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Methodology for Cutting tool selection system based on STEP_NC. Part 1: Development of tool Management system according to ISO13399 standard

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ABSTRACT
Computer aided process planning (CAPP) systems are considered as an important interface between computer aided design and computer aided manufacturing systems. One of the main objectives of CAPP systems is to assign adequate tools to manufacture the part. In fact, selecting the best tool is a critical activity and depends on numerous factors related essentially to the part and tool characteristics, machining conditions, etc. This paper describes a methodology for cutting tool selection based on STEP_NC and using tool definition according to ISO 13399 standard. The main focus was on milling process. A study of influencing parameters was conducted and some concluding remarks were made. The paper emphasizes the importance of the definition of cutting tools according to STEP-NC and ISO13399 standards in data tool exchange and proposes an automated optimized methodology for cutting tool selection. In this paper, a database was developed to ensure management of cutting tool using MySQL SERVER. Data tool were extracted from Sandvik Corormant ISO 13399 product library, by development of a new software using object oriented approach.
Keywords: Cutting tool selection, STEP_NC, ISO13399,Object oriented programming, database.

I. INTRODUCTION

Cutting tool selection is considered as an important stage in the process planning and it is a critical activity that has a great influence on machining productivity and efficiency.

To keep up with fast paced technology, modern factories tend to use new solutions to reduce cost and time labor and to achieve their performance objectives. Yet, CAPP system were increasingly used to automate process planning activities.

In the early 1980s, research work was undertaken in the area of computer-aided manufacturing and process planning systems have been developed to select a tool or a set of tools for a specific operation or a set of operations.

Xiaoping Ren, Zhanqiang Liu and Yi Wan [1] developed a computer-based intelligent system for Automatic tool selection for different tool materials. The procedure of selection goes through several main steps: feature specification, machining type selection, cutting tool selection and optimum cutting conditions.

Carpenter and Maropoulos [2] developed a flexible tool selection decision support system for milling operations, the system is called OPTIMUM (Optimized Planning of Tooling and Intelligent Machinability evaluation for Milling).It combines a knowledge based logic and statistical methods.

Mookhrejee and Bhattacharyya [3] developed an expert system Extool which automatically selects the turning tool/insert or milling insert, the material and geometry.

Edalew, Abdalla and Nash [4] developed a system for the selection of cutting tools. It's a dynamic programming based system that utilizes mathematical modules and heuristic data to determine and calculate cutting parameters and total component cost. The system contains the following modules: the knowledge acquisition module, the knowledge base module, the inference engine, the user interface and the database.

Arezoo, Ridgway and Al-Ahmari [5] developed a knowledge based system for selection of cutting tools and conditions of turning operations. It contains an inference engine, a user interface and explanation facility, a knowledge base and an optimization module for machining conditions.

The literature review shows that there have been considerable efforts in developing cutting tool selection systems, nevertheless, there still a lack of manufacturing interoperability between CAD/CAPP/CAM/CNC chains. In fact, design and cutting tool information are lost when exchanging information between dissimilar systems. For example, at the process planning stage, cutting tools are defined with their associated parameters (diameter, length, grades etc…), however, when moving to machining stage, the CNC program define the tool with only its position, (e.g. T0100), and no further information is given about it.

Unlike the traditional standard ISO 6983 (G-code), STEP-NC has the ability to link the machining chain components providing a bi-directional flow of data between them. Considering the power of STEP_NC standard and the importance of cutting tool management in enhancing machining productivity, this project aims the development of an automatic optimized cutting tool selection system based on the STEP_NC standard.

This project is the perspective of previous works launched recently by Research team in Engineering, Innovation and Management of Industrial Systems, FST of Tangier, which deals with CAD/CAPP/CAM integration using STEP_NC standard.

El mesbahi et al presented an automated and optimized cutting tools selection system for milling process[6].

In [7], Jaider proposed a CAPP system "CAPP TURN" based on STEP and STEP_NC standards for turning process.

