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Integrated structure of manufacturing data for computer aided manufacturing engineering

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1. Introduction

In modern manufacturing environment the computerization of general functions, exchange of information between all departments and people, application of paperless technologies and concurrent engineering methods are essential. Design, planning and manufacturing control functions must be fully integrated using special models, genetic algorithm-based approaches, CIM (Computer Integrated Manufacturing) principles, Web solutions and other methodologies [1-4].

For computerization of manufacturing engineering different computerized systems are used for process planning, material and manufacturing resources planning, and other functions [1, 4-7]. It is very important, especially in modern manufacturing environment, to integrate the whole manufacturing engineering process into one integrated computer aided manufacturing engineering system (CAME), as universal as possible. The integration of computer aided systems requires the effective communication of information about engineering properties and manufacturing environment between different systems, using common information models, data structures, dictionaries etc. [8, 9]. One of the most significant work stages is developing the optimal and effective structure of data and data bases, that can include and cover all necessary information and ensure the functions efficiency of CAME subsystems.

2. Integration for computer aided manufacturing engineering

The integrated computerised system mainly consists of subsystems, performing particular design functions, and data base (DB):

$$IS = \bigcup_{i=1}^{n} S_i + IDB + \bigcup_{j=1}^{m} \left(JB \right)_j \ , \qquad (1)$$

where *IS* is the integrated system; S_i is the systems or subsystems that compose integrated system, $i = 1,...,n$; *IDB* is the data base of integrated system; $(JB)_j$ are the joining blocks (interface) for systems, subsystems or modules $j = 1,..., m$.

In manufacturing enterprises for computerization of manufacturing engineering (ME) in general are used [9]:

- computer aided process planning system (CAPP);
- material resource planning system (MRP);
- manufacturing resource planning system (MRP II).

Computer Aided Manufacturing Engineering system integrates CAPP, MRP and MRP II systems – their functions, data and results. In general MRP II systems already integrate the MRP system. Then mathematical formalization of data functions and factors of integrated CAME system:

$$f:\left(CAME\right) = f:\left(CAPP\right) \bigcup f:\left(MRPII\right) = \\ = f:\left(PT, M, Sh, PP, Q, D, E, PMS, T\right), \qquad (2)$$

where *PT* is the product type; *M* are the materials; *Sh* is the shape of the parts or components; *PP* are the product parameters (qualitative and quantitative); *Q* is the quantity of the parts; *D* are the machine-tools and devices; *E* is the technology equipment, *PMS* are the parameters of manufacturing system, *T* are the manufacturing traditions.

Integration of all these separate systems and modules, their specific functions and data bases into one integrated manufacturing engineering system increases efficiency ensuring fast and qualitative manufacturing engineering process. Such integration allows:

- no dubbing data and functions;
- general initial preparation of data base;
- common storage, search and selection of information;
- operative exchange of data and results for design and calculations;
- common technological documentation formation.

Basic integration objective is to develop the manufacturing technology process guaranteeing the lowest production expenses. For efficient integrated CAME system the data base (DB) is one of the most important component.

3. Recommendations for data structure and DB for integrated manufacturing engineering

For developing the recommendations for efficient integrated data structure of CAME system, the comprehensive and deep analysis of manufacturing engineering data and information flow structure was provided. This analysis shoved, that in general all data for ME belong to one of the groups:

- variable data – it is original information about particular mechanical component (MC) or product, part, assembly unit, for which the manufacturing engineering process (technological route, manufacturing resources etc.) should be designed; for example: product code and name, quantity, parts parameters, work pieces, materials, primary blanks, technology processes, etc.
- constant data – it is information about manufacturing system (MS), for which the manufacturing en-

gineering processes of MC should be developed. These data does not change with changes in MC. In general it is catalogues, lists and classifiers of necessary information, used for process planning and manufacturing engineering problems solution; for example: catalogues of materials and primary blanks, technological operations, equipment and tools, typical technological processes, etc.

Developing the integrated data structure and DB for CAME system all necessary information must be integrated and cover all data (variable and constant) used by all subsystems. Recommendations for data structure and DB were formulated after discussions with mechanical engineers in Lithuanian small and medium enterprises and the deep and comprehensive analysis of manufacturing engineering data. During this analysis the tasks allotted for different CAPP and MRP systems, their functions, also the structure of used data bases was considered.

