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An integral system for automated cutting tool selection

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The importance of cutting tools in production systems demands modern approach to their selection. Automation of tool selection can significantly enhance the efficiency of process planning. Presented in this paper is a development of a geometry-based and feature-based system for automated selection of cutting tools. The developed system represents an integral solution, since, besides cutting tool selection, it allows selection of cutting parameters and cutting medium. The system is built on a modular principle, comprising a database, knowledge base, dedicated and external software applications. Furthermore, the system features an RFID-based module which gives it vital capability of automated cutting tool inventory management. The proposed system was successfully tested in industrial environment, while in this paper an example featuring a hole boring machining operation is presented.

Key words: Cutting tool, data base, knowledge base, radio-frequency identification technology.

INTRODUCTION

Constant advancement of computer technology contributes to its ever greater application in engineering, including the process planning. The basic idea behind this process is to enable manufacturing technologies to be highly adjustable to market demands, while providing high product quality, high output volumes and reduced manufacturing costs (Zuperl et al., 2011). There are numerous examples of developed computer-aided everything (CAx) systems which successfully automate the tasks of product design (Zhao et al., 2002), process planning (Simunovic et al., 2010), production management (Abdul-Rahman and Wang, 2010), etc. Within a manufacturing system, there are several factors which most prominently influence the quality of process plans: blanks, sequence and structure of machining processes, concentration of machining operations, machine tools, cutting tools, fixtures, measuring devices, etc. (Smith, 2008). Enhancement of process planning procedure requires optimization of these parameters. In the chain of factors which influence the quality of final product, cutting tools are of exquisite importance (Zuperl and Cus, 2008). Inadequate management of cutting tools contributes to lower efficiency and effectiveness of production systems in general. Therefore, efficient tool management requires constant monitoring of cutting tools flow and use. This necessitates establishment of a comprehensive and well organized cutting tools database which is in the center of all information flows within every cutting tools management system. Cutting tools management requires a number of synchronized activities which demand a large number of information. There are three basic types of activities within such a system and they pertain to: selection of cutting tools, inventory management and management of cutting tools in using. Considering the fact that an average manufacturing system utilizes several thousand cutting tools, that their availability impacts the deadlines for introduction of new products, and modification of existing products, as well as the fact that shop floor, tool flow can also be very complex, therefore it is important to create an automated system for cutting tools selection. Consequently, this problem has been addressed by numerous authors. Giusti et al. (1986) developed an expert module for automatic tool selection of turning

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operations (computer aided tool selection system) which is a part of a process planning software.

Mathieu et al. (1987) developed an expert system for cutting tools selection for turning processes, aimed at defining a general methodology for the selection of optimal tool for every turning process. They used minimum operational cost criteria for tool selection. Chen et al. (1989) developed an automatic tool selection system for rough turning on a computer numerical controlled (CNC) lathe. Selection was made from the developed tool library employing a heuristic method in order to reduce the search time. The only criterion for tool selection was minimum cost. Arezoo et al. (2000) presented the development of a knowledge-based system for selection of cutting tools for simple turning processes. The system developed could be used to select the toolholder, insert and cutting conditions. Fernandes and Raja (2000) implemented a tool selection process for external and internal turning, limiting their consideration to cylindrical and face turning operations. Zhao et al. (2002) developed an integrated CAD and generative system for cutting tool selection. Their system was based on initial graphics exchange specification (IGES) specification and feature recognition approach for turning processes. Lai (2004) proposed an object-oriented cutting tool database system. This system incorporated the required organization model (ROM) and IDEF1X data model. Oral and Cakir (2004) developed a generative computer aided cutting tool selection system for rotational parts. Cutting tools were selected based on workpiece, machine tool, workholding and the set-up number information. Chen at al. (2008) presented a database and search system for grinding cutters. Xiang et al. (2008) presented a high-speed cutting database system based on hybrid reasoning. The case-based and knowledge-based features were closely combined through the data mining technology. Arshad et al. (2010) developed a WEB based cutting tool management system for the selection of milling cutters. One common weakness of all of these systems is their orientation on workpieces of a strictly predefined geometric form. Most often, these systems were developed to accomodate either solely prismatic or rotational workpieces. Moreover, these systems were developed to select tools for a limited number of predefined machining processes (most often turning or milling). Some of the systems failed to consider all the parameters relevant for the selection of cutting tools. The number of these parameters is much larger than presented in these investigations. Furthermore, some of these systems lack flexibility, while others are limited to a mere concept, without practical verification, that is, case study. There is no generally adopted approach which would be flexible enough to meet the requirements of every manufacturing system, without or with minimum modification. Besides, none of the proposed solutions take into consideration the current availability of tools, that is, warehouse inventory, which represents a very real problem in industrial conditions, knowing that cutting tools are limited resources.

Very often, the selected tools or tool components are already engaged at a particular workstation, which implies a waiting time for the tool or tool component to become available again. Sometimes, this waiting time can last from several hours to several days, even months, depending on the batch size being manufactured. All this is further complicated by the fact that, in the process of cutting tool selection, several tool designs can meet the set requirements, which means that their availability in the warehouse must be considered. This provides the necessary time saving which, in turn, increases the overall system productivity, thus proving that cutting tools and tool components warehouse inventory represents one of the critical factors for their selection. The goal of this paper is to solve the above stated problems, through the development of an integral, intelligent system for automated cutting tools selection. The system should provide selection of cutting tools for as many machining processes and typical operations as possible, regardless of their complexity. Moreover, the system should monitor cutting tool inventory which is available in the warehouse. In addition to selecting cutting tools, the system should allow user to select cutting conditions, cutting medium and cutting process sequence, depending on the problem in hand.

