production process potentials identification for a given product technical specifications. It also represents support for the process of decision making at the beginning of process planning. This is not the case with the products that are ordered by specific technical documentation, since there is no design stage in that case.

Phase II–Conceptual processes planning

This phase is based on the input data, such as ease of product manufacturing (manufacturability), stock part selection and definition, production processes options and preliminary selection of the best production process for each operation, machine selection, production times and costs estimate. The output is preliminary or conceptual process plan. Program systems used for this phase are called CAPP systems (CCAPP). Due to their complexity and important input of the designer, these software packages have been scarcely used. Selection of the technology type has to be made in this phase i.e. whether individual, typical or group technology will be used. In Fig. 3, link between conceptual product design and conceptual process planning is shown. Basic phases, integrated components, basic activities of product detailed design and detailed process planning are also shown in the same figure.

Linking product design, process planning and other activities associated with the product's life cycle requires certain conditions such as product's functionality, productability, easy assembly, disassembly, recyclibility, and some other "X" specific requirements. Based on that, "Design for X - DfX" can be defined. It covers wide spectar of specific approaches like DfM (Design for Manufacturing), DfA (Design for Assembly), DfQ (Design for Quality), DfE (Design for Environment), DfR (Design for Recycling) and others.

Phases III and IV– Detailed process planning

In the technological preparation the central place is occupied by systems of process planning. They are often seen as a "bridge" between product design (CAD) and their manufacturing (CAM). Based on product's detailed design and preliminary process plan, final selection of process plan is done in this phase.

Phase III relates to macro and phase IV relates to micro definition of manufacturing process planning. Contents of manufacturing process, operations, production resources, production parameters and regimes, times and costs are defined in these phases. The borderline between macro and micro planning cannot be precisely defined. Program systems used for this phase are CAPP systems. Depending on the selected software and other influential factors there are three basic types of CAPP systems: variant, generative and vario-generative (hybrid) CAPP systems [1, 2, 3, 5, and 7].

Due to variety of products and non existence of universal efficient software for design and planning of large number of activities in processes planning, specialized CAPP systems are often develop and used, such as [8, 20]. Consequently, only a few CAPP systems are utilized, and manufacturing process definition is quite often a bottleneck in the integrated manufacturing process. As an illustration, CIM application in small and middle-sized enterprises is given in Fig. 4, according to [9].

Basic characteristics that define use of CAPP systems and its ranking [10] are:

- Design approach (variant, generative and hybrid).
- Part type (rotational, prizmatic, etc.).
- Production operations (turning, milling etc.).
- Design functions-modules (machines selection, fixtures and tools selection, etc.).
- Level of automation (interactive, partly automated, automated).
- Hardware (Workstation, PC, etc.).
- Programming technique (artificial intelligence, etc.).

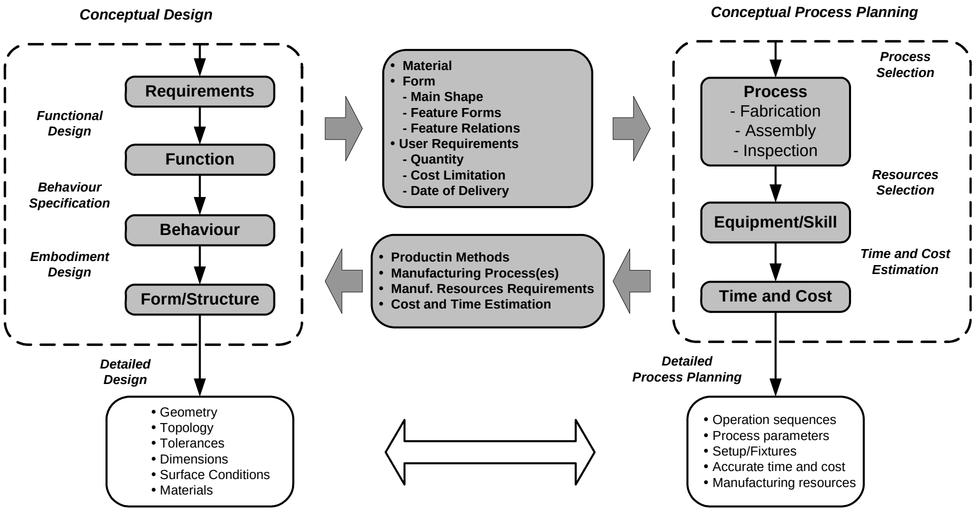

Fig. 3. Integrated conceptual product design and conceptual process planning [6].