The conclusion was made, that before creating DB for integrated CAME system it is necessary and especially useful such preliminary steps:

- generalisation of the user needs;
- consideration DB structures and control systems of existing local computerised systems and subsystems;
- analysis of the nature of usable information, relationship between common and specific data.

The other general recommendations for integrated CAME system data structure and DB are as follows:

- all information for manufacturing engineering has to be separated into variable and constant data;
- variable data is necessary to divide into hierarchical levels;
- variable data can be systematized and grouped according to user needs; for example, an archive of finished technological solutions can be created; also the data can be grouped by production type, technological processes, customers, orders etc;
- all data (variable and constant) is necessary to separate into common (necessary for all ME functions) and specific (needed only for particular ME functions);
- DB and all data files have to be created according to developed data structure. Data has to be precisely distributed into particular data files or segments seeking exhaustive and not excess information in DB;
- the integrated DB structure must be tested and corrected according to the testing results.

The detailed recommendations in particular for variable and constant data structures also were formulated.

4. Data integration

As mentioned before, for computerization of various ME functions different variable and constant data are required. All data, used by various subsystems, has to be integrated and structure of DB has to cover all necessary data – variable and constant. Mathematically this general integration can be expressed as follows:

$$IDB = IVD \bigcup ICD, \tag{3}$$

where *IDB* is the data base of integrated system; *IVD* is a lot of variable data of integrated systems; *ICD* is a lot of constant data of integrated system.

The common steps for data integration was formulated and recommended for developers of computerised systems for manufacturing engineering:

- analysis and generalization of user's needs;
- analysis of data structure and control principles of each particular subsystem and function;
- development of the common integrated data structure;
- specification of the nature of data (needed information from catalogues or from drawing, etc.);
- separation all data into variable and constant;
- development of the integrated constant data segments and its structure, formation and specification of each data segment;
- development of the integrated variable data sets and its hierarchical structure, formation and specification of each hierarchical level;
- data separation into common – for all ME functions (and subsystems) and specific – only for particular ME functions;
- specification of each data field (type, length etc.);
- testing and correction of new integrated data structure.

For creating the integrated structure of constant data it is also necessary to analyse, systematize and integrate all constant data, used in separate subsystems. Mathematical formalization of constant data integration for integrated CAME system is expressed as follows:

$$ICD = \bigcup_{i=1}^{n} S\left(CD\right)_i ; \tag{8}$$

$$S(CD)_i = \bigcup_{j=1}^{m} CD_{ij} ; \tag{9}$$

$$CD_{ij} = \{F_{ij1}, F_{ij2}, \ldots, F_{ijr}, \ldots, F_{ijq}\}, \tag{10}$$

where *ICD* is a lot of constant data of integrated system; $S(CD)_i$ is the lots of constant data files of each local subsystem S_i, $i = 1,...,n$; CD_{ij} is the constant data file of local subsystem S_i, $j = 1,...,m$; F_{ijr} is the data field of local subsystem S_i data file CD_{ij}, $r = 1,...,q$.

5. Data base of integrated CAME system "SAT"

Data base and data structure for integrated computer aided manufacturing engineering system "SAT" [9] was developed according to presented recommendations and requirements After the analysis and specification of the data, needed for particular CAME subsystems (CAPP, MRP etc.), the common integrated data structure was created (Fig. 1). All data was separated into variable and constant according to nature of information. Then hierarchical structure for integrated variable data was developed and each hierarchical level was specified. For constant data the DB segments and its structure were created, each data segment was specified. Also all data relatively was defined as common (for all manufacturing engineering functions and subsystems) or specific (only for particular functions or hierarchical level). Then parameters of each data field (type, length etc.) were specified. And finally the testing and correction of new integrated data structure was provided.

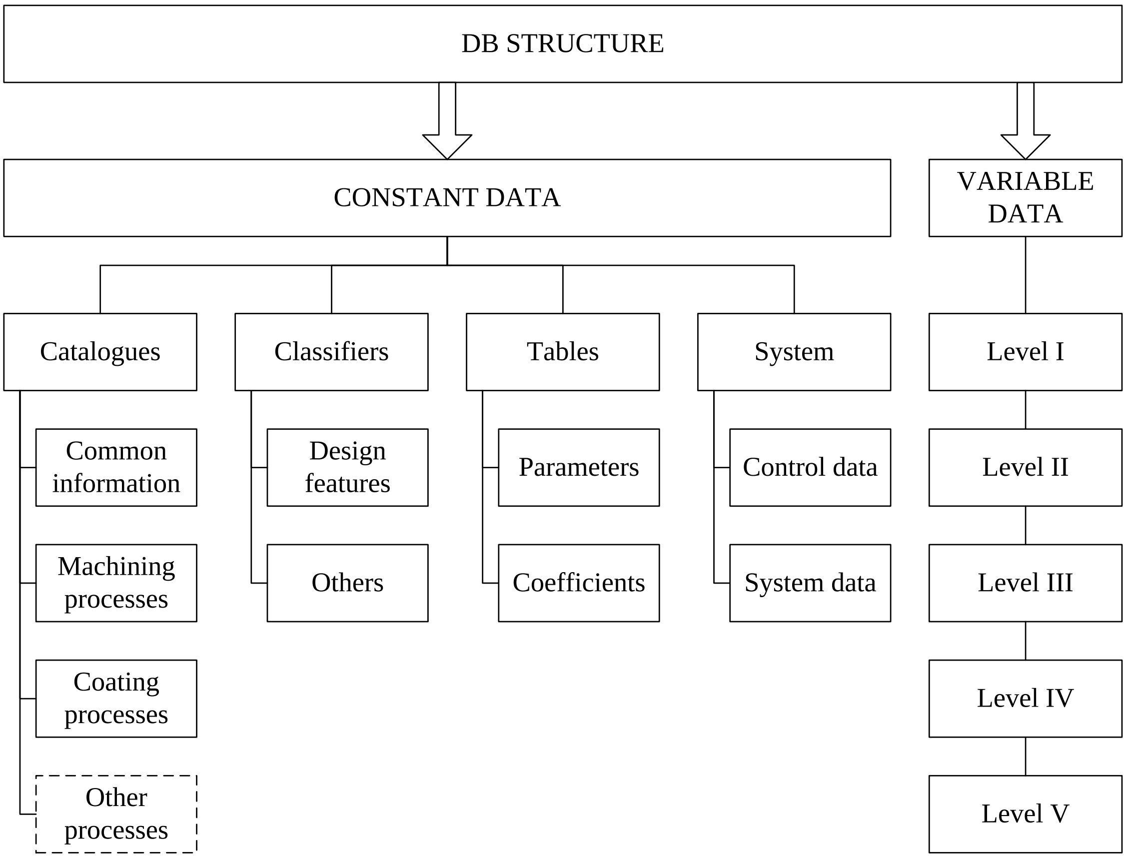

Fig. 1 CAME „SAT“ data base structure

Very important part of data base of integrated CAME system “SAT”– the files for constant data (Fig. 1). They are used for conditionally constant information about manufacturing system, which is needed for computer aided manufacturing engineering – process planning, manufacturing resources planning, calculations, formation of documents etc.

Catalogues are used for storing and selections of needed information for ME design (Fig. 2). This group consist of files for common information used for various processes (users, customers, materials, primary blanks etc.) and data for machining, coating and other process planning. The structure of some catalogues is quite complex, for example, “Primary blanks” (Fig. 3), because of the necessary comprehensive information about material, profile parameters etc. The other catalogues, for example “Equipment” (Fig. 4), “Operations” (Fig. 5), used only for particular information, is not so complex. There are also catalogues-lists of very simple structure, for example, the file “Temperature” for coating processes, etc.

The special group is the classifiers of typical features. They are used for computerization of ME parameters calculation. The main classifiers of typical features are:

- classifier of typical design features (TDF) – for calculation of part’s parameters (mass and area);
- classifier of typical bending features (TBF) – for calculation of evolvent’s measurements.

Coefficients’ tables are separated into special group because of its specific data and structure and more complicated relations with other data and files. Stored information is used for calculations of material consumptions, mechanical operations processing time etc.

Control data files are used for storing intermediary and temporary calculations and designing results, and for documentation formation. They are created, used and eliminated automatically by CAME system “SAT”.

System data files are used for CAME system “SAT” control functions. There is stored specific and control information (data relations, selection rules, comments, translations, parameters definition etc.)

All constant data files are grouped into few segments; each segment consists of one or more data files (Table).

The practical application of developed data base in CAME system „SAT“ showed the advantages of such structure for constant data:

- the DB unify and include all constant data, necessary for manufacturing engineering;
- the structure of data files ensure no redundant information about manufacturing system and other parameters of enterprise;
- the information in DB suit for all general manufacturing engineering functions: process and manufacturing resources planning, computerized calculation of parameters, formation of technological documents etc.;
- the DB structure and control principles are user-friendly: the data in DB are easy accessible for review and corrections; the addition of new information, copying of required data and deleting of old information is simple and easy;

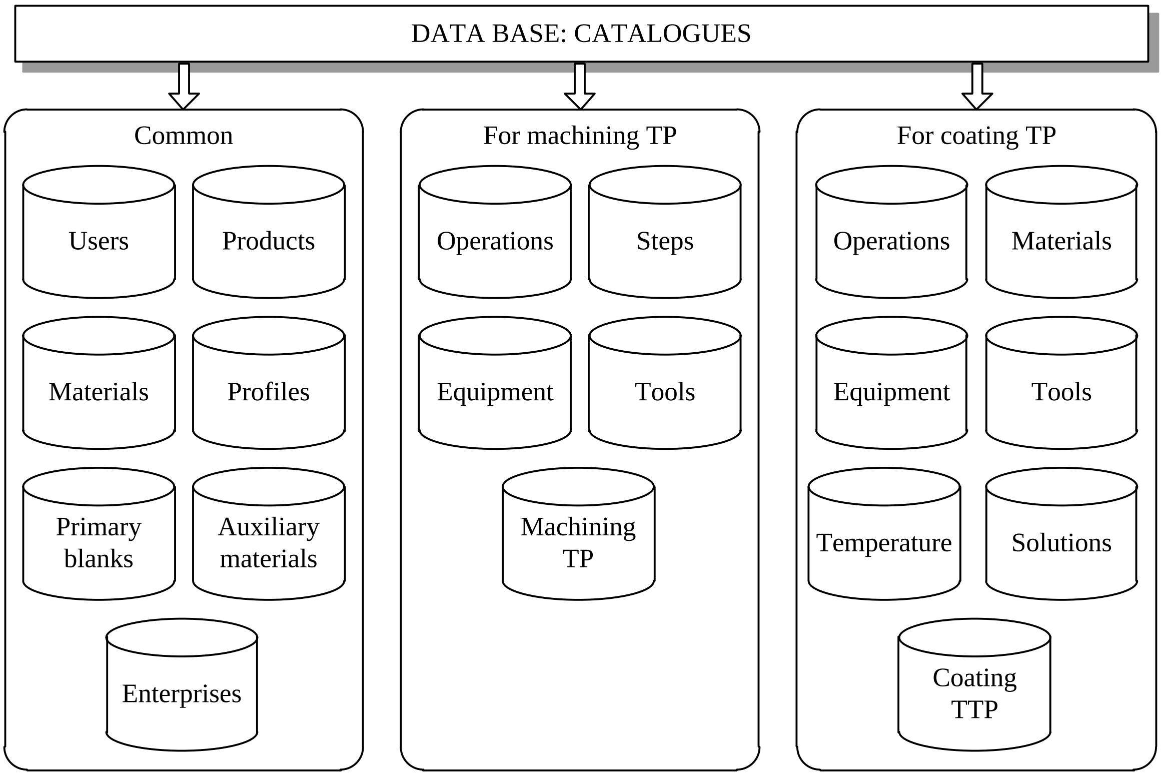

Fig. 2 The catalogues in CAME system "SAT" data base (TP – technological process, TTP – typical technological process)