METHODS

Based on the previously stated analyses, a flow chart of the cutting tools selection system is presented (Figure 1). The core of the proposed system is an expert system which uses Boolean logic. System input consists of information which are critical for system functioning. This information can be grouped into three larger categories:

A) Information about machining,
i) Batch size,
ii) Machining process (turning, drilling, milling, grinding),
iii) Machining operations (turning operations: external longitudinal turning, internal longitudinal turning, external transverse turning, internal transverse turning, external grooving, internal grooving, external chamfering, internal chamfering, turning of external tapers, turning of internal tapers, internal threading, external threading, external profile turning, internal profile turning, drilling of axial holes and openings, drilling operations are: drilling with twist drills, reaming with spiral and straight flutes, countersinking, counterboring, center drilling, tapping, deep drilling, boring, milling operations are: planar milling (milling of flat surfaces), profile milling (milling of profile surfaces), copy milling (milling of complex surfaces), hob milling, grinding operations: circular grinding – external, circular grinding – internal, radial circular grinding, profile circular grinding, planar grinding, superfinish, lapping, honing),
iv) Type of geometry (rotational, prismatic),
v) Complexity of feature (simple, complex),
vi) Geometry of feature (face, step, U slot, V slot, 2 side pocket, 3 side pocket, 4 side pocket, blind hole, through hole, chamfer, thread, fillet, etc.),
vii) Type of machining (external/internal, roughing/finishing),
viii) Feature parameters (start parameters/stop parameters),
ix) Surface finishing,

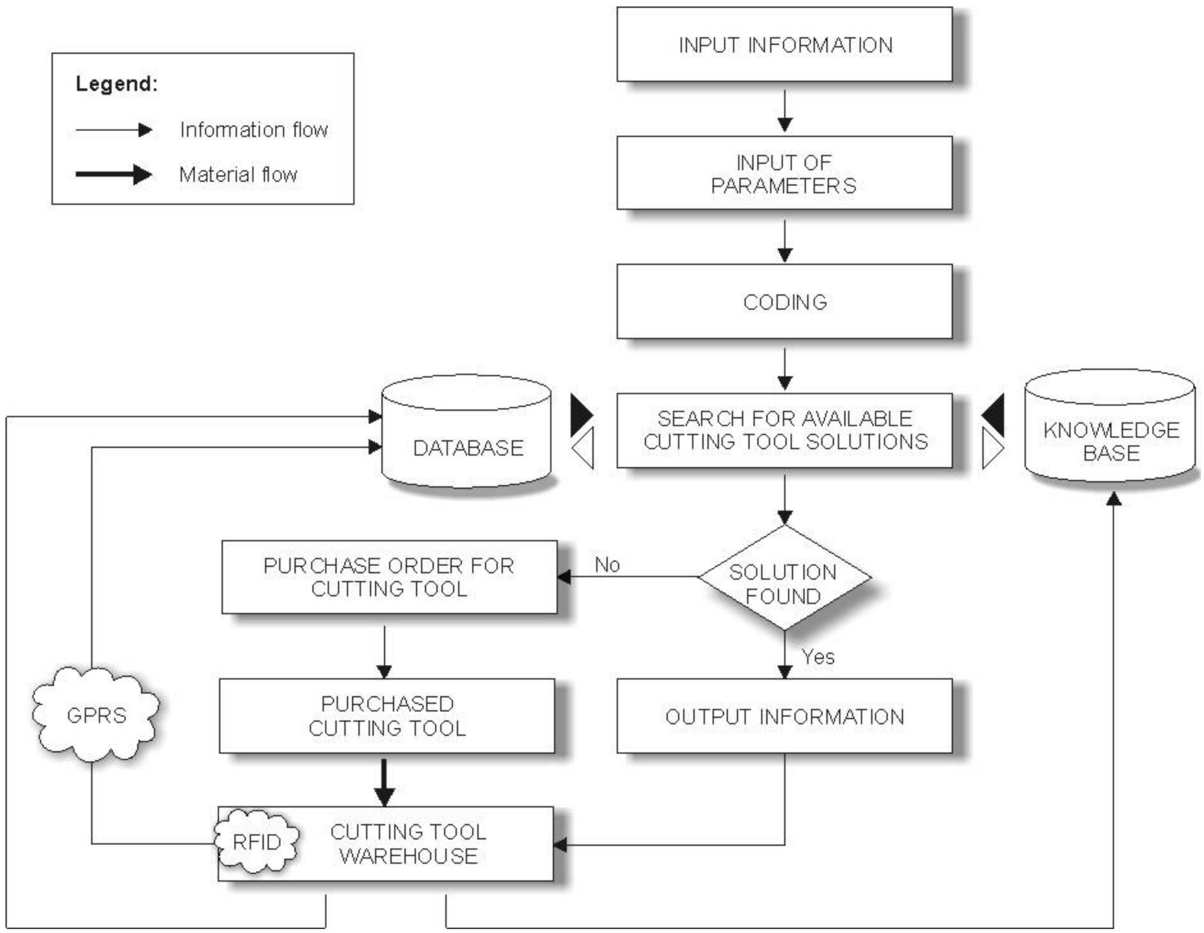


Figure 1. Flow chart of the cutting tool selection.

x) Dimensional tolerances (length, with, height, angular, diameter, radius),
xi) Geometric tolerances - single feature (cylindricity, flatness, profile of line, profile of surface, roundness, concentricity),
xii) Geometric tolerances - related features (parallelism, squareness, angularity, position, concentricity, symmetry, runout).

B) Information about machine tool:

i) Machine tool type,
ii) Machine tool subtype,
iii) Unique identifier (UID) of machine tool.

C) Information about workpiece:

i) Workpiece material type,
ii) Workpiece material subtype,
iii) Workpiece material UID,
iv) Properties of workpiece material.

Input information are awarded special codes and entered into the system according to the presented systematization. For example, if machine tool type = conventional machine tool, then machine tool type is awarded code ‘311’. Similarly, if machine tool type = numerical control machine tool then machine tool type is awarded code ‘312’ (Figure 2). The codes must be convenient for computer implementation. Once awarded the special code, the input information is used in conjunction with the developed set of production rules to search knowledge base for the solutions which meet the criteria. Based on the coded input information and using the developed set of production rules, knowledge base is searched for the solutions which meet the criteria. One of the critical criteria is the current availability of cutting tool in warehouse inventory. Inventory state of cutting tool, that is, the currently available number of particular tool items in the warehouse is identified using the radio-frequency identification (RFID) technology. Should the knowledge base search fail for all the production rules, or there are no available items of the required cutting tool in the warehouse, the system concludes that the task cannot be solved with presently available information. The system either aborts operation, or demands additional input information from the user. In case when a larger number of cutting tools satisfy the set criteria, the system sorts the available solutions. If no appropriate tool design can be found in the database, the parameters of such tool are stored in the database, and the procedure for its procurement is initiated. In addition, production rules are also developed and stored in the knowledge base to accommodate the new tool. Output information is not unique for all cutting tools, but is tailored to their individual characteristics. System output consists of four major groups of information:

D) Information about cutting tools:

i) Type of cutting tool (integral cutting tool, non-integral cutting tool),

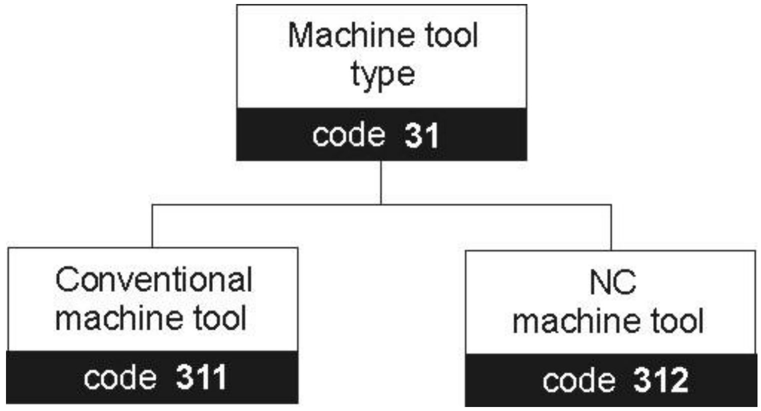


Figure 2. An example of code assignation to particular machine tool types.

Figure 3. A detail of cutting tools warehouse.

ii) Cutting tool designation,
iii) Cutting tool UID,
iv) Cutting tool location in warehouse.

E) Information about cutting medium (medium for cooling, lubrication and cleaning):

i) Type of cutting medium,
ii) Cutting medium UID,
iii) Cutting medium location in warehouse.

F) Information about cutting parameters:

i) Cutting speed,
ii) Feed rate,
iii) Depth of cut.

G) Information about operation:

i) If a particular surface requires machining by two or more cutting tools, that is, operations, the system outputs separate information for each particular operation.

It should be noted that the information about cutting tools are presented to use it only for the tools which are presently available in the warehouse inventory. If the system finds in the database a better tool design which is currently unavailable, the user is informed, and can decide whether to wait for the tool to become available again, or opt for the readily available tool from the warehouse. The user bases his/her decision on the reported waiting time. The cutting tool warehouse which uses RFID technology (Figure 3) is structured as a system of racks, with compartments for various types of cutting tools. Each compartment is RFID tagged. Stored in the RFID tag memory are following information: cutting tool type, cutting tool designation, cutting tool UID (which represents a unique identification of each cutting tool). This allows the operator to visually compare the information read from the RFID tag, and the cutting tool found in the compartment. In case of any inconsistencies, the RFID tag for that particular tool is updated with valid information. Data management is performed as follows: the operator brings order form for the required cutting tool, which, among other information, carries the cutting tool UID, and the cutting tool location in the warehouse. This significantly speeds up the locating of the compartment with the wanted tool. Once the compartment is found, before taking the tool, the operator positions the portable RFID reader (7 cm) from the RFID tag. The reader's operating frequency is 13.56 MHz. The operator initiates

communication, and downloads the data written on the RFID tag. Crucial piece of information is the cutting tool type, and the field for required tool quantity. Once the quantity data are entered and confirmed, data transfer is initiated via general packet radio services (GPRS) protocol, and the data are stored in the database on a remote computer. This allows real-time management of cutting tools inventory in the warehouse.

Successfull implementation of this system demands a well-established knowledge base, cutting tool database, and a graphical user interface.

Cutting tool data base

Database is fundamental for the selection of cutting tools, since it provides the system with all required information, allowing query search and update. The database was designed in three stages: conceptual database design, logical design and physical design. Conceptual design involves: semantic description of the problem, definition of all entities and their relationships, and creation of entity-relationship (ER) database model. ER model is defined by entity diagram, which shows all the database entities, their relationships and types of relationships. Logical database design involves: detailed description of data and creation of relational model. Within the detailed description of data, attributes for each entity are listed, and primary keys are defined. Physical database design consists of: physical description of data structure, definition of tables, data types, length, indices, and data entering. Physical database design is the process which also takes place during system exploitation. Database design is based on the analysis of three crucial groups of elements:

a) Entities are objects (for example, tools) or events (for example, machining processes) which need to be described by the database. The database can store a virtually unlimited number of instances of a particular entity (for example, face turning);
b) Relationships are established between two or more particular entities (for example, the relationship between a particular machining process, and the required cutting tool);
c) Attributes describe properties of entities and their relationships. For example, each cutting tool is defined by following attributes: UID, type, designation, material, status, condition, maximum speed, maximum feed rate, minimum feed rate, holder, drawing, tool life, quantity, etc. In case when a particular attribute has certain properties by itself, it too can be declared an entity (for example tool insert). The same holds for attributes which can have multiple values.

The database operates with two types of data: static and dynamic. Static data are invariable during system exploitation, while the dynamic data are subject to changes. Static data are related to fixed characteristics of particular entities, and remain constant through all stages of system exploitation. Typical examples static data are the data on cutting tools materials, manufacturer, etc. In contrast, dynamic data are subject to changes during system operation. Examples are cutting conditions, cutting tool geometry, etc. The system database utilizes several data files: data files with machining data, machine tools, workpieces, cutting tools, cutting media, cutting parameters. The cutting tool file contains following informations: type of cutting tool (intergal cutting tool, non-integral cutting tool), cutting tool designation, cutting tool UID, material group of cutting tool, material properties of cutting tool, material hardness of cutting tool (material density, hight temperature hardness, melting point, etc.), cutting tool geometry (dimensions, angles, tool radius, etc.), cutting tool quantity and location in warehouse, cutting tool quantity in operation, cutting tools in maintenance (sharpening, reparation, etc.), total cutting tool quantity, cutting tool drawing, etc. The machining data file contains informations on: machining process type, operation type, shape of machining feature, type of machining feature, batch size, surface finishing, dimensional tolerances, geometrical tolerances - single feature, and geometrical tolerance - related features. Each of the listed information is further subdivided according to detailed systematization given in this study. The workpiece data files store data on: workpiece material type (steel, ceramic, etc.), material subtype (cast steel, high speed steel, etc.), workpiece material designation, workpiece material UID, workpiece material mechanical properties and workpiece material thermal properties. The machine tool data files contain informations on: machine tool designation, machine tool type, machine tool subtype, machine tool UID, machine tool manufacturer, machine tool cutting speed range (minimum-maximum), machine tool feed rate range (minimum-maximum), machine tool depth of cut range (minimum-maximum), maximum power of machine tool. The cutting media data files (medium for cooling, lubrication and cleaning) store informations on the type of cutting medium (water, oil, emulsion), UID of cutting medium, manufacturer of cutting medium, cutting medium location in warehouse. The cutting parameters data files contain informations on cutting conditions, that is, cutting speed, feed rate, and depth of cut. It is convenient to organize these data into tables (Figure 4), so that the table rows represent existing cutting tools, while the table columns represent their geometric, manufacturing, and other characteristics.