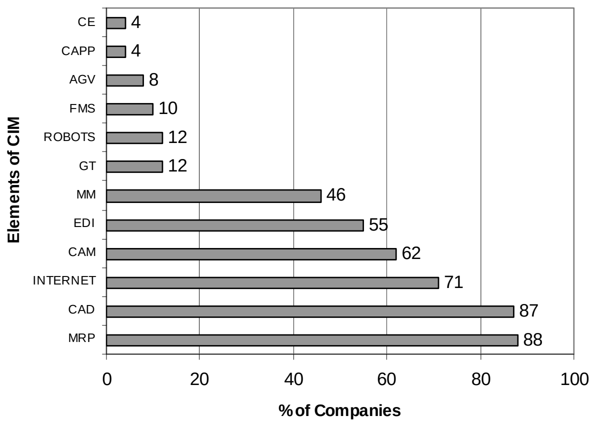

Fig. 4. CIM elements application in small and middle-size enterprises [9].

Phase V – Generation of control prgrams/information

This phase of technological preparation relates to processes, generation of control information/programs for NC machines and other related systems. Many different software packages are used in this phase, such as CAM systems (in the short sense) for generation of NC programmes, CARC systems for robots, CATC systems for storage and transport systems, CAT systems for measuring and control systems, CAA for assembling systems. These systems allow simulations to some degree. Some authors, like [11] call these systems CAPE – systems for computer aided production engineering.

Phase VI – Production process simulation

This is the phase in which modeling, simulation and optimization of manufacturing processes are taking place. These activities help in achieving good effects in production. Basic information needed for the realization of this phase are the output data from phases II, III and IV – schedule and type of operations, machines, production times, quantities etc. Simulating models are created based upon this information and some other, related data. Models are experimental and they work in real time providing information of the best process option. Simulation of manufacturing and production processes can be done by using some of the programming languages of the general use (C, C++, etc.) or by using commercial simulation software packages (Arena, Flexsim, Tecnomatix, etc.) [12].

Phase VII – Final documentation and data check

This function covers final project data check and correction, as well as the project related documentation and production systems. Output data from this phase are represented with the data used for production planning and scheduling, and also as a base for good quality and standardized production process.

Beside above-mentioned phases, product related databases and knowledge databases are also needed. Without them, it would be hard if not impossible to work on production preparation. Databases provide data availability during product's life cycle. Knowledge databases cover wide range of knowledge areas. Some of these areas cover manufacturing, geometrical or functional characteristics of the product, and some are related to process control knowledge. As knowledge database interface artificial intelligence, expert systems, neuron networks, fuzzy logic are often used.

4. INTEGRATION OF TECHNOLOGICAL PREPARATION ACTIVITIES

The main goal of production technology activities is integration off all segments of production and realization of computer integrated manufacturing (CIM). CAPP systems have a key role in the integration of product design and manufacturing. They represent a "bridge" between CAD and CAM systems.

The main output data from CAD system is a product model and at the same time it is input information for manufacturing process planning. CAD and CAPP systems integration require known communication language. Communication between different CAD systems is usually done by the use of existing languages or data translators, such as IGES, SET, VDA-FS, etc. Most of these standards offer format with data about product geometry information that are not sufficient for production process planning. But if a CAD product model is represented by manufacturing features, that express product's characteristics on the highest possible level, that is done to provide not just geometric data, but also manufacturing data, then these features can become means of integration of CAD, CAPP and CAM systems.

Data transfer between CAD and CAPP systems is one of the most important activities of production process automation. Three basic approaches of CAD and CAPP systems integration can be discrabed [13]:

- A drawing is first analyzed by a designer, who inputs manufacturing features by using special language (usually symbolic language).
- A system for determination and selection manufacturing features from CAD models is developed.
- CAD system based on the features is developed. Typical shapes from featueres library are used for CAD system development. Each manufacturing feature relates to a specific process plan (on a micro level). It can be said that that manufacturing process planning is actually composition of typical manufacturing sequences.

4.1 Features as the integration elements

Model of features must contain sufficient amount of information needed for the manufacturing process planning. It can be said that there are two types of features that are usually used in the process planning:

- Geometric (design) feature or same feature.
- Manufacturing (machining) feature.

Features used for product design are often quite different from the manufacturing features used for manufacturing process planning. Furthermore, this results with the different approach in the product design and manufacturing process planning. An illustration of this different approach is given in Fig. 5.

