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AUTOMATIC FEATURE RECOGNITION FOR ROTATIONAL PARTS

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Abstract. Recently, many research works have been done for CAPP integration since CAPP systems represent the main bridge between Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). One of the most difficult tasks in CAPP systems is to generate automatic process plans. This task is impossible unless that a feature recognition system is implemented in CAPP systems. Research in feature recognition has received significant attention, however, the majority of feature recognition systems for rotational parts treat isolated features. Feature recognition becomes more complex when features interactions occur, and a huge number of features combinations is generated, which can lead to computational combinatorial explosion. The aim of this paper is to explain on one hand, a new system of recognizing both isolated and interacting features for rotational parts by analyzing geometric and topological data extracted from STEP AP203 data file. And on other, to show how systematically, the system can reduce the number of combinations generated due to interacting features, taking into account manufacturing rules and metal removal principles. An illustrative example is presented to test and validate the method.

1 INTRODUCTION

The main purpose of any manufacturing companies is to produce high quality products at the lower possible cost. At the same time, the continuous changes in customer needs are to be satisfied. To suit these requirements, manufacturing industry needs more automation from design activities to manufacturing activities, ensuring an easier, a faster and a flexible workflow [1]. In the recent years, the integration of Computer Aided Process Planning (CAPP) has received significant attention because it provides a vital link between computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). CAPP selects the necessary resources including machine tools, cutting tools, fixtures, processes, and generates automatic sequences of operations and instructions to manufacture a desired workpiece, taking into account, manufacturing features, surface roughness and Geometric Dimensioning and Tolerancing (GD&T) related to part features, and economic and technological precedence constraints. To achieve these tasks, CAPP has to extract and recognize manufacturing information such as machining features directly from 3D solid model.

In spite of using advanced automation technology, the link between CAD and CAPP systems is still not integrated as desired [2]. the data of the neutral files such as STEP, IGES generated by CAD systems consist of geometric and topological information that cannot be used for direct application to CAPP systems such as process planning, since CAPP systems require manufacturing features, not geometric and topological information, otherwise, CAPP systems do not understand the three dimensional geometry of the designed parts in term of their manufacturing meaning related to other product information, such as material properties, technological parameters, and required manufacturing precision [3]. Many research efforts have been done for automatic feature recognition for rotational parts and the majority of authors have focused on recognizing isolated features. However, feature recognition becomes more complex when features interactions occur, some surfaces of features are lost by interactions. Another problem is the huge number of features combinations generated due to interactions. This can lead to computational combinatorial explosion and time consuming.

To solve the CAD and CAPP interface problems, the implementation of a feature recognition module in CAPP systems is imperative, in which manufacturing information, geometric and topological data are extracted, recognized and stored together. For the purpose, a neutral format for the representation is required for facilitating an interface between different CAD/CAPP/CAM systems. There are different neutral files available, IGES, STEP, DXF, STL files etc. In this paper, the STEP AP203 file [4], is taken as an input to the developed system. STEP is an emerging international standard protocol for the exchange of technical product data. It enables all individuals contributing to the design, manufacturing, marketing and supply of a product and its components to contribute, to access, and to share information. Many major multinational companies have investigated significant resources for its development and implementation [3]. The main objectives of the work presented in this paper are to recognize features for rotational parts on one hand, and on the other hand, to generate optimal combinations of interacting features based on features elimination. The developed system includes three modules. They are as follows:

Module 1: Development of a Geometric and Topological Data Extraction system to extract information from STEP AP203 file.
Module 2: Development of Automatic Feature Recognition system and feature elimination system.
Module 3: Development of a Feature Generator system to generates all possible interpretations of interacting features.

2 LITERATURE REVIEW

Automatic Feature Recognition (AFR) directly from a CAD model is the first and the most difficult task in a CAPP system to achieve downstream activities such as automatic process planning. There have been many previous attempts to recognize form features for manufacturing purposes, which can be broadly classified into four major categories: Syntactic pattern recognition, Graph based, Rule based, and artificial neural network method.

Ismail & Abu Bakar (2005) [5] used syntactic pattern recognition method for feature recognition. An upper half of the 2D profile information of a part is given, which is a series of lines and arc segments that represent semantic primitives written in some description language. A set of grammar using a sequence of characters, which consists of some rules, defines a particular feature. The parser for input sentence analysis has been then used to apply a grammar to the part description (features connected to form a part). If the syntax agrees with the grammar, then the description can be classified in a corresponding class of features.

Mehalawi & Miller (2003) [6] used an attributed adjacency graph (AAG) for building a database that captures the geometric and topological similarity in order to facilitate extraction of machining features. Workpieces are represented using attributed graph-based on STEP file, in which the nodes correspond to the surfaces of the Workpiece and the links correspond to the edges of the Workpiece. The main limitation of this approach is its inability to detect features with non-planar surfaces.