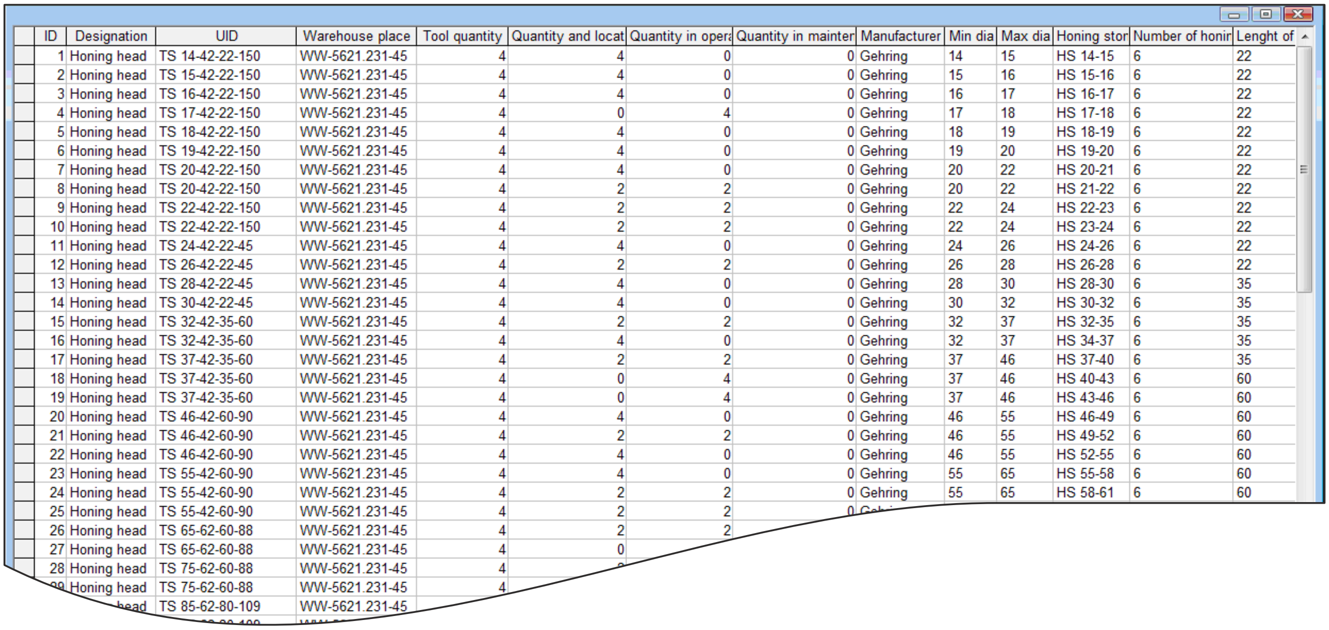
These tables can be used by the automated system as a means of formalization of the process of selection of cutting tools. Users are allowed to edit the existing data, and also append the database with any number of new records. Considering the fact that the entities representing various cutting tools have different attributes, even if the tools belong to the same group, the user interface is designed to accommodate all such requirements. Graphical user interface (GUI) (Figure 5) is one of the critical system components, since it has to provide not only the adequate interactivity, but also an efficient data input control. There are three GUI control features which provide proper and unambiguous data input:

a) User help is available through all stages of data input. User can ask the system for assistance regarding the type, and value range of data that have to be entered. The system also offers graphical illustrations - typical example being an operation chart with all typical dimensions required to fully define the machined surface;
b) Input value control is a built-in mechanism which prevents users from entering inadequate data types. For example, the system does not allow a text string to be entered instead of a numerical value and vice versa;
c) Input range control provides instructions for the user in case of input error. This control mechanism can be easily updated to provide more stringent criteria for data input. Besides, where possible, the mechanism provides a list of eligible data values which can be either entered by the user or selected from the list box or combo box. Although this is the safest way to enter data, it lacks flexibility. An example of such method is the entering of initial and final diameters for hole reaming, where the initial diameter must always be smaller than the final diameter. In case of erroneous input, the system reports error, and notifies user to repeat data input.

In addition to efficient data input, the discussed control features also provide maximum protection from incorrect output results which are caused by input errors.

Cutting tool knowledge base

The knowledge base is the core of this system. Knowledge is represented in a formalized way where there are several methods for knowledge representation. Production rules are a general