It can be seen that product designer during his work uses ribs as typical shapes because they are functional, while production process planner looks at the stock part and defines both a rib and a slot equally important from the production process perspective. A rib and a slot are represented by using manufacturing features.

Above mentioned different approach consequently requires geometric information translation to manufacturing information. This is called typical manufacturing features recognition (manufacturing recognition) [15].

Manufacturing features contain both geometric and manufacturing process data. Production processes are tailored so that machining of manufacturing features is used. Machining of manufacturing features is defined by operation sequences, cutting tools, production parameters etc.

Manufacturing features can be grouped in many different ways, but the most common way is to group them by features' representation:

- Surface feature for Boundary Representation (B-rep);
- Volumetric feature for Constructive Solid Geometry (CSG).

A product designed by the use of features for which surface and volumetric manufacturing features were defined is shown in Fig. 6. Manufacturing features are commonly defined as profile elements along certain path.

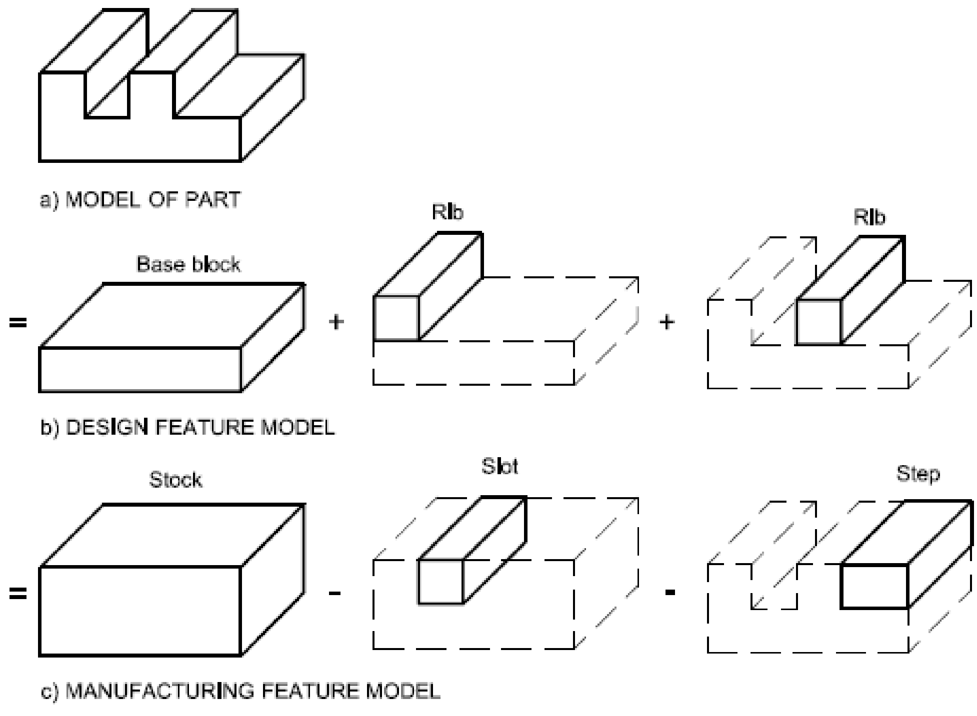

Fig. 5. Different approach in product design and manufacturing process planning [14].

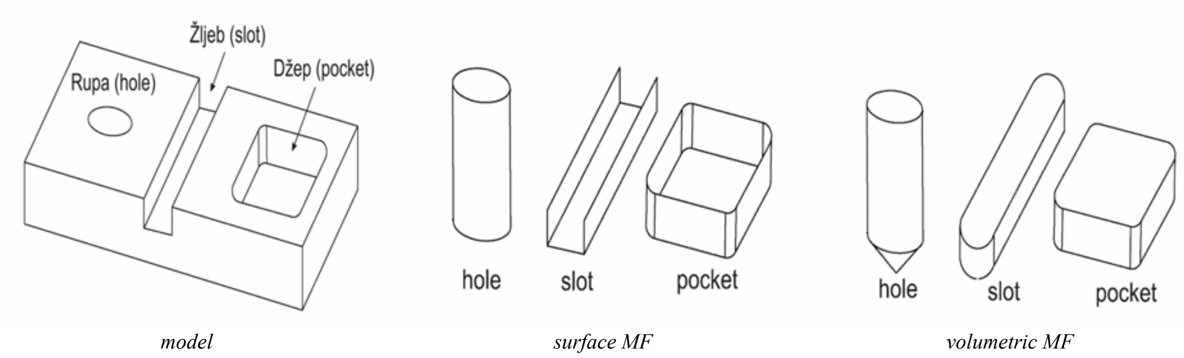

Fig. 6. Surface and volumetric manufacturing features of a product [14].