Abouel Nasr & Kamrani (2006) [7] proposed a methodology for 3D prismatic parts that are modeled using constructive Solid Geometry (CSG) technique as a drawing tool. The system takes a neutral file in Initial Graphics Exchange Specification (IGES) format as input and translates the information in the file into manufacturing information. The boundary (B-rep) geometrical information of the part design is analyzed by a feature recognition program that is created specifically to extract the features from the geometrical information based on a geometric reasoning approach, by using object oriented design software. A feature recognition algorithm is used to recognize different features of the part such as step, holes, etc.

Sivakumar & Dhanalakshmi (2012) [1] developed a system that uses a simplified and generalized methodology of extracting manufacturing features from STEP AP203 file for cylindrical parts. The dimensional and geometric information of the part features and their positions are extracted from STEP file using feature extraction process. The extracted dimensional and geometric information are stored in a text file and these data are analyzed using logic rules for identifying turning features. An example logic rule to recognize a cylinder feature is used as follows:

IF STEP data contain CILYNDRICAL_SURFACE and the radius is same at both end surfaces

THEN the feature is identified as straight cylinder

This method lack of extracting topological information, and classifies features as elementary surfaces as shown in STEP file, like tapers, plans, cylinders and so on. Therefore, features formed by several elementary surfaces such as grooves are not recognized. Another drawback is that the method does not handle interacting features.

Malleswaria & Sarcar (2013) [3] developed a new feature recognition software for rotational parts which uses STEP file as input. The software analyses various strings and entities (# number) in the STEP file and extracts dimensional, geometric and topological information including, EDGE_CURVE construction of surfaces, circle centers, radius of the circles, type of surfaces, surface radius and axis coordinates of surface. The software evaluates and interprets the exacted data in terms of manufacturing and recognizes features for turned components. Rule based technique is used during recognizing process.

Nawara & Atia (2009) [8] presented a methodology of 3D prismatic parts classification based on the geometry of their machining features. The methodology works in three main phases. The first phase takes a neutral file in STEP-AP203 format as input, restructures it and extracts the geometric information of the machining features. The second phase recognizes the machining features through training neural network (NN) with a large set of feature patterns. The third phase classifies parts based on the variation in geometry of their machining features using self-organized map (SOM) NN.

3 GEOMETRIC AND TOPOLOGICAL DATA EXTRACTION (GTDE) FROM STEP FILE

The STEP file is a text file that contains geometric and topological data of a component including boundary representation data such as shells, faces, edge loops, vertices; surface geometric data such as planes, cylinders, cones, toroidal, spherical; curve geometry such as lines, circles, B-splines, ellipses. The STEP text file is begun by the keyword ISO-10303-21and is terminated by keyword END-ISO- 10303-203. The high level of description in STEP is the shell. A shell is a topological item that is constructed by joining faces along edges. Searching STEP file starts with a string CLOSED_SHELL and ends with the coordinates of points such as circle centers, line centers, cylinder centers, vertices and so on. Extraction of various strings and entities (# number) from STEP file is done according to the hierarchical structure shown in Fig. 1. In this research, C++ language is used to search various strings and entities in the STEP file. C++ is based on object oriented programming, as a result, representation and extraction of geometric and topological data from STEP file become simple and easy. The command string::size_type loc = str.find(" CYLINDRICAL_SURFACE ", 0) is an example of one of the functions that can be used to locate a specified text string. Like this all the strings are located and stored in a data base in such a way that the extracted data are coherently ordered.

4 FEATURE RECOGNITION, CLASIFICATION, AND ELIMINATION

4.1 Automatic Feature Recognition (AFR)

The proposed system for feature recognition has its own method for the evaluation of the extracted geometric and topological data obtained from the GTDE module. geometric data analysis addresses the evaluation of circle centers coordinates, cylinder centers coordinates, taper centers coordinates, torus centers coordinates, hemisphere centers coordinates, circle radii, cylinder radii, circles, lines, surfaces, and so on. Topological data analysis concerns the evaluation of loops, edge curve construction, inner bounds, outer bounds, vertices and so on. This system possesses a database of thirty turning-pre-defined manufacturing features including internal features, external features, and complex features such as grooves and recesses. The developed system adopts the rule-based approach that uses algorithms to identify a feature according on certain prespecified rules that are characteristic to the feature. It must be noticed that the coordinate system that was adopted is XY (X for the diameter and Y for the length). In this paper, the groove feature has been proposed to use in feature recognition system for explanation of above aspects. An example part which contains a groove feature and a partial STEP file of the same example part are given in Fig. 2 and Fig. 3 respectively. The following set of heuristic rules is used to describe recognition of a groove:

- *Geometric rules:*

Rule 1:

The STEP data must contain two CYLINDRCAL_SURFACEs with different radius (#56, #113) and circle centers (#123, #149, #137 and #154) of the cylinder with minor radius (#113) lie between centers of end circles (#80, #97, #175 and #201) of the cylinder with major radius.