	ID	Designation	UID	Warehouse place	Tool quantity	Quantity and locat	Quantity in opera	Quantity in mainter	Manufacturer	Min dia	Max dia	Honing stor	Number of honir	Lenght of
	1	Honing head	TS 14-42-22-150	WW-5621.231-45	4	4	0	0	Gehring	14	15	HS 14-15	6	22
	2	Honing head	TS 15-42-22-150	WW-5621.231-45	4	4	0	0	Gehring	15	16	HS 15-16	6	22
	3	Honing head	TS 16-42-22-150	WW-5621.231-45	4	4	0	0	Gehring	16	17	HS 16-17	6	22
	4	Honing head	TS 17-42-22-150	WW-5621.231-45	4	0	4	0	Gehring	17	18	HS 17-18	6	22
	5	Honing head	TS 18-42-22-150	WW-5621.231-45	4	4	0	0	Gehring	18	19	HS 18-19	6	22
	6	Honing head	TS 19-42-22-150	WW-5621.231-45	4	4	0	0	Gehring	19	20	HS 19-20	6	22
	7	Honing head	TS 20-42-22-150	WW-5621.231-45	4	4	0	0	Gehring	20	22	HS 20-21	6	22
	8	Honing head	TS 20-42-22-150	WW-5621.231-45	4	2	2	0	Gehring	20	22	HS 21-22	6	22
	9	Honing head	TS 22-42-22-150	WW-5621.231-45	4	2	2	0	Gehring	22	24	HS 22-23	6	22
	10	Honing head	TS 22-42-22-150	WW-5621.231-45	4	2	2	0	Gehring	22	24	HS 23-24	6	22
	11	Honing head	TS 24-42-22-45	WW-5621.231-45	4	4	0	0	Gehring	24	26	HS 24-26	6	22
	12	Honing head	TS 26-42-22-45	WW-5621.231-45	4	2	2	0	Gehring	26	28	HS 26-28	6	22
	13	Honing head	TS 28-42-22-45	WW-5621.231-45	4	4	0	0	Gehring	28	30	HS 28-30	6	35
	14	Honing head	TS 30-42-22-45	WW-5621.231-45	4	4	0	0	Gehring	30	32	HS 30-32	6	35
	15	Honing head	TS 32-42-35-60	WW-5621.231-45	4	2	2	0	Gehring	32	37	HS 32-35	6	35
	16	Honing head	TS 32-42-35-60	WW-5621.231-45	4	4	0	0	Gehring	32	37	HS 34-37	6	35
	17	Honing head	TS 37-42-35-60	WW-5621.231-45	4	2	2	0	Gehring	37	46	HS 37-40	6	35
	18	Honing head	TS 37-42-35-60	WW-5621.231-45	4	0	4	0	Gehring	37	46	HS 40-43	6	60
	19	Honing head	TS 37-42-35-60	WW-5621.231-45	4	0	4	0	Gehring	37	46	HS 43-46	6	60
	20	Honing head	TS 46-42-60-90	WW-5621.231-45	4	4	0	0	Gehring	46	55	HS 46-49	6	60
	21	Honing head	TS 46-42-60-90	WW-5621.231-45	4	2	2	0	Gehring	46	55	HS 49-52	6	60
	22	Honing head	TS 46-42-60-90	WW-5621.231-45	4	4	0	0	Gehring	46	55	HS 52-55	6	60
	23	Honing head	TS 55-42-60-90	WW-5621.231-45	4	4	0	0	Gehring	55	65	HS 55-58	6	60
	24	Honing head	TS 55-42-60-90	WW-5621.231-45	4	2	2	0	Gehring	55	65	HS 58-61	6	60
	25	Honing head	TS 55-42-60-90	WW-5621.231-45	4	2	2	0						
	26	Honing head	TS 65-62-60-88	WW-5621.231-45	4	2	2							
	27	Honing head	TS 65-62-60-88	WW-5621.231-45	4	0								
	28	Honing head	TS 75-62-60-88	WW-5621.231-45	4									
		Honing head	TS 75-62-60-88	WW-5621.231-45	4									
			TS 85-62-80-109	WW-5621.231-45										

Figure 4. A segment of the database table for honing heads.

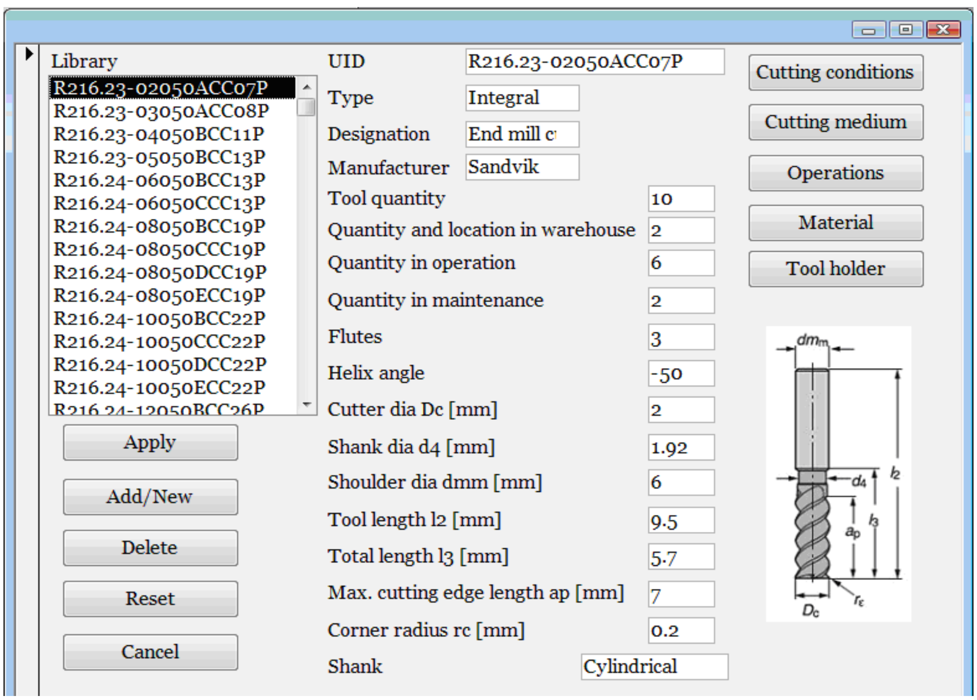


Figure 5. Database GUI – example shown for a milling cutter.

method for knowledge representation. The rules can be considered elements of knowledge. A rule represents a logical relationship and can be expressed in the following way:

IF <conditions> THEN <actions>

The knowledge base is specialized, and contains expert knowledge in the area of cutting tool management. Knowledge is entered into the system via the knowledge collection system, and is not subject to changes during system operation. In contrast to the cutting tool data from the database which is passive, the knowledge contained in the knowledge base is active. The inference engine is a form of finite state machine whose typical cycle comprises three action states: match rules, select rules, and execute rules. A form of notation termed predicate logic is used for knowledge

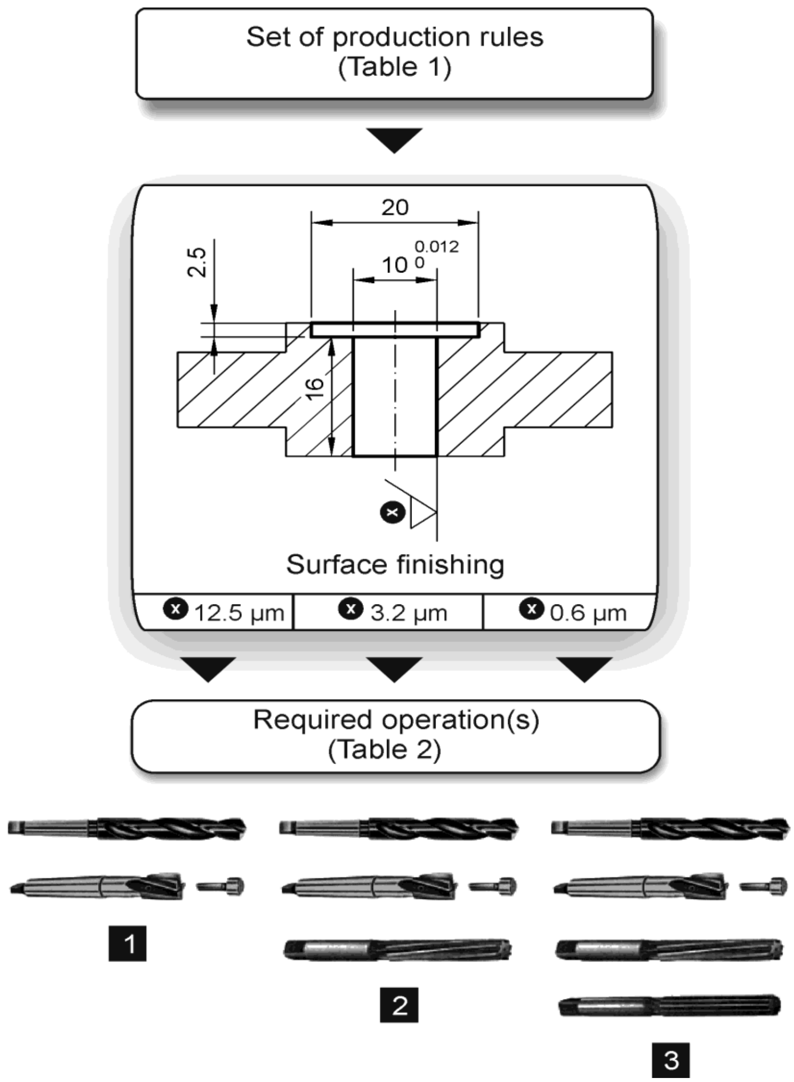


Figure 6. Example of application of production rules for the selection of cutting tools.

representation. The basic idea behind production systems is to iteratively apply rules to the problem defined by the data stored in the operating memory. If the problem definition matches the IF-clauses of one or more rules, the solution to the problem can be found in the THEN-clause of the rule(s). The task of inference mechanism is to find appropriate knowledge in the knowledge base. Inference mechanism communicates with the knowledge base, on the one side and GUI, on the other. It contains a special rule interpreter which processes and interprets production rules during system operation. In the course of inference process, based on initial information in the operating memory, (stored in the operating memory are current data on the cutting tool being searched), and the knowledge from the knowledge base, the inference engine attempts to find the appropriate cutting tool. Initial data stored in the operating memory stem from the input information. Inference engine then applies the knowledge to that data, generating new data in the operating memory. This novel state of operating memory can be sufficient for the selection of cutting tool, in which case the inference process is finished. Conversely, the extended data set is processed again, using knowledge stored in the knowledge base, which causes new updates in the operating memory. This process is reiterated until either the state in the memory is reached which allows the selection of cutting tool, or the process is aborted due to inability to produce solution. In case when the system produces several cutting tool solutions for a particular machining operation, the user decides which solution to accept. Production rules have been developed for the four groups of parameters: cutting tools, cutting conditions, cutting medium and cutting operations.

Shown in Figure 6 is an example of application of production rules for the selection of cutting tools in a step hole drilling process. It is interesting to note that the machining parameters are identical, while there are three different surface finishings which are required. The set of production rules used in this case is shown in Table 1, while Table 2 presents actions required for achieving the target quality.

RESULTS

In order to verify the proposed system model, vital modules were coded. To check their functionality, tests

Table 1. Set of production rules.

Condition
Workpiece material type = Steel.
Workpiece designation = Unalloyed steel.
Workpiece unique identifier = C45.
Workpiece hardness = 190 HB.
Machine tool type = Conventional machine tool.
Machine tool designation = Single-spindle pillar drilling machine.
Machine tool unique identifier = DM-121.22.
Batch size = 100.
Machining process = Drilling.
Operation = Drilling.
Type of geometry = Rotational.
Complexity of feature = Complex.
Geometry of feature = Step hole.
Nominal diameter (through hole) = 10 mm.
Upper tolerance limit (through hole) = 0.01 mm.
Lower tolerance limit (through hole) = 0.
Cutting length (through hole) = 18.5 mm.
Nominal diameter (blind hole) = 20 mm.
Cutting length (blind hole) = 2.5 mm.

Table 2. Required actions.

Action	Operation	Cutting tool	Cutting conditions	Cutting medium
I	Drilling (twist drill)	Designation = Twist drill	Cutting speed = 28 (m/min)	Type = Emulsion
		UID = FRA-KD3019 - 10	Feed rate = 0.2 (mm/rev)	UID = EM-2.11011
		Location in warehouse = WW-1221.322-21	Depth of cut = 10 (mm)	Location in warehouse = SW-0045
		Quantity = 1		
	Counterboring (counter bore)	Designation = Counter bore	Cutting speed = 25 (m/min)	Type = Emulsion
		UID = FRA-KD3340- 20	Feed rate = 0.3 (mm/rev)	UID = EM-2.11011
		Location in warehouse = WW-1455.711-09	Depth of cut = 20 (mm)	Location in warehouse = SW-0045
		Quantity = 1		
II	Drilling (twist drill)	Designation = Twist drill	Cutting speed = 25 (m/min)	Type = Emulsion
		UID = FRA-KD3019 - 8	Feed rate = 0.20 (mm/rev)	UID = EM-2.11011
		Location in warehouse = WW-1221.322-26	Depth of cut = 8 (mm)	Location in warehouse = SW-0045
		Quantity = 1		
	Counterboring (counter bore)	Designation = Counter bore	Cutting speed = 25 (m/min)	Type = Emulsion

Table 2. Required actions.