Model of a manufacturing feature, as a basic input data for manufacturing process planning, can be obtained in many different ways, based on the design approach [14]:

- Design by feauture – DBF;
- Automated feature recognition – AFR, and
- Interactive form feature definition.

4.2. STEP role in integration

Complete integration of technological production preparation activities and other production related □ctiveties requires easy product data sharing and exchange. With that goal in mind, numerous standards for data exchange were developed. One of the most important is ISO 10303 (STEP) standards, that was initially developed as a data translator and later as an international standard for data sharing and exchange during production process and product life cycle [16, 17].

Conventional integration of CAD/CAPP/CAM systems is shown in Fig. 7. This conventional integration is not based on STEP. It is based on development of specific interface that help data exchange between various Cax systems.

Simplified structure of STEP based on the integration of CAD/CAPP/CAM systems is shown in Fig. 8. SDAI interface for standardized access to STEP databases, as a part of this system, is used for data exchange between specificic AP (Application protocols) and databases. Structure of the object is described by EXPRESS or other languages.

There are many different concepts of the design and production activities integration that use STEP standard. We will focus on the initial concept according to [17]. This concept shows production process supported by STEP in certain steps, i.e. functions done in some of the production process phases and used application protocols (see Fig. 9). These standards, when grouped, form a group of STEP standards for design and production SMS (STEP Manufacturing Suite).

STEP standard is supposed to replace existing ISO-6983 standard for CNC machines control with the new ISO-14649 (STEP-NC) standard, that provides important advantages, such as object-oriented data, bi-directional information flow between design and production, no need for postprocessor, possibility of Web based manufacturing (XML technology), etc.

More intensive use of internet based technologies is expected in the future, through use of global databases as support for concurrent and collaborative engineering, as well as in development of digital factory and e-manufacturing [18].

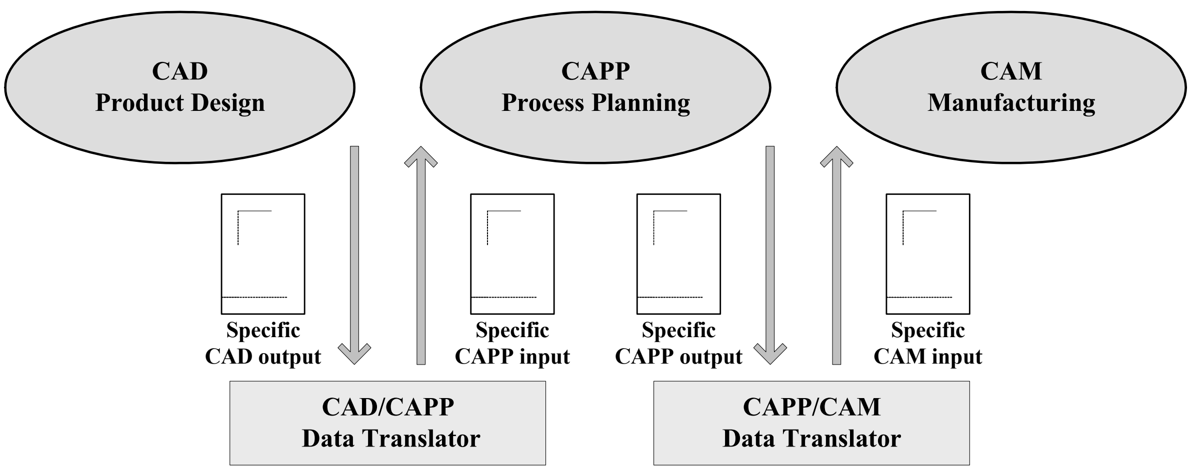

Fig. 7. Conventional CAD/CAPP/CAM integration [15].