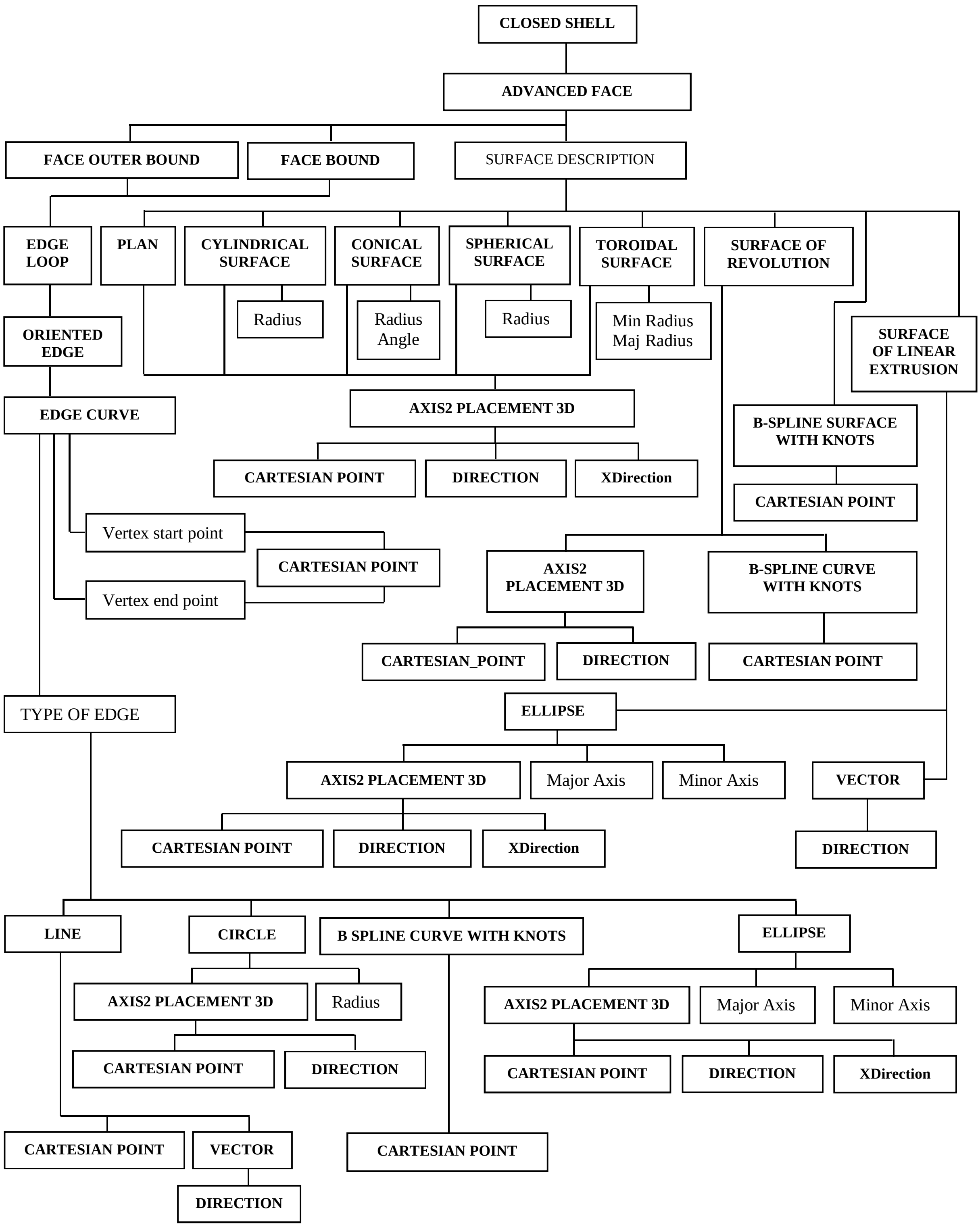


Figure 1: Page Hierarchical structure of STEP AP203

Rule 2:
X and Z coordinates of cylinder centers and circle centers are the same, and Y coordinate is different.
Rule 3:

The length of the feature must be less than 16mm. The length of the groove is equal to the distance between end circle centers of the cylinder with minor radius. The depth of the groove is equal to the difference between the big and the small radius.