		UID = FRA-KD3340- 20 Location in warehouse = WW-1455.711-09 Quantity = 1	Feed rate = 0.3 (mm/rev) Depth of cut = 20 (mm)	UID = EM-2.11011 Location in warehouse = SW-0045
	Reaming (spiral flute)	Designation = Reamer with spiral flute UID = FRA-KD3121 - 10 Location in warehouse = WW-1311.261-05 Quantity = 1	Cutting speed = 25 (m/min) Feed rate = 0.22 (mm/rev) Depth of cut = 1 (mm)	Type = Emulsion UID = EM-2.11011 Location in warehouse = SW-0045
	Drilling (twist drill)	Designation = Twist drill UID = FRA-KD3019 - 7.8 Location in warehouse = WW-1221.322-28 Quantity = 1	Cutting speed = 25 (m/min) Feed rate = 0.18 (mm/rev) Depth of cut = 7.8 (mm)	Type = Emulsion UID = EM-2.11011 Location in warehouse = SW-0045
III	Counterboring (Counter bore)	Designation = Counter bore UID = FRA-KD3340- 20 Location in warehouse = WW-1455.711-09 Quantity = 1	Cutting speed = 25 (m/min) Feed rate = 0.3 (mm/rev) Depth of cut = 20 (mm)	Type = Emulsion UID = EM-2.11011 Location in warehouse = SW-0045
	Reaming (spiral flute)	Designation = Reamer with spiral flute UID = FRA-KD3121 - 9.9 Location in warehouse = WW-1311.361-07 Quantity = 1	Cutting speed = 20 (m/min) Feed rate = 0.2 (mm/rev) Depth of cut = 1.05 (mm)	Type = Emulsion UID = EM-2.11011 Location in warehouse = SW-0045
	Reaming (straight flute)	Designation = Reamer with spiral straight UID = FRA-KD3132 - 10 Location in warehouse = WW-1466.501-03 Quantity = 1	Cutting speed = 10 (m/min) Feed rate = 0.25 (mm/rev) Depth of cut = 0.05 (mm)	Type = Emulsion UID = EM-2.11011 Location in warehouse = SW-0045

were performed on real industrial examples. Shown in Figure 7 are the blank, process plan, and the finalized workpiece. The system was verified on a hole boring operation. The workpiece is shown in Figure 8, underwent a process of internal boring of Ø125 hole on a conventional boring machine. Production was serial, with a 1000 pieces batch size. Workpiece material was alloyed cast iron (special cast iron) with following properties:

A) Chemical composition: (3.0 to 3.6)%C, (1.6 to 2.7)%Si, (0.5 to 1.0)%Mn, (0.35 to 0.6)%P, <0.1%S, (0.25 to 0.6)%Cr, (0.3 to 0.5)%Mo;
B) Mechanical properties: hardness 250 to 260 HB.

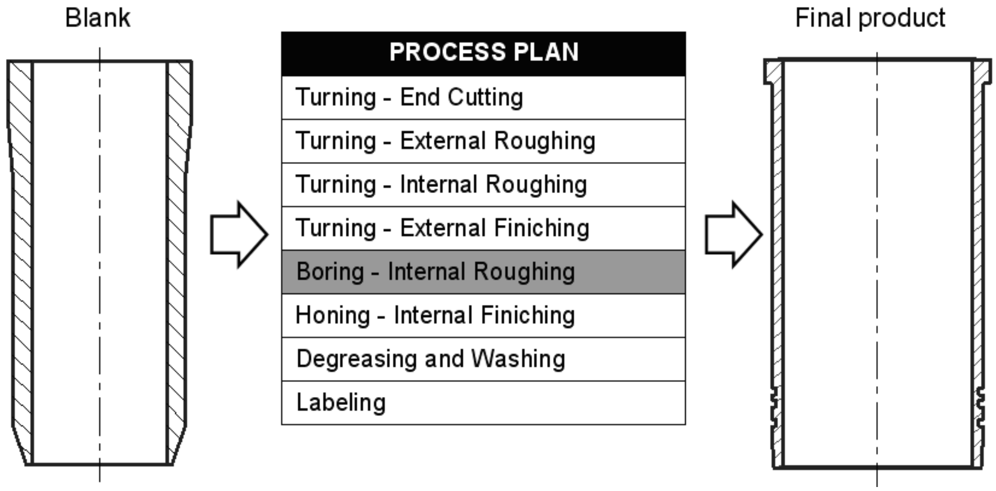


Figure 7. The blank, process plan and the final product.

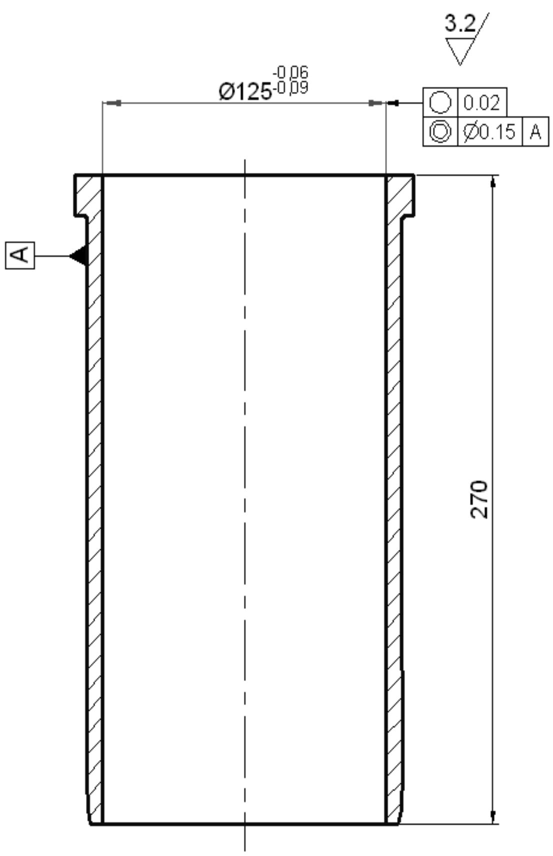


Figure 8. Workpiece for the boring operation.

Depending on the requirements and the defined process plan, the user defines input parameters for the selection of cutting tools. The user interacts with the system through a series of input and dialogue forms (Figure 9). The forms allow the user to either select required parameters from predefined lists, or to enter them manually. It is important to note that the system does not require the user to enter complete information in the forms. Instead, the user enters only the information presently available to him/her. Based on the user input, the system outputs a form which completely reviews the selected cutting tool solution. All the required data are drawn from the data file with readily available cutting tools solutions. Shown in Figure 10 is an example of output information generated for the boring operation on a cylinder lining. In this case, three groups of output information were defined: information on cutting tool, cutting conditions, and cutting medium. This form also provides access to additional informations on the selected parameters. These informations are drawn from the system database and are reported on a separate form.