In this paper a cutting tool selection methodology is presented. First, the paper outlines the utility of proposed standards, shows the results of cutting tool parameters study, then gives the architecture of cutting tool selection system with description of its principal modules. Finally, database implementation and data tool extraction module are described with a case study.

II. STEP_NC STANDARD

The STEP_NC_AP238 and ISO 14649 standard is the result of a 10 year international effort to replace the ISO 6983 G and M code standard with a modern language connecting CAD data with CAM process data [8].

STEP /ISO 10303, the standard for the exchange of product model describes a complete and unambiguous product definition throughout the life cycle of a product. STEP standards consist of numerous Application Protocols (APs). Each AP is focused on defining information for a particular application domain. An AP had three parts:

• Application activity model (AAM)—a model of the activities and data flows of the application.

• Application reference model (ARM)—a model of the data needed for a particular application.

•Application interpreted model (AIM)—an encoding of the ARM in terms of the STEP integrated resources. This is the model that is intended for implementation in systems that use STEP.

Figure 1 describes design and process data flow with main associated STEP application protocols. The STEP AP 203 describes geometric representation data while AP 224 is used to describe machining features. The machining feature definitions are used as inputs to process planning stage. Micro process planning for machining is then carried out using AP 238. STEP-NC is the application of STEP methods to NC machines. Its title is "STEP Data Model for Computerized Numerical Controllers", representing a common data specifically aimed at NC programming. STEP-NC has been and continues to be a global effort with the goal of providing a data model for a new breed of intelligent CNC controllers.

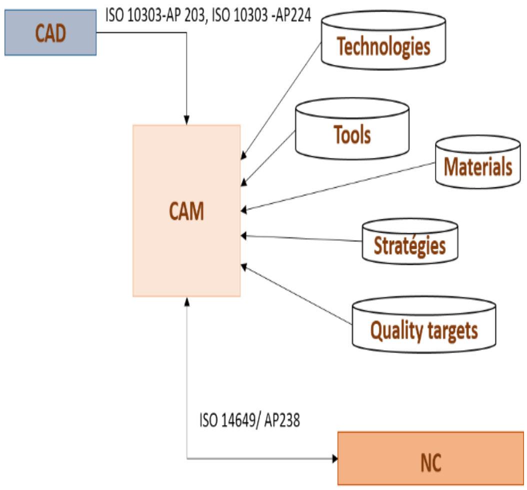


Figure 1. Design and process DATA flow with associated standards

III. CUTTING TOOL DATA EXCHANGE

Regarding the poor representation of tool in the older ISO 6983 G and M code language, there is an increasing need for manufacturers to adapt a standard for cutting tool data representation. This urgent need emanates from the fact that the G& M code describes only the path of the tool center point with respect to machine axes. Consequently, even if the tool selection is done automatically with CAM systems, information about tool (geometry, properties…) will be lost when moving to the machining stage.

Responding to this problematic, the proposed tool selection methodology is based on both STEP_NC and ISO13399 emerging standards.