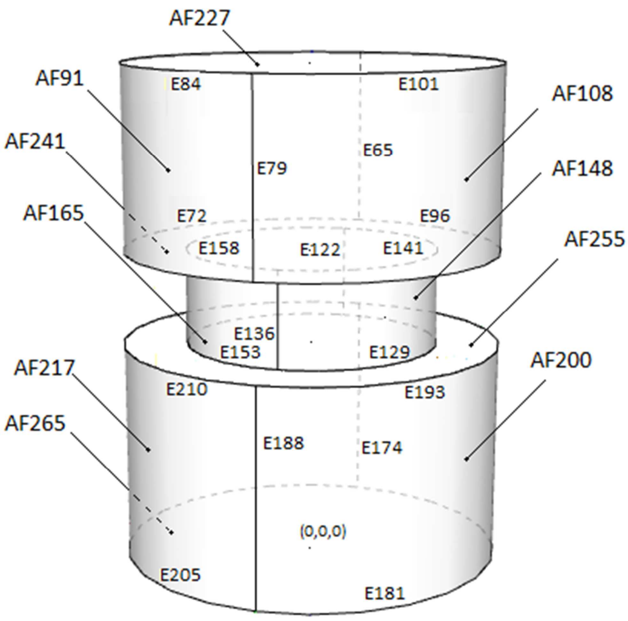


Figure 2: An example part containing a groove.

- *Topological rules:*

Rule 1:

Edge curve construction of CYLINDRICAL_SURFACEs must be; line, circle, line circle (#117, #126, #133 and #140), or; circle, line, circle, line.

Rule 2:

Every CYLINDRICAL_SURFACE (ADVANCED_FACE) shares two common linear edges with another of the same type.

Rule 3:

STEP data must contain two PLANEs (#232, #246) bounded respectively each by an inner loop (#240, #254) and an outer loop (#236, #250). Circles that form each inner loop are the same circles of the cylinder with minor radius (#140, #157, #152 and #126). Circles that form each outer loop are four circles (#95, #69, #192 and #209) among eight of the cylinder with major radius.

```
#56=CYLINDRICAL_SURFACE('generated cylinder',#55,40.) ;
#52=CARTESIAN_POINT('Axis2P3D Location',(0.,35.,0.)) ;
#113=CYLINDRICAL_SURFACE('generated cylinder',#112,20.) ;
#109=CARTESIAN_POINT('Axis2P3D Location',(0.,35.,0.)) ;
#69=CIRCLE('generated circle',#68,40.) ;
#66=CARTESIAN_POINT('Axis2P3D Location',(0.,50.,0.)) ;
#95=CIRCLE('generated circle',#94,40.) ;
#92=CARTESIAN_POINT('Axis2P3D Location',(0.,50.,0.)) ;
#83=CIRCLE('generated circle',#82,40.) ;
#80=CARTESIAN_POINT('Axis2P3D Location',(0.,70.,0.)) ;
#100=CIRCLE('generated circle',#99,40.) ;
#97=CARTESIAN_POINT('Axis2P3D Location',(0.,70.,0.)) ;
#126=CIRCLE('generated circle',#125,20.) ;
#123=CARTESIAN_POINT('Axis2P3D Location',(0.,30.,0.)) ;
#152=CIRCLE('generated circle',#151,20.) ;
#149=CARTESIAN_POINT('Axis2P3D Location',(0.,30.,0.)) ;
#140=CIRCLE('generated circle',#139,20.) ;
#137=CARTESIAN_POINT('Axis2P3D Location',(0.,50.,0.)) ;
#157=CIRCLE('generated circle',#156,20.) ;
#154=CARTESIAN_POINT('Axis2P3D Location',(0.,50.,0.)) ;
#178=CIRCLE('generated circle',#177,40.) ;
#175=CARTESIAN_POINT('Axis2P3D Location',(0.,0.,0.)) ;
#204=CIRCLE('generated circle',#203,40.) ;
#201=CARTESIAN_POINT('Axis2P3D Location',(0.,0.,0.)) ;
#192=CIRCLE('generated circle',#191,40.) ;
#189=CARTESIAN_POINT('Axis2P3D Location',(0.,30.,0.)) ;
#209=CIRCLE('generated circle',#208,40.) ;
#206=CARTESIAN_POINT('Axis2P3D Location',(0.,30.,0.)) ;
#148=ADVANCED_FACE('Corps principal',(#147),#113,.T.) ;
#147=FACE_OUTER_BOUND('',#142,.T.) ;
#142=EDGE_LOOP('',(#143,#144,#145,#146)) ;
#143=ORIENTED_EDGE('',*,*,#122,.T.) ;
#144=ORIENTED_EDGE('',*,*,#129,.F.) ;
#145=ORIENTED_EDGