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Features of the Functionally-Oriented Engineering Technologies in Concurrent Environment

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Abstract

Algorithms, criteria forming of the optimal technological process structure and parameters, the advantages and disadvantages of the object-oriented and functional-oriented preproduction engineering planning are given. Implementation of cutting processes rheological simulation (Computer Aided Forming) and concurrent engineering for Product Life Management System realization are proposed.

1. Introduction

Over the last decade, the main factor of economic growth in the industrialized countries was the development and implementation of integrated knowledge-intensive industries management information systems. Integration enterprise CAD/CAE/CAPP/CAM software (best - creating hybrid systems engineering production) and the creation of interactive paperless workflow system for a more efficient exchange of engineering and technological information in a single unified STEP-format (ISO 10303 «Standard for Exchange of Product Model Data») and prototype data repository (MIL-STD-2549 «Configuration Management Data Interface») are characteristic for all the most commonly used engineering CAD with middle and upper class complexity (Pro/Engineer, Unigraphics, CATIA, Power Solutions, Solid Works; ASCON, Solid Edge, etc.) [2,3].

2. Problem statement.

All of these integer computer aided manufacturing systems (ICAM) used a classic algorithm of preproduction engineering planning. Sequentially interconnected stages of noniterative downward structural and parametric synthesis are executed in this algorithm. That is, initially based on the input data (as a result of CAD and CAE-systems: macrogeometric part's configuration, material, size-weight characteristics, precision geometric dimensions surfaces, physical-mechanical properties of the functional part's surfaces, type and organizational form of production) created of the operation-routing sequence, then determined the structure of manufacturing operations, assigned the process rates (CAPP-system) and then projected or selected equipment, tools, software designed for CNC machines (CAM system) (Fig.1(a)) [1,4,6]. This classification planning in the context of this goal can be considered as object-oriented. This technology is completely abstracted from the problems of functional (operational) the nature of the object, believing that the appointment standards of accuracy and surface quality of products - it is the prerogative of the designer. Obviously, the use of this concept is most effective in a manual preproduction engineering planning. However, copying classical algorithm for decision-making process significantly limits the potential of an integrated system of pre-production, does not allow a comprehensive implementation of PLM-system (Product Life Management) [5].

The primary purpose of the article is to describe a new concept of functionally-oriented preproduction engineering planning that is different from the traditional object-oriented engineering planning. In addition, an important feature is the establishment of new criteria optimization of structure, process parameters and algorithm of integrated CAD/CAE/CAPP/CAF/CAM system.

3. Main results of the research.

The objective conditions of a market economy in today's globalized society recognize the importance of research goal orientation, the design and manufacture of machinery for the formation of a higher quality than the competition throughout the product life cycle. As a result of gradual market saturation of the interchangeable products-analogs, effectiveness of price competition reduces but importance of non-price rates are increase (as a result of the expansion and improvement of operational and service products properties). This makes the relevance of search for new evaluation criteria and techniques of quality management of various technical systems at each stage of product's life cycle. It is structured as a fundamental basis for qualimetry cybernetic principle of functional equivalence. Thus, the introduction of PLM-system requires functional-oriented engineering planning [7]. At the stage of preproduction engineering planning into account not only the dimensional accuracy and surface roughness of machined surfaces, but also a complex system qualimetric performance. These rates make a significant impact on the provision of operational, maintenance, utilization, and other functional properties of the products according to this methodology.

Consequently, two alternative concepts can use for the integer computer aided manufacturing systems - object-oriented and functional-oriented engineering planning.

The main criterion for the formation of the optimal structure and parameters of the object-oriented process is to ensure a minimum manufacturing cost object production (product). Limitations for this optimization problem are support of the formalized quality rating (accuracy, roughness, physical and mechanical surfaces properties) and guaranteeing given production program of products manufacturing and based on technological inheritance of existing production. The main feature of functionally-oriented engineering planning is that the primary in determining the structure and parameters of technological operations is to provide a set of functional and performance properties of the product, subject to specified parameters exactly the required resource of his work as well as organizational and technical and economic limitations. In this case, the integral qualimetric index is the main criterion when deciding on the optimal structure and parameters of the engineering process. This parameter characterizes the system wear resistance, fatigue strength, corrosion resistance for the most loaded surfaces of the product. It is obtained as a result of the formation during morphogenesis of the surface layer microtopology, residual stresses and strains.

Alternative concepts for technological planning are differ not only from the criterion of choosing the optimal structure and parameters of technological processes, but also the algorithm implementation. The method of analysis is characteristic for the object-oriented engineering planning: an algorithmic search for structural prototype (unified process) for the design and technological features, its downward correction and detailed route processing products according to the input on the design. Algorithmic synthesis method is used for feature-oriented engineering planning. This is consistent upward planning optimal structure and parameters of manufacturing operations, based on the results of the predictive simulation of stress-strain and thermodynamic state rheological modeling in process of part's formation, structural and logical combination of cutting passes in the operation of forming technological route processing product as a whole.

Functionally-oriented planning methodology is based on a Concurrent Engineering System - CAPE (Concurrent Art-to-Product Environment [1]) with parametric relationships between model elements, components and software modules. Stratification digital product model and coordination functions CAPE-system can significantly reduce the cycle of a product, to improve the technical level projects to avoid inconsistencies and errors due to the relationship and controllability information at all stages of the preproduction engineering planning. That means you can implement concurrent engineering recurrent and iterative cross-correlation functional stages of pre-production: 3D product modeling (CAD-system), simulating the conditions of their future operation (CAE-system), engineering planning the structure and parameters of the technological process (CAPP-system) programming CNC (CAM-system) (Fig.1). This chain lacks a system that formalizes the relationship between technology products forming with potential and critical conditions of their future operation.

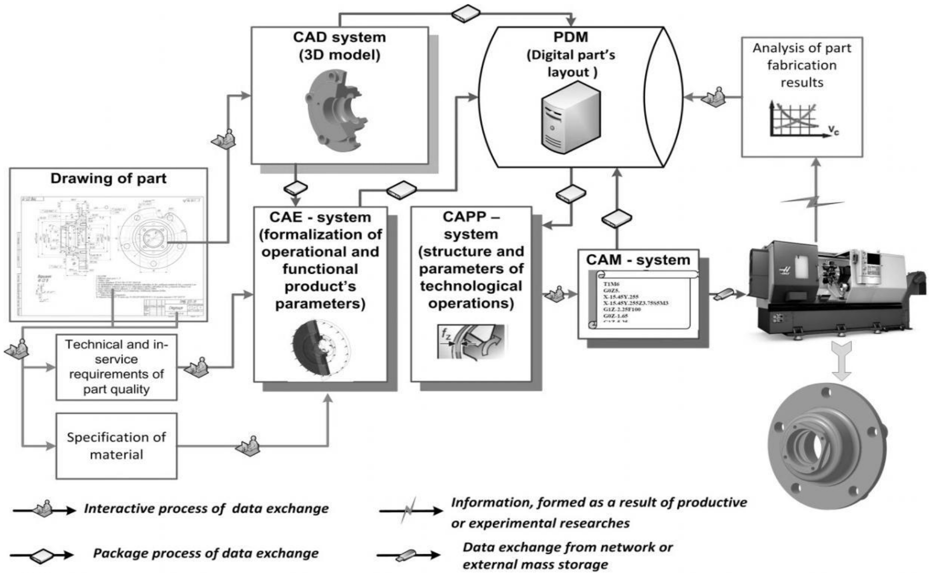

Fig.1. Scheme of the existing integrated design and technological process planning system

The use of CAF-system (Computer Aided Forming) is the main feature of the functionally-oriented technologies realization for effective PLM implementation methodology in engineering on the basis of Concurrent Engineering system (Fig.2) [5]. At the heart of this system is based on the analysis of the simulation of rheological models of cutting passes, set of functional modules and analytical applications of precision forming parameters, thermally and deformation, microgeometrical and structural phases parameters of machined surfaces. Filling repository data by improving the digital product model is already at the stage of the preproduction engineering planning rather than as a result of difficult experimental studies.