II.1. CUTTING TOOL REPRESENTATION IN STEP_NC/ ISO14649

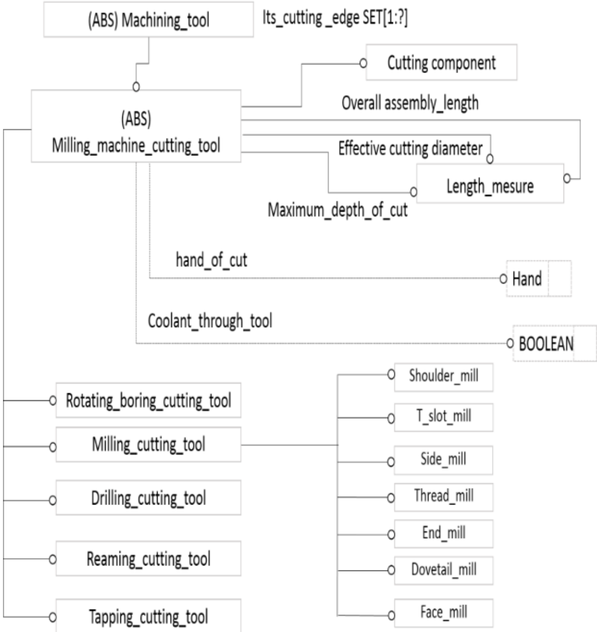


Figure 2. Express G diagram for milling machine cutting tool

Description of cutting tool data for turning and milling are specified in ISO 14649 part 111[9] and ISO14649 part 121[10] respectively.
ISO 14649 defines a richer model for information transfer between CAD/CAM systems and computerized numerical control (CNC) machines than that of the older ISO 6983 "G and M code" language. As we had already mentioned, in ISO 6983, tools are defined with only their identifiers without any further information, while in a STEP_NC file, tools are defined in express language with values of properties required in machining (e.g. cutting length, hand of tool, depth of cut …) figure 2 describes milling tool representation in STEP_NC.
II.2. Data tool representation in ISO13399 Standard
ISO13399 includes the data representation of everything between the workpiece and the machine tool: Information about inserts (e.g. regular and irregular shaped replaceable cutting items), solid tools (e.g. solid drill and solid end mill), assembled tools (e.g. boring bars, indexable drills and indexable milling cutters), adaptors (e.g. milling arbor and chucks), components (e.g. shims, screws and clamps) or any combination of the above can be exchanged.
The cutting tool data described include, but are not limited to:

- geometrical and dimensional data,
- identification and designation data,
- cutting material data, and component connectivity.

The purposes of ISO 13399 and ISO 14649, in regards to tool information, are different. ISO 13399 is a standard for the description of cutting tool as products, while ISO 14649 only describes some simple tool requirements to be used by the CNC when deciding what cutting tool to use [11].

An ISO 13399 exchange file contains an electronic representation of cutting tool data as defined by the information structure that can be exchanged by tooling applications.

ISO 13399 is defined as a Schema in the ISO 10303 Express language. The ISO 13399 schema develops a framework in which to define tooling properties, tooling assemblies, and relationship between tooling elements. There are no actual tooling properties in the ISO 13399 schema. Instead ISO 13399 develops a programming structure in which to embed ISO 13584, which is the Industrial automation systems and integration – Parts library (PLIB) [12]. As depicted in Figure 3, the P21 file contains links to other files that is needed.

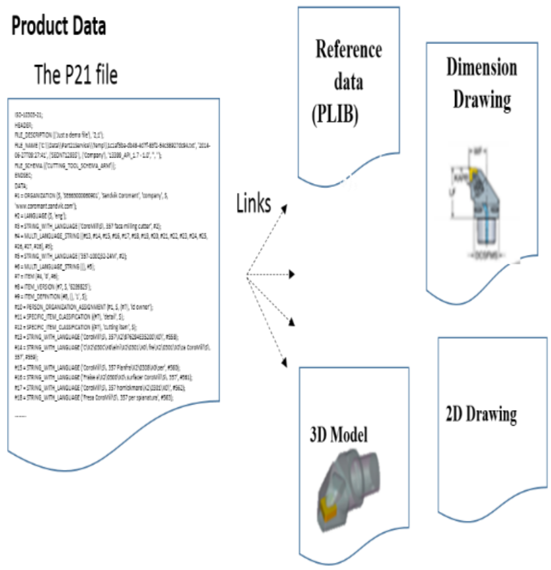


Figure 3. Product data representation in ISO 13399

IV. STUDY OF INFLUENCING PARAMETERS

One important step in designing Tool database is to study cutting parameters which are of great importance in selecting cutting tools. Our main focus was on milling process. The result of study shows three types of factors that influence tool selection.

