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Djordje VUKELIC[1], Branko TADIC[2], Mitar JOCANOVIC[3], Ognjan LUZANIN[1], Nenad SIMEUNOVIC[3]

A SYSTEM FOR COMPUTER-AIDED SELECTION OF CUTTING TOOLS

ABSTRACT:
The importance of cutting tools in production systems requires modern approach to their selection. Automation of tool selection can significantly enhance efficiency of processes planning. Presented in this paper is development of a system for automated selection of cutting tools. Global concept as well as the concepts of the system's constituent modules are reviewed. Basic modules of the system are knowledge base, and cutting tools database. A case study is also presented. Finally, concluding remarks are given with suggested directions for future investigation.

KEYWORDS:
cutting tool, data base, knowledge base

INTRODUCTION

Constant advances in computer technology widen the field for computer application in engineering, and, therefore, process planning. Basic goal is to create conditions for application of manufacturing technologies capable of rapid adjustment to new production programs, while maintaining high quality, increased productivity, and reduced costs of manufacture.

These technologies feature high level of automation and flexibility, which is the strategy of development of flexible manufacturing systems. This can be illustrated by numerous examples of developed CAx systems and software applications of various purpose, which are used to automate tasks in product design, process planning, product management etc [1, 4].

Within a manufacturing system, the factors which most influence the quality of process planning are: type of blank, cutting technology, sequence of machining processes, machine tools, structure of machining processes, concentration of processes and operations, cutting tools, fixtures, measuring devices, and other. In order to improve process planning, all of these parameters must be optimized [8]. In the chain of factors influencing the output effects of manufacturing process, cutting tools are of great significance. Inadequate management of cutting tools reduces efficiency and economic effects of manufacturing system as a whole.

Development of a proper system for cutting tools selection allows improvement and rationalization of process planning. Computer-based system for cutting tools selection is one of the segments of computer integrated system (CIM), and as such is integrated into the sub-system for production planning and management [6].

There are several general characteristics of the so far developed systems for automated cutting tools selection [2, 3, 5, 6, 7]:

- these systems were developed for parts of pre-defined geometry,
- they allow interactive selection of cutting tools for specific set of machining processes,
- they are based on a rigid, algorithmic structure,
- they do not take into account all parameters that influence optimum selection of cutting tools.

The goal of this paper is to solve the above listed problems, through a development of an integrated and intelligent system for automated cutting tools selection. The system should allow selection of cutting tools for as large number of cutting processes, and typical operations as possible, regardless of complexity of part geometry.

SYSTEM STRUCTURE

The structure of the system for automated cutting tools selection is shown in Fig. 1.

The system input consists of necessary input information. These information are crucial for system functioning. According to entity characteristics which they describe, input data can be classified into:

- geometry data – comprise all data which are directly related to workpiece design, including the data related to geometric specification of product (dimensions, tolerances, surface quality, etc.).

- *manufacturing data – which completely define manufacturing process, and are listed within process charts of the pocess plan. One part of manufacturing data is entered by the user, while the rest of the data are generated during system operation which relies on the knowledge base.*

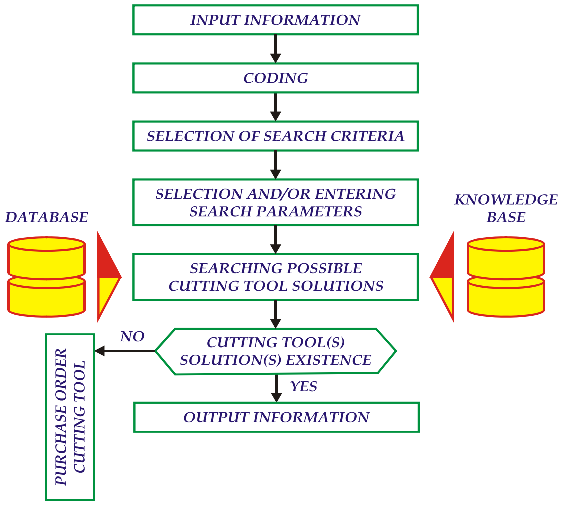

Fig. 1 System structure

Input information pertain to:

- *characteristics of workpiece material (type, sort, strength, hardness, tensile strength, etc.),*
- *type of machining,*
- *machine tool group,*
- *machine tool used for machining,*
- *number of machined surfaces,*
- *quality of machined surfaces*
- *type of machining process,*
- *typical operation,*
- *batch size,*
- *cutting regimes (speed, feed, etc.),*
- *surface quality,*
- *characteristic dimensions of machined surfaces,*
- *used coolant, etc.*

In order to select cutting tools which are required for particular cutting operations within a cutting process, it is necessary to perform coding. The coding must be suitable for software implementation. Based on the coded input information and the developed production rules, stored in the knowledge base, the database is searched for solutions which satisfy the set criteria. In this phase, cutting tools are selected. If there are several solutions that satisfy the criteria, which is often that case, the user selects a final solution which is derived based on built-in production rules.