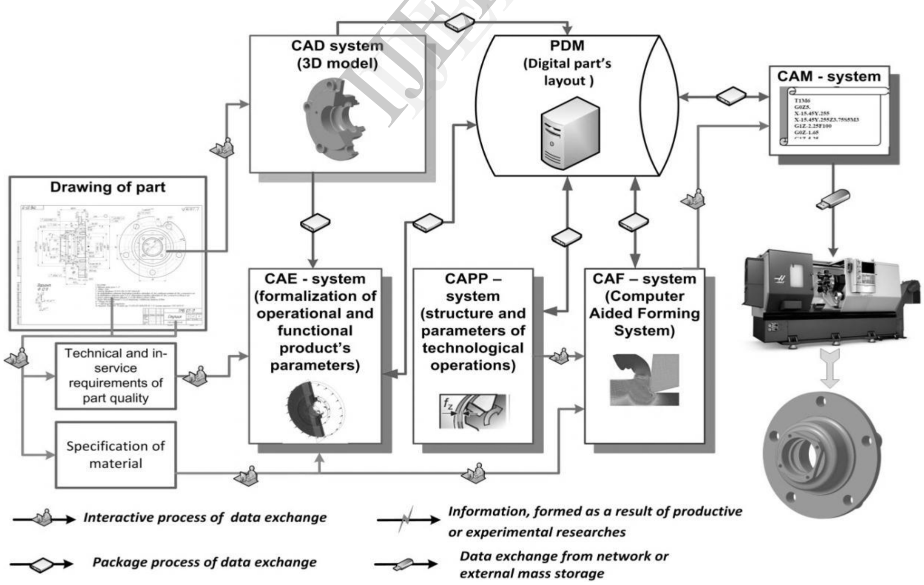

Fig.2. Scheme of the integrated functionally-oriented preproduction engineering process planning system

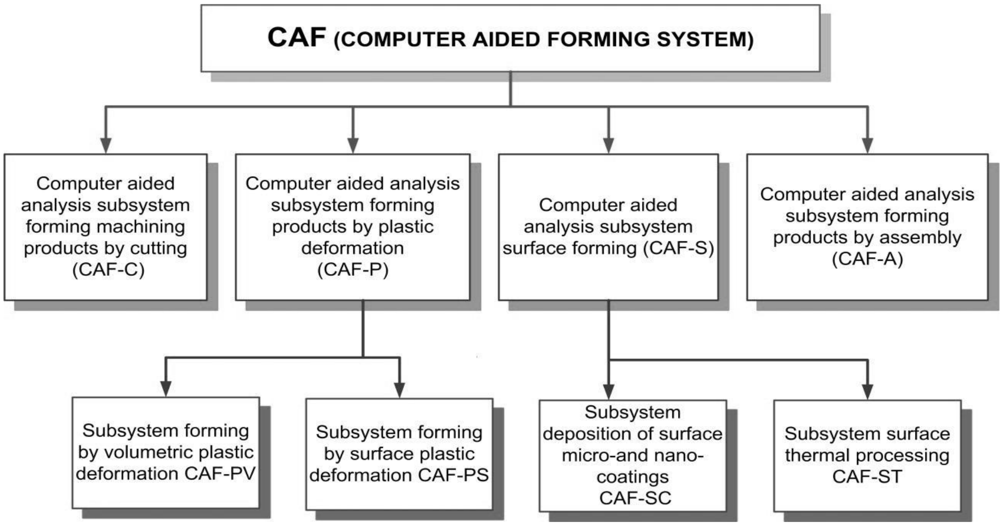

Fig.3. CAF subsystems classification.

The classification of the structural subsystems product forming is shown in Fig.3.

Such well-known software as DEFORM, ABAQUS, AdvantEdge, LS-DYNA are the basic software products for CAF-system. All these systems are multipurpose FEM analysis and applications designed to solve two-and three-dimensional dynamic nonlinear problems of plastic deformation and fracture mechanics. Explicit and implicit finite element method with the possibility of constructing Lagrange, Eulerian and hybrid mesh, multicomponent hydrodynamics, smooth lattice method, based on the Galerkin method are used in these tasks. CAF-system fully complements the existing complex of integrated CAD/CAE/CAPP/CAM systems. This system provides dependence of the main qualimetric product's indicators from structure and process parameters machining parts.

Fig.4 shows the algorithm of the CAF-system based on iterative and recursive relations. The process of planning such technologies based on the following stages:

– form a digital layout of the product;

– formalization and simulation environment to ensure the efficient operation of products;

– simulation of rheological modeling of stress-strain, thermodynamic and structural-phase state of the most critical parts of surfaces during their formation;

– models predict functionally-oriented properties of the product;

– structure and process parameters and the process of object-oriented technology;

– adjustment of structure and synthesis technology based on the principles of functional-oriented technologies;

– providing the necessary boundary properties depending on the characteristics of use in the technological system.