III. 1. Parameters related to workpiece

Feature type: The type of feature is considered as a decisive parameter when selecting cutters. Suitable tools are selected by feature category. Indeed, machining features can be divided into two categories, simple features and complex features. Simple features are realized by using one machining operation, for example, a face and a shoulder can be performed by face milling and shoulder milling respectively. Complex features require at least two machining operations such as curved surfaces and freeform surfaces (features), which require roughing and profiling operations.

Surface roughness: Surface roughness is considered as a critical parameter to select tools and number of applications. For example, a feature having surface roughness of 0.8 (Ra =0.8) have to be machined in three applications, roughing, semi-finishing, and finishing application.

Material of the workpiece: Material of workpiece is a determinant factor for selecting the type of the cutter, the insert grade and the machining parameters. The manufacturer gives the designations of materials and their characteristics such as Specific cutting force and Brinell hardness. Depending on the insert grade and the type of material, the manufacturer gives the maximum chip thickness and the recommended cutting speed.

Dimensions of the feature: Dimensions of the feature represent an important parameter that lead the choice of milling tool. In fact, the depth of the feature is critical to determine the type of the cutter and the insert size, on the other hand the length of the feature represents an indicator of which diameter to choose.

III.2. Parameters related to Cutting tool:

Depth of cut (ap): in mm (axial) is what the tool removes in metal on the face from the workpiece. This is the distance the tool is set below the un-machined surface.

Tool material: Different machining applications require different cutting tool materials. The cutting tool material affect directly the cutting hardness, temperature stability and tool life.

Cutting width (ae): in mm (radial) is the width of the component engaged in cut by the diameter of the cutter. It is distance across the surface being machined or, if the tool diameter is smaller, that covered by the tool.

Entering angle: As regards cutting geometry in milling, the entering angle (κr), or the major cutting edge angle, of the cutter is the dominant factor affecting the cutting force direction and chip thickness. The choice of insert geometry has been simplified into three practical areas of varying cutting action effects: Light (L), general purpose (M) and tough (H) geometries.

Zc: The number of effective cutter teeth (Zc) in the tool varies considerably and has a direct effect on table feedrate and productivity. The material, width of component, stability, power, surface finish influence how many teeth are suitable.

III.3. Parameters related to machining process

Cutting speed (vc): in m/min indicates the surface speed at which the cutting edge machines the workpiece. This is a tool oriented value and part of the cutting data which ensures that the operation is carried out efficiently and within the recommended scope of the tool material.

Spindle speed (n): in rpm is the number of revolutions the milling tool on the spindle makes per minute. This is a machine oriented value which is calculated from the recommended cutting speed value for an operation.

Feed per minute (f): also known as the table feed, machine feed or feed speed, in mm/min is the feed of the tool in relation to the workpiece in distance per time-unit related to feed per tooth and number of teeth in the cutter.

Maximum chip thickness (hex): in mm is the most important limitation indicator for a tool, for an actual operation. A cutting edge on a milling cutter has been designed and tested to have a recommended starting value and a minimum and maximum value.

V. GLOBAL SYSTEM ARCHITECTURE

Based on the results of Functional analysis stage, we defined the global architecture of the automatic tool selection system.

Figure.4 shows flow chart of tool selection systems with inputs, outputs and relations between its modules: Tool management module, recognition module, Selection module and optimization module.
The data tool management module consists of a solid tool database linked to a data tool extraction software. Extraction procedure starts by uploading the ISO13399 file which contains information about tool, then these information are extracted and stored in the database.

Considering that the system is based on STEP_NC standard, the process of tool selection starts by uploading the AP238 file of the Part. This numerical file contains necessary information to manufacture the part. It also comprises geometrical, topological and technical (material, tolerances...) definitions of the part to manufacture.