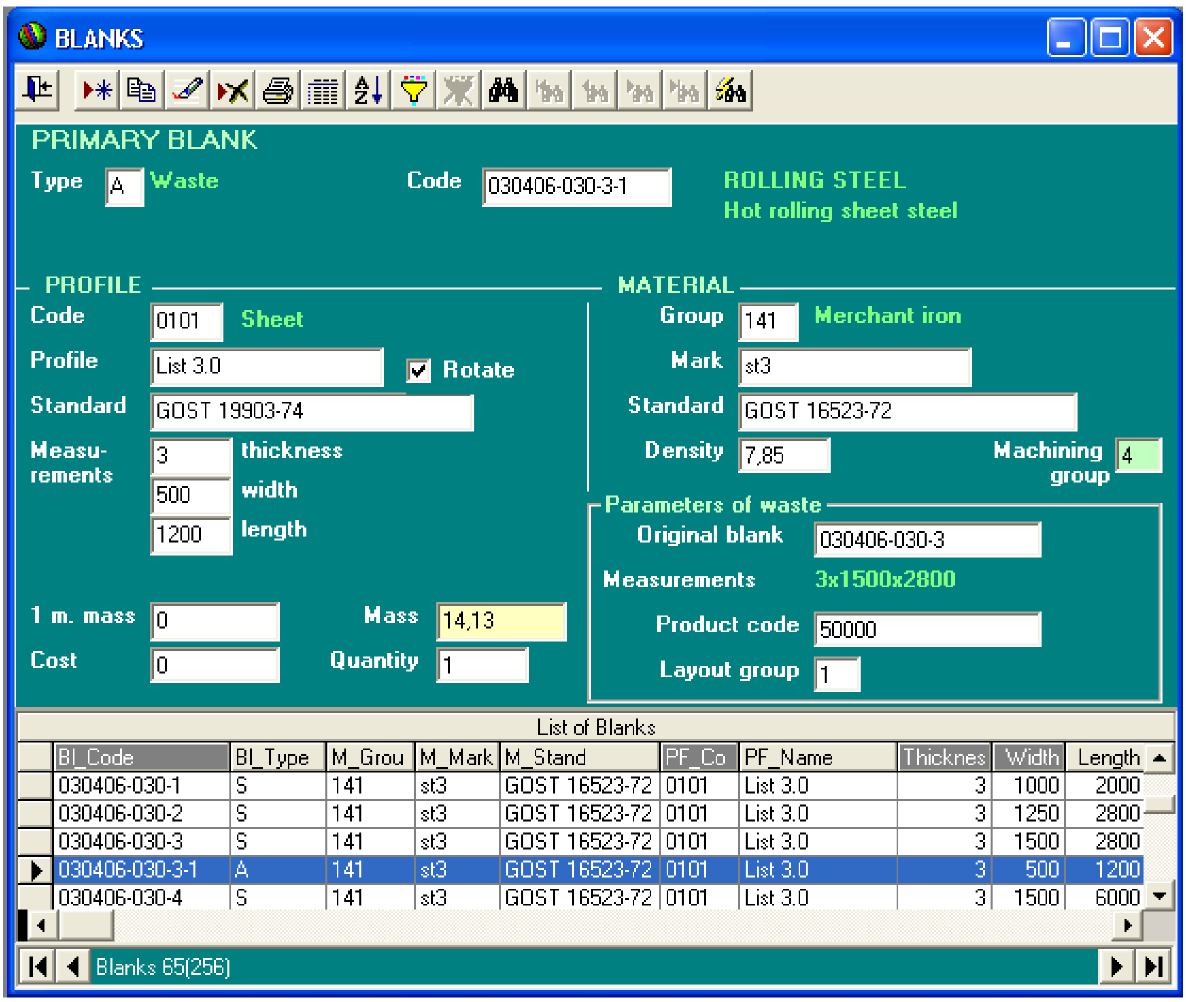

Fig. 3 The data file of primary blanks

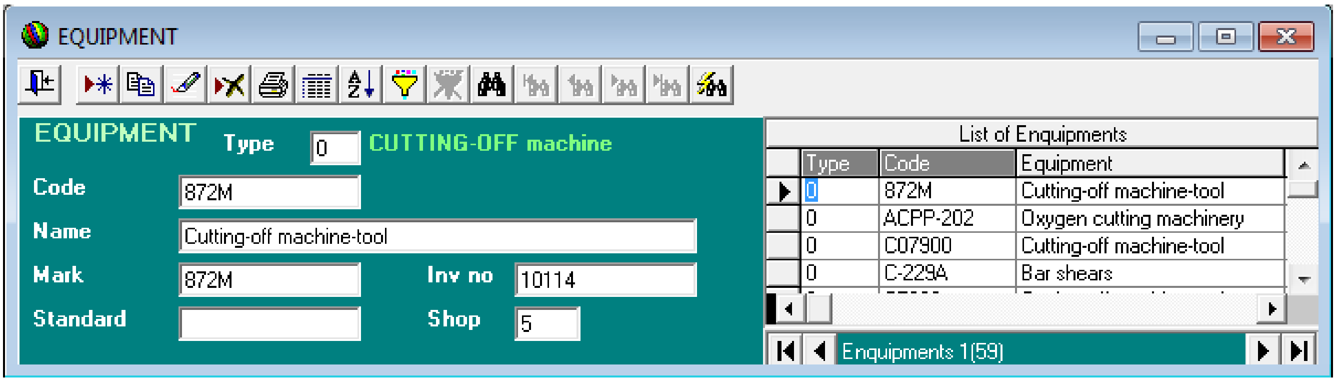

Fig. 4 The data file of equipment

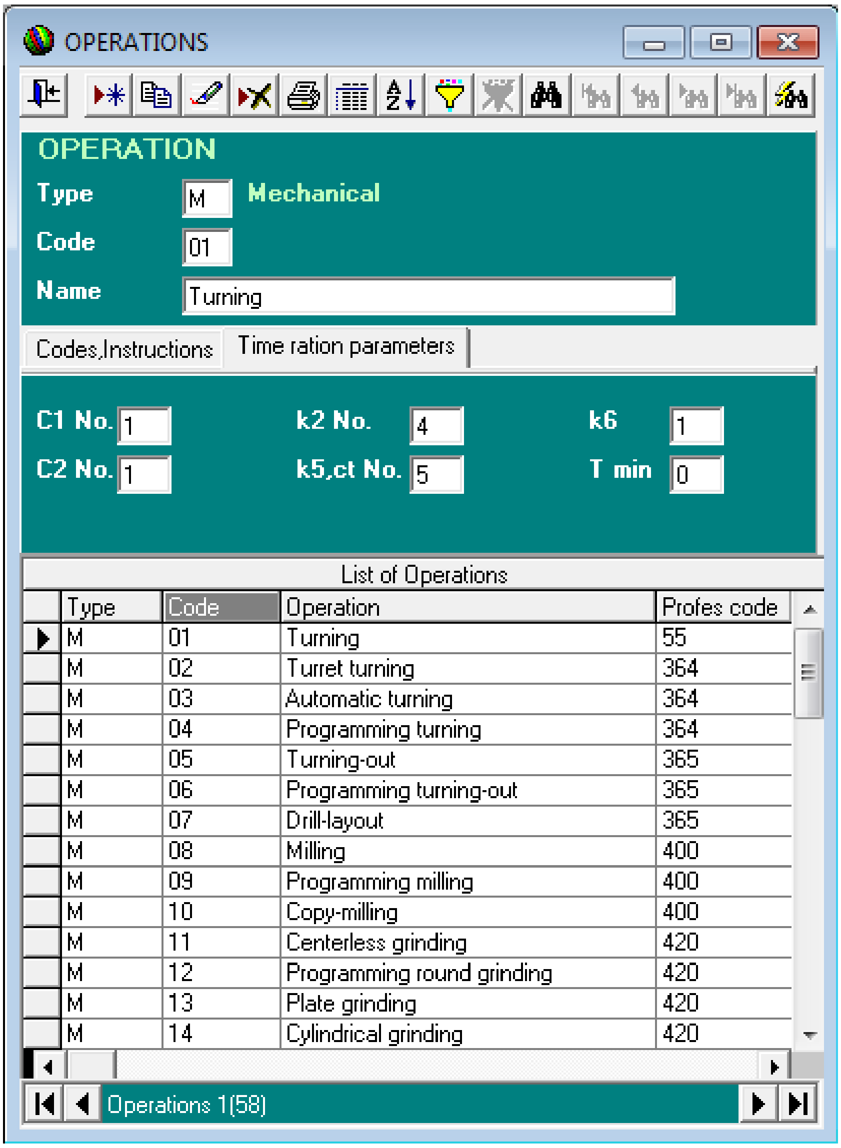

Fig. 5 The data file of operations

- the selection of necessary constant data from catalogues, lists and classifiers is fast and easy due to:
  a) segmented structure of DB,
  b) special identification (classification) codes for particular data,
  c) special DB control functions (“fast find”, “sort”, etc.);
- the structure of DB and constant data files, also special files for system data ensure efficient interface for sharing of calculated parameters during each ME design stage, and for technological documents formation;
- the developed data structure for typical technological solutions, especially for coating TTP, allows accelerate the process planning and manufacturing resources calculation;
- the DB structure for constant data is open and fit for data and system integration for CIM environment.

Table

Segments of constant data files (fragment)

Segments for common data	Data File
Users	Employees
	Designers
Enterprises	Enterprise codes
	Division codes
	Virtual enterprises
Production	Products codes
Materials	Material types
	Material groups
	Material codes
	Material marks
Blanks	Profiles
	Blank types
	Blanks
Auxiliary materials	Auxiliary materials, components
Classifiers of typical features	Typical design features (TDF)
	Typical bending features (TBF)

Segments for mechanical TP	Data File
Operations	Operation types
	Operations
	Operation documents
	Steps
Equipment	Equipment types
	Equipment
Tools	Tool types
	Tools

Segments for coating TP	Data File
Coatings	Coating types
	Coating processes
	Coatings materials
	Coating operations
	Coating equipment
	Coating solutions
	Coating tools
	Temperature
Coatings TTP	Coatings TTP
	TTP operations
	TTP materials

6. Conclusions

The DB structure for integrated CAME system ”SAT” was created according to developed requirements, tested and corrected by testing results and users’ requests. All manufacturing information in DB is exhaustive and not redundant; the structure of data is open and fit for data and system integration.

The efficient data structure and DB of this system allows fast and easy computer aided manufacturing engineering of a new product: technological process planning, manufacturing resources calculation, technological documentation formation. Using developed integrated data structures the optimal model for efficient manufacturing engineering system can be developed.

The practical experience of CAME system “SAT” application justifies the presented recommendations for data structure and DB for integrated system.

1. For integrated computer aided manufacturing engineering the efficient integration not only CAPP and MRP II functions, but also the structure of data and data bases is necessary. Such integration allows: no dubbing data and functions; general initial preparation of data base; common storage, search and selection of information; operative exchange of data and results for design and calculations; common technological documentation formation.
2. For efficient data integration the primary steps are necessary: summarizing the user’s needs; considering the DB structures and control systems of existing local computerised systems and subsystems; analysis of the nature of usable information, relationship between common and specific data.
3. Data structure must be integrated and cover all data used by all subsystems. One of the most important tasks – proper and correct separation of manufacturing data into variable and constant. This separation ensures comprehensive data structure and allows efficient DB control and application.
4. Formulated recommendations for data structure for integrated computer aided manufacturing engineering systems offers valuable suggestions seeking efficiency of created databases and data structures. They are useful not only for designers of CAME systems, but also for solution of other problems of computer integrated manufacturing.

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R. Mankutė

INTEGRUOTA GAMYBINIŲ DUOMENŲ STRUKTŪRA TECHNOLOGINIAM GAMYBOS RENGIMUI KOMPIUTERIZUOTI

R e z i u m ė

Straipsnyje nagrinėjama gamybinių duomenų, skirtų technologiniams procesams ir gamybos sąnaudoms integruotai projektuoti, struktūra. Pateikiamos rekomendacijos ir reikalavimai integruotai duomenų struktūrai ir duomenų bazei, užtikrinančiai efektyvų technologinį gamybos rengimą. Supažindinama su originalios integruotos technologinio gamybos rengimo sistemos duomenų struktūra ir duomenų baze.

R. Mankutė

INTEGRATED STRUCTURE OF MANUFACTURING DATA FOR COMPUTER AIDED MANUFACTURING ENGINEERING

S u m m a r y

This paper describes the structure of manufacturing engineering data for integrated process and manufacturing resources planning. The recommendations and requirements for data structures integration for effective computerization of manufacturing engineering are presented. Examples of data structure and data base of original integrated Computer Aided Manufacturing Engineering system are provided.

Keywords: Computer aided manufacturing engineering, integration, data base, data structure.

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