Initial data for CAF-system are:

– - 2D or 3D model parts (has influence on the kinematic angle cutting, shaping in Euler or Lagrangian mesh). Source of information - CAD system.

– - The structure of the technological operation (has a direct influence on the rheological model cutting). Source of information - CAPP system.

– - Geometry of cutting tool (has influence on the dynamics, geometric parameters of technological step). Source of information - CAPP system.

– - Tool material (has a direct influence on the rheological model of technological step).

– - Modes of treatment. Source of information - CAPP system.

– - Strength, physical, mechanical, thermal characteristics of processed material (has influence on the choice of the curve thermodynamic strengthening friction and selection criteria destruction). Source of information - CAD system.

– - Models wear blade tools and dynamics of chip buildup (have a direct influence on the rheological model of technological step). Source of information - analytic modeling.

– - The error convergence of simulation results on the force vector and the velocity vector and the acceptable level of accuracy geometric, select the type of task (Lagrangial Incremental or Steady-State Machining), the choice of iterative method (direct or iterative Newton-Rafsen) Choosing a kernel method (sparse matrices or method Skyline). Source of information - an interactive mode with the designer.

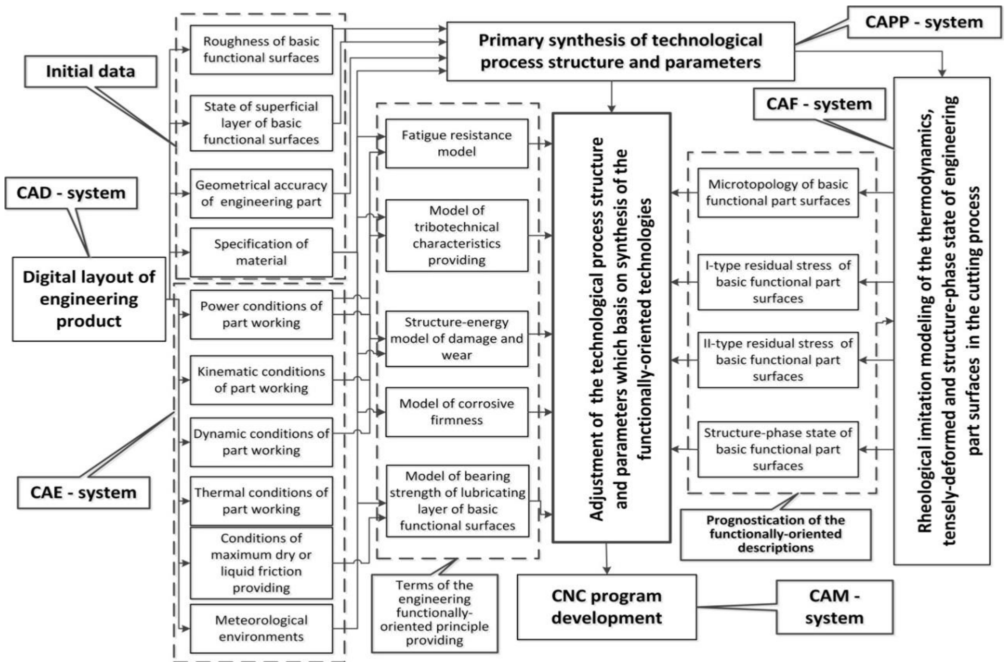

Fig.4. The structure and logic chart of technological preproduction functionally-oriented planning

According to the theory of classical Systems Engineering [5], for any design characteristic ascending sequential algorithmic synthesis of optimal structure and parameters of separate technological transitions, operations, are based on the results of the predictive simulation of rheological modeling of the stress-strain state and thermodynamic product during its formation.

Benefits of functionally-oriented design to object-oriented are quite evident:

– formalization of recursive relations between the results of technological design and conditions of the product allows an optimum set of its functional qualimetric indicators;

– providing system integration and hybridization automated technological process planning (Integer Computer-Aided Manufacturing - CAD/CAE/CAPP/CAF/CAM systems) by means of concurrent engineering.