CONCLUSION

The development of the proposed computer-aided system for cutting tools selection contributes to advancement and rationalization of process planning. The computer-aided system for cutting tools selection is a component of computer-integrated manufacturing (CIM) module which performs the tasks of manufacturing planning and control. The system proposed and verified in this paper allows efficient selection of cutting tools for machining processes which include: turning, drilling, milling and grinding. The system enables user to perform selection of cutting tools for numerous typical cutting operations, either external/internal, or roughing/finishing. At the present level of complexity, the system can offer several types of solutions: a single cutting tool for a single cutting operation, a single cutting tool for several operations, several cutting tools for a single cutting operation and several cutting tools for several cutting operations. Furthermore, once the cutting tool(s) are

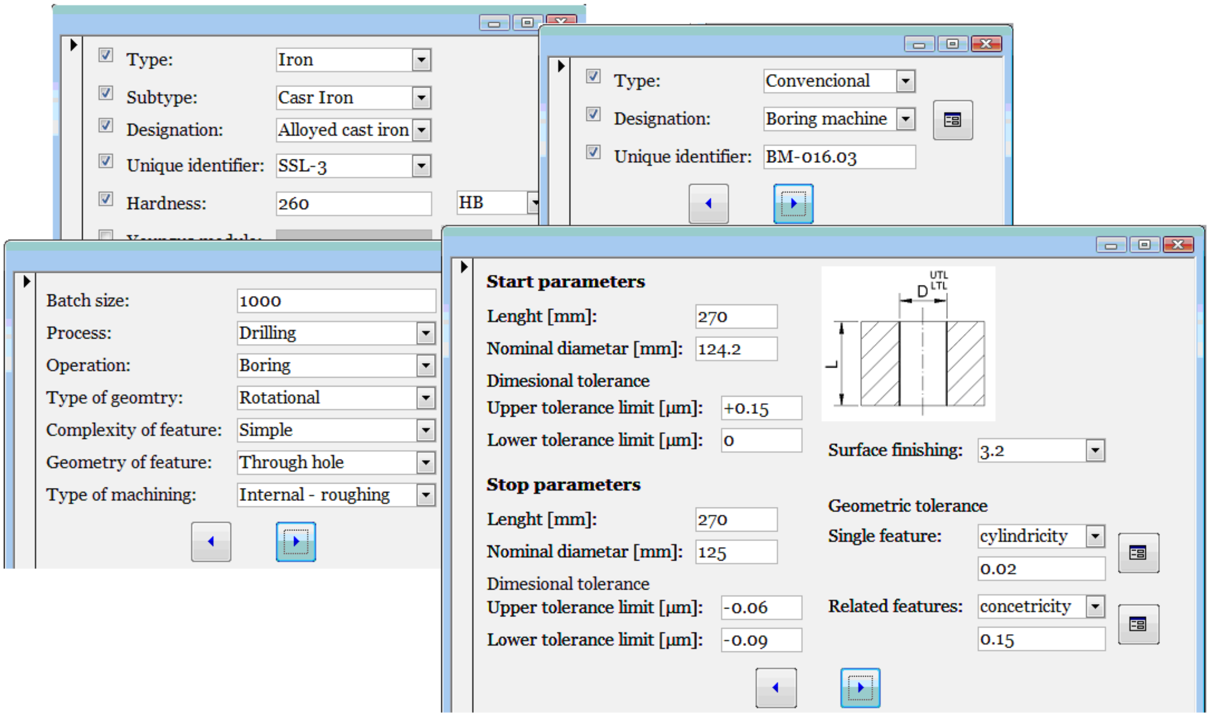


Figure 9. Data input forms.

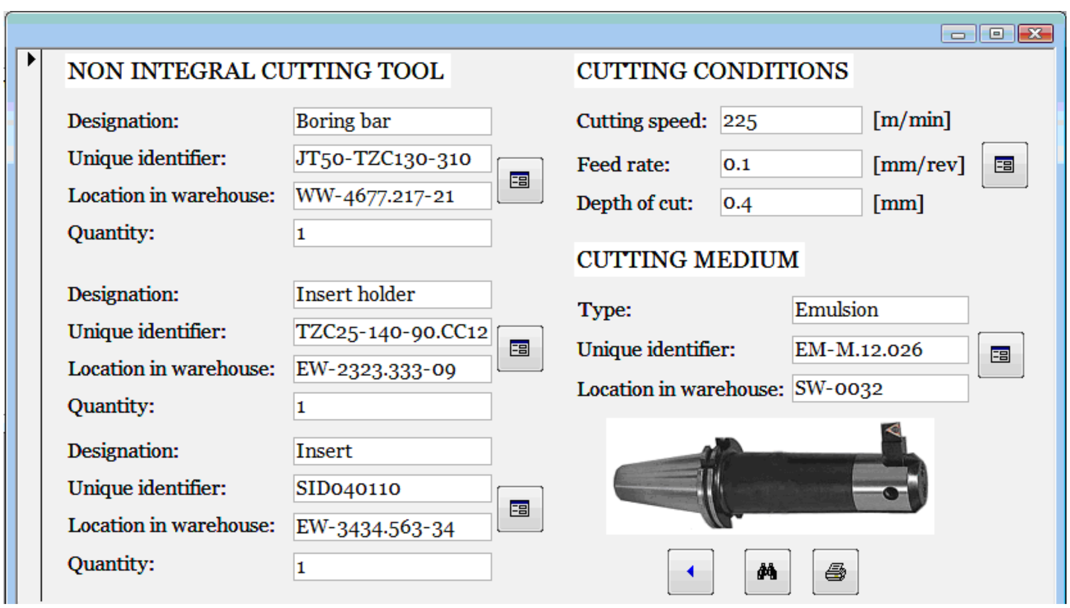


Figure 10. Output information from the system.

selected, the system suggests appropriate cutting tool conditions, and cutting medium. The process of identification and indirect management of cutting tool warehouse inventory is automated using RFID technology. Currently, the proposed system utilizes this technology for requisition of tools from the warehouse, while the rest of the cutting tool-related information is entered manually into the database. Considering the fact that RFID performed satisfactorily, future efforts shall be focused on implementation of RFID technology on the tracking of all other cutting tool flows in the system. In this way, the system also provides for a simple analysis of cutting tools requirements, as well as the analysis of the use of resources in the given period, which is necessary

for production management. In order to ensure wider application of the developed system, and provide economic effects, the system needs important improvements as regards the development of additional production rules, and database update with new cutting tools. The existing system modules shall also undergo continuous improvement.

Finally, system efficiency could be increased by an integration with a computer aided design and process planning system. This should significantly improve the quality and efficiency of the input data preparation stage.

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