Output information (cutting tool data) do not have unique format for all cutting tools, but are custom formatted for each tool. In no solutions have been found, an order for acquisition of the required cutting tool is issued.

Successful application of the system is possible only if prerequisites for its development have been provided. The basic prerequisites for the development of this system are knowledge base and cutting tools database.

SYSTEM DATABASE

Database design was based on the analysis of the three required groups of elements:

- *entities (objects or events) - represent an element for which the data should be stored. This element can be identified at any moment, i.e., it is possible to establish whether it exists or not. Entity can be an object (e.g., a cutting tool), or an event (e.g., a cutting process). There can be any number of instances of a particular type in the database (for example, a cutting process is the type which has following instances: face turning, hole drilling, slot milling, etc.),*
- *relationships (relationships between entities) - are established between two or more types of entities (e.g., relationship between machining process and a matching cutting tool for that process),*
- *attributes (features of entities and their relationships) - An entity is described by its attributes, i.e. its features. Thus, for instance, a product is described by its classification code, designation, material, dimensions, etc. If an attribute has some particular features, then it can also become an entity (e.g., exchangeable insert tip in a cutting tool). The same rule holds if an attribute can have several different values simultaneously.*

The development of the database was realized through three distinctive phases:

- *conceptual database design,*
- *logical database design, and*
- *physical database design.*

Conceptual database design comprises: semantic description of the problem, definition of all entities and relationships between them, creation of entity relationship (ER) diagram of the database data model. The result of conceptual design phase is materialized in the conceptual scheme, i.e., the ER model of the system database. The ER model is defined by entity diagram, which shows all the database entities with their relationships, and types of relationships.

Logical database design contains: a detailed description of data and creation of entity relationship model. The detailed data description means listing of attributes of all entities in the database, with their primary keys.

Physical database design encompasses following: physical description of structures which contain data, definition of tables, data types, lengths, indices, entering of data into database. Physcial database design is essentially the process which extends into the system exploitation phase. Beside the data entered by users, there is also a large quantity of data generated during the decision-making process which is based on the knowledge base. After that, the data are incorporated into the physical databse structure.

The database stores all the data required for successful functioning of the system. It contains data on each stored cutting tool. These data contain: identification number of cutting tool, cutting tool designation, cutting tool manufacturer, geometric features of cutting tool (dimensions, characteristic angles, etc.), and other.

The database can be constantly updated with new data, while the existing data can also be edited. The database user interface is adjusted to various database entities. This is logical, having in mind that, for example, attributes of the cutting tools which are entered in the database are different, even if they belong to the same group. The input of such data is controlled by input masks (which check on the data syntax, data ranges, and data types) which are implemented within the user interface to prevent user errors which could ultimately compromise the data consistency.

SYSTEM KNOWLEDGE BASE

System knowledge base must comprise a large volume of various knowledge in order to allow efficient integration of all elements of system architecture. There are several types of knowledge which the knowledge base must incorporate: procedural knowledge (rules, strategies procedures), declarative knowledge (concepts, objects, facts), meta-knowledge (knowledge on other kinds of knowledge and ways of their implementation), heuristic knowledge (unwritten, empirical knowledge), and structural knowledge (sets of rules, relationships between constructs, relationships between constructs and objects). One of the key components is heuristic knowledge which is based on assessment, and engineering intuition.

The knowledge base was developed by combining the data structures stored in the database, and the developed procedures. In this way, a system based on IF/THEN production rules was created.

IF represents a condition, while THEN represents a consequence of rule. If a condition is fulfilled, then the consequence is true, while the successive activation of several rules constitutes an inference chain. In this particular case, forward chaining was used, which is also known as the strategy driven data, since the user starts with the known conditions and searches for the consequences.

Shown in Fig. 2 is an example of using production rules for the selection of cutting tools for a hole drilling cutting process.

If
Workpiece material = Cast iron, and
Workpiece hardness = 220 HB, and
Typical operation = Drilling, and
Feature type = Inner hole, and
Batch size = 100, and
Nominal diametar = 8 mm, and
Upper tolerance = 0.012 mm, and
Lower tolerance = 0, and
Cuttnig lenght = 10 mm, and
Surface quality = N7

Then
Cutting tool = Twist drill
Cutting tool code = 338 - 7.8
Cutting tool = Reamer
Cutting tool code = 212 - 8

Fig. 2. An example of production rules

A condition can contain one or more conditional clauses which are interconnected by logical operators: AND, OR, NOT, ... If a condition is true, that is, if it satisfies all logical operators, the rule is activated, which means that the corresponding consequence is executed. In the opposite case, the rule is rejected.

The architecture of the knowledge base for cutting tools selection comprises parameter-based decision levels. The basic level of decision-making is based on typical operations, and it is further differentiated into decision-making sub-levels, which, depending on a particular case, are based on following parameters: machine tool, cutting process, and dimensions. By applying the knowledge base, one generates all required cutting tools for the cutting process in hand.

CASE STUDY

In order to verify the proposed system model, software solutions of some system modules were developed. To check their functionality, some tests were performed on real industrial examples.

The workpiece (cylinder liner) shown in Fig. 3, undergoes a process of internal honing of $Ø125^{+0.025}$ hole on a conventional vertical honing machine. Machining speed is 120 m/min, feed 22 m/min. Production is serial, with a 1000 pcs. batch size. Workpiece material is cast iron (SSL-3) with 250 HB hardness.

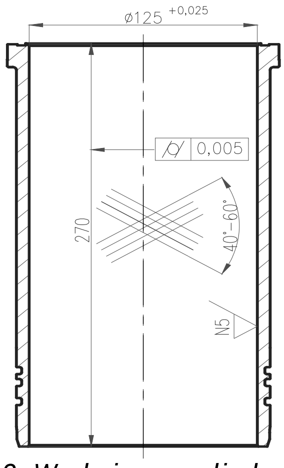

Fig. 3. Workpiece – cylinder liner

Upon starting the software application, the user begins an interactive work using interface forms. During work, the user answers the read questions by entering data and/or by selecting pre-defined data in particular fields. The user defines his/her own search criteria, depending on the problem in hand, by checking appropriate boxes (Fig. 4). It is possible to set one or more serach criteria for the selection of cutting tools. Depending on the set criteria, various forms are open (Fig. 5) and are used to select and/or directly enter appropriate geometric and manufacturing parameters.

Fig. 4. Selection of search criteria

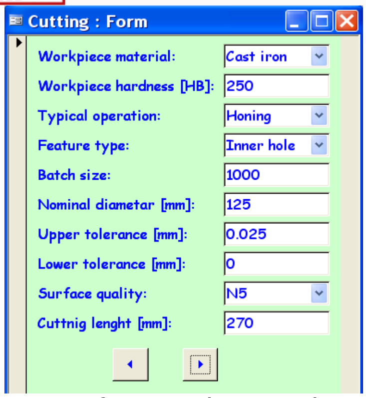

Figure 5. Forms for entering search parameters

In this way, by making queries based on input information, and the developed production rules, reports containing search results are generated. Shown in Fig. 6 is an example of output information for the selection of cutting tool (honing head) for the machining process of cylinder liner honing.

Fig. 6. Form showing a selected cutting tool

CONCLUSION

The system for cutting tools selection presented in this paper is based on modular principle, and relies on a database, a set of production rules, and an integrated software solution. The structure of this system required thorough systematization of prerequisite information for the selection of cutting tools. The basic pre-requisites are selection criteria and adequate decision-making logic. Under the given conditions, the developed system produces adequate solutions in real industrial applications, which results in the selection of the cutting tool which is most appropriate for the required cutting process.

Bearing in mind that computers by far surpass human abilities regarding processing capacity, memory, speed, and quality of work, automation of cutting tool selection results not only in higher quality solutions, but also significantly speeds up the process, thus reducing total costs. Furthermore, the level of designer's satisfaction is higher, while his/her work effort is reduced in almost all design phases.

Wider application of the proposed system which would result in practical manufacturing and economic effects, requires further comprehensive activities on database development, accompanied with adequate number of reliable manufacturing data. In addition, the modules within the already developed system structure require further improvement. Their introduction into practical industrial application should be alleviated by adjustments to the needs of particular production programs. System efficiency rate could be increased through integration with a system for computer-aided design (CAD), and computer-aided process planning (CAPP). These systems are capable of generating most of the input information required by the proposed system.

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AUTHORS & AFFILIATION

[1] Djordje VUKELIC
[2] Branko TADIC
[3] Mitar JOCANOVIC
[4] Ognjan LUZANIN
[5] Nenad SIMEUNOVIC

[1,4] DEPARTMENT FOR PRODUCTION ENGINEERING, FACULTY OF TECHNICAL SCIENCES, UNIVERSITY OF NOVI SAD, SERBIA.
[2] DEPARTMENT PRODUCTION ENGINEERING, FACULTY OF MECHANICAL ENGINEERING, UNIVERSITY OF KRAGUJEVAC, SERBIA.
[3,5] DEPARTMENT INDUSTRIAL ENGINEERING AND MANAGEMENT, FACULTY OF TECHNICAL SCIENCES, UNIVERSITY OF NOVI SAD, SERBIA