However, besides the positive features there are many problems in implementation of functionally-oriented design, including:

– complexity of the macrogeometric parts settings for technological process structure formation;

– the necessity of the structural integration and provision a common format STEP data exchange between different CAD/CAE/CAPP/CAF/CAM systems (CAPE technology) (ISO 10303);

– difficulty of formalizing input data for the functionally-oriented engineering planning;

– the necessity for an automated technological system shaping of the product (CAF - system)

– the need for substantial improvement of existing CAE systems (MicroCAE, NanoCAE).

Classic CAE-systems of engineering analysis are, in essence, a MacroCAE systems (Macro Computer Aided Engineering System). These CAE-systems are not designed for study frictional, micro- and nano-deformation surfaces processes such as analysis of wear resistance, contact stiffness, fatigue strength, corrosion resistance, etc. The theories of this research were studied enough but needs to design such systems engineering analysis as MicroCAE and NanoCAE in engineering practice has not been so far. Therefore, changes of the existing CAE systems are necessary for the effective implementation of the functionally-oriented preproduction engineering planning concept (subsystems MicroCAE and NanoCAE add to MacroCAE).

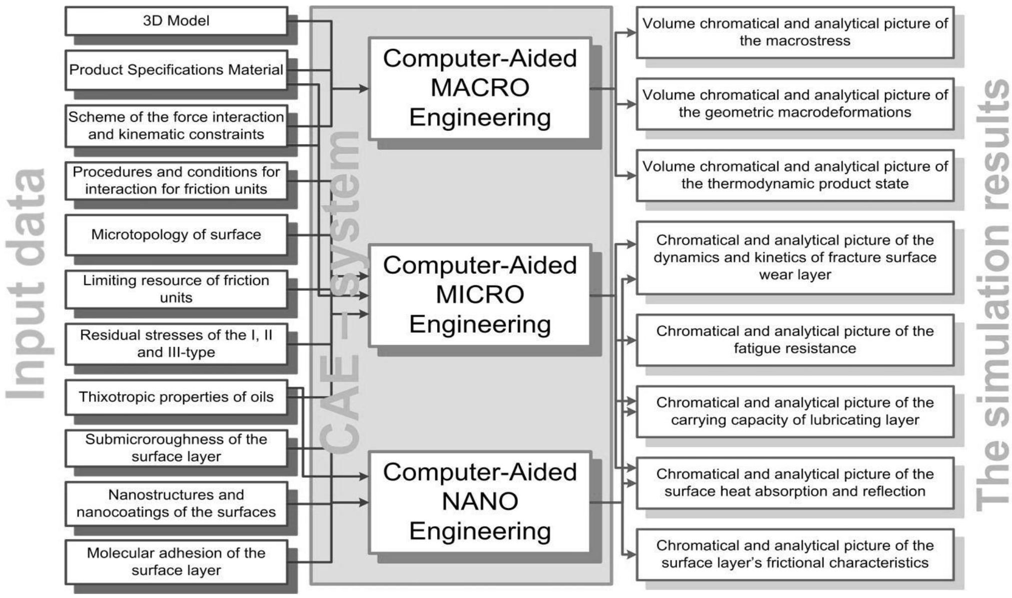

Fig.5. Integrated structure of CAE system (MacroCAE, MicroCAE and NanoCAE)

4. Conclusion.

You can draw the following conclusions, given all the positive and negative features of alternative concepts for technological planning. Applying the algorithm of planning the optimal technological processes structure and parameters with the concept of functionally-oriented engineering planning can be recommended only for parts with important functionally surfaces which to be in service by increased mechanical, thermal, chemical or frictional load. But such parts often provide the operational quality of the product as a whole. The algorithm that implements the traditional concept of object-oriented planning process, should be used only for products that do not meet these criteria functioning. However, the combination of alternative planning concepts is the best methodology. This process includes the synthesis of the previous structure and process parameters with regard macrogeometrical rates of the product (object-oriented planning step) and subsequent adjustment of process parameters based on simulated potential and critical conditions of product's future use (functionally-oriented planning step). Thus, the technological preparation of production can be significantly optimized by the criterion of complexity. The potential of existing CAD/CAE/CAPP/CAM software will be the most used and the system will be the largest PLM included in this case.

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