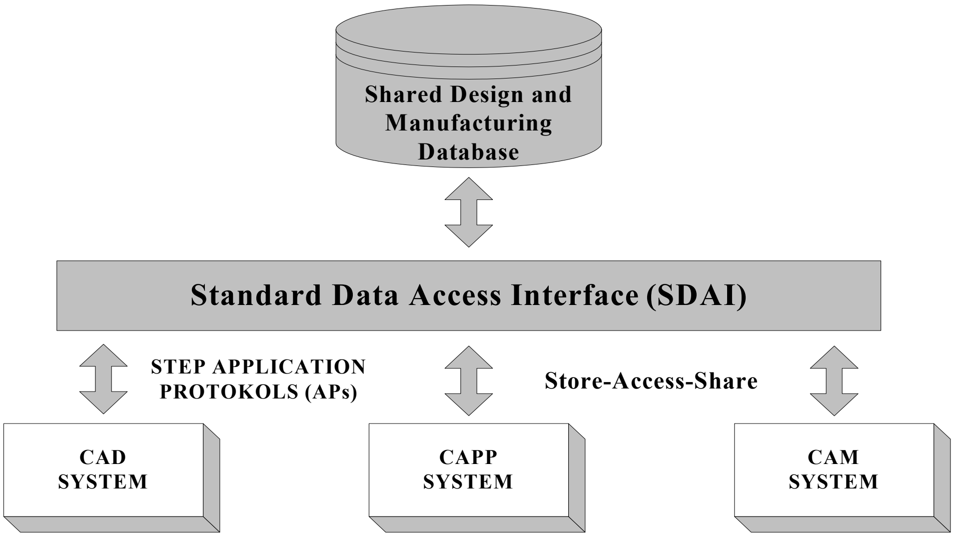

Fig. 8. STEP based structure of CAD/CAPP/CAM integration [15].

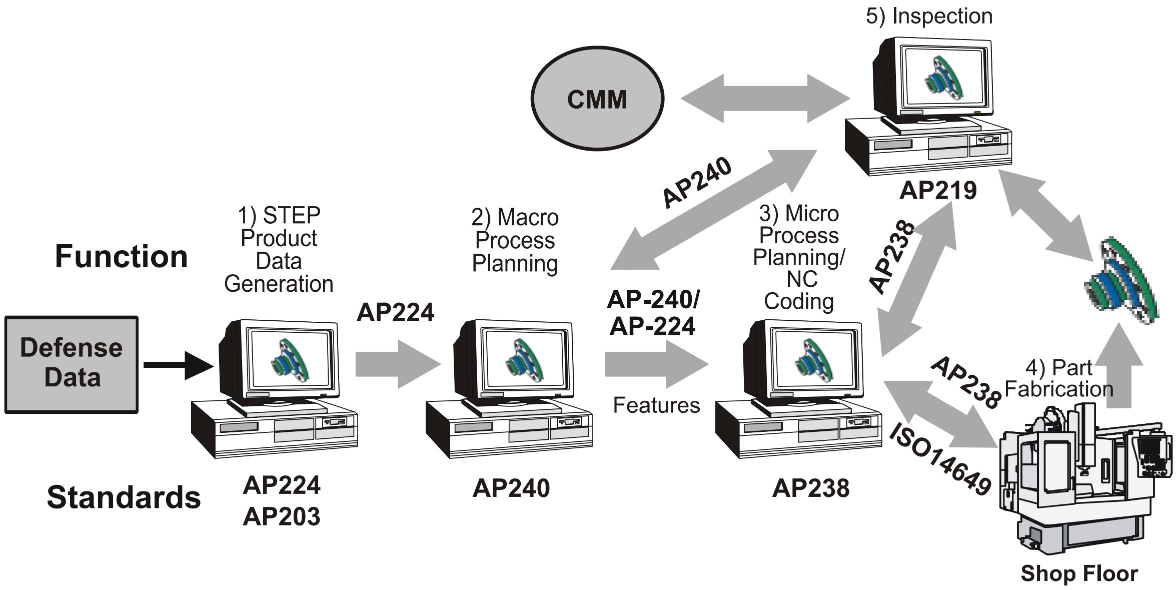

Fig. 9. STEP standard application in the design and production activities integration [17].

5. CONCLUSIONS

Technological preparation represents a link between product's design and production planning and scheduling. Regardless of the production system organization type technological preparation has to be based on the knowledge, application of modern engineering approaches and information technology.

The main goal of this paper related to the basic model of technological preparation setup and definition of basic tasks in the process phases. The target of the presented model was to note the meaning of technological preparation in the modern, market oriented production systems.

Basic development goals of the modern technological preparation relate to: development and application of CAPP systems, integration of CAD, CAPP, CAM systems and other CAx programme systems and applications; development and application of global manufacturing database, application of the artificial intelligence, application of the methods of group and typical manufacturing, development and application of STEP standards; simulation and visualization of manufacturing and production processes, techno-economical optimization of manufacturing processes; application of concurrent engineering concept, as well as collaborative engineering, e-manufacturing etc.

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