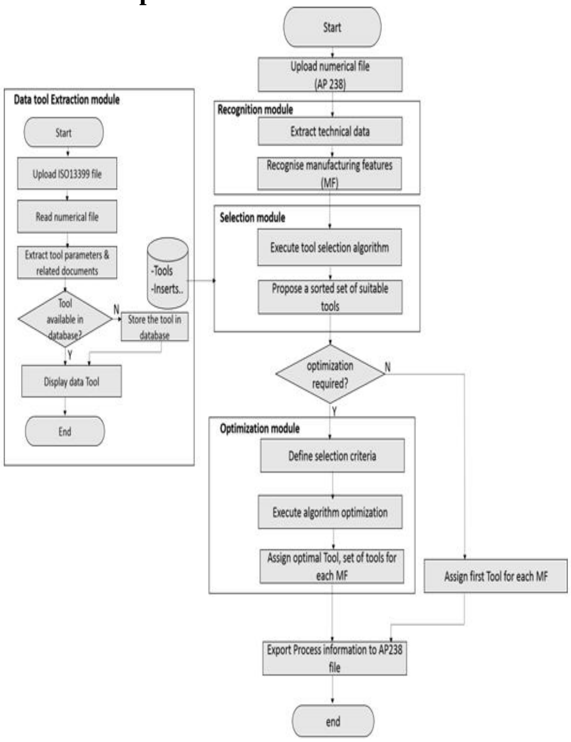
All of these technical definitions will be extracted using an object oriented program that allow also recognition of manufacturing features. Then, based on information stored in Tool database, and using an appropriate tool selection algorithm, Milling cutters are sorted and affected to Manufacturing features of the part.

A user interface allows planners to determine either to stop selection process and generate STEP_NC AP238 file for machining or to activate optimization module before generation.

In the second case, the user is invited to select optimization criteria and determine its preferences before starting optimization algorithm. Finally, optimal tools will be assigned to manufacturing features and the result is the numerical file STEP_NC AP238 which contains machining process information.

VI. DEVELOPMENT OF DATA TOOL MANAGEMENT MODULE

VI.1. Development of tool database



A tool database was created to provide better management of tools. The first step was the elaboration of data dictionary. The next step was data tools classification into entities and attributes. Then, identification of relationships between tables was undertaken before database implementation. The relational diagram depicted in figure 5 was developed under MySQL workbench software. It consist of 21 tables. The tool table is the principal entity, tool can be either a milling tool represented by mill table or a turning tool represented by turn table. Each tool can be linked in machine direction to a holder or an adaptive item. In the workpiece direction, the tool is linked to the insert. There are different child insert tables (round insert, equilateral equiangular insert, etc) that derive from principal insert table due to different existing insert categories.

Inheritance relationships between classes were conceived based on tool and cutting item classification in ISO13399 part 2 [14] and ISO 13399 part 3[15] respectively. For example, a face mill derived from Mill class which derived from tool item class.

We choose to feed database automatically with data from The Sandvik Coromant [16] ISO 13399 catalogue for milling and turning tools. For this purpose an object oriented program was created using c# programming to extract technical data from ISO file and ensure data feed and update of database. More details on software functionalities are given in the following section.

VI.2. Development of data tool extraction software

In this section, we present the data tool management module and its principal functionalities. Figure 6 is a use case diagram which illustrates interactions between actors and tool management system.

There are two principal actors:The tool administrator: its principal role consist on feeding database with updated information tools by uploading the P21 file of products(tools, inserts, holders..) according to ISO 13399 standard.

The tool administrator could also modify an existing tool in the database.

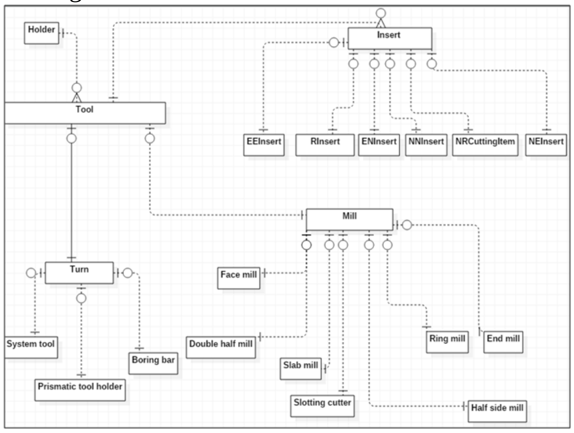


Figure. 5. Data tool relational diagram

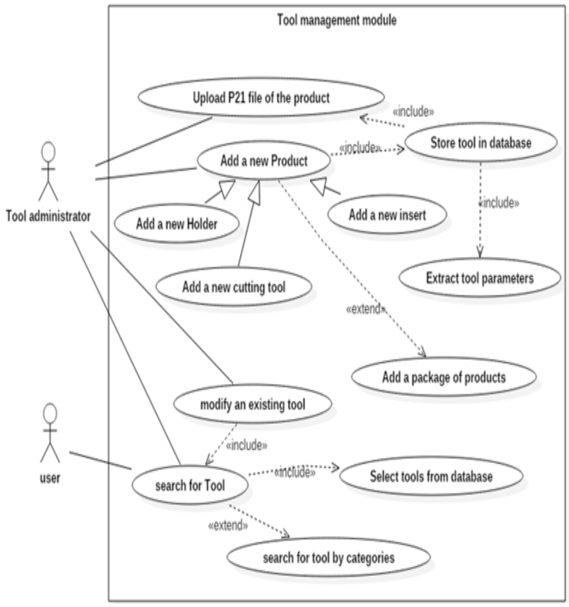


Figure 6.Tool management module: Use case diagram

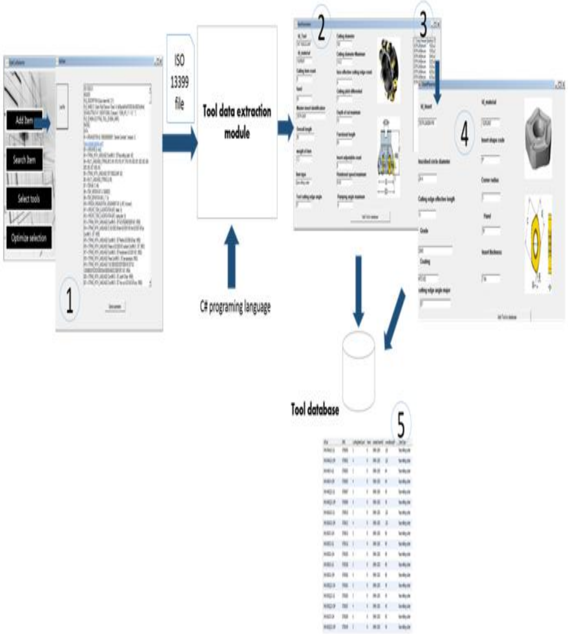


Figure 7. Data tool extraction software.

The ordinary user: The user has the possibility to search for available tools in the database. The research could be for a unique tool or by tools categories/classes (e.g. tools for turning tools for face milling, etc.). Figure.7 is an example of adding a new milling tool “CoroMill 357” and its corresponding insert to database. In widget 1, the tool administrator upload the corresponding ISO13399 file of the tool. He activates tool extraction procedure by click on extraction button, then tool parameters are shown in widget 2 with corresponding 2D and 3D views. Search for related inserts is done and results are displayed in a list (3). By clicking on the extract button, search for the Iso 13399 file of the insert is done automatically and the same extraction procedure is run. Insert parameters are shown in details in widget 4. By clicking on “add to database button”, the tool administrator could add the tool and the insert to database (widget 5).

VII. CONCLUSION

The aim of this paper was to dress the architecture of our automatic optimized cutting tool selection system which is currently under development, based on STEP_NC standard. The paper dealt also with the development of the data tool extraction module and database that will be of great importance to the automation of cutting tool selection.

The data tool extraction module was the automatic solution to feed and update database. Since tools manufacturers tends to adopt ISO13399 standard, we consider to update database with recent tool data to provide an effective way of tool selection. Development of feature recognition, tool selection, and optimization modules will be the object of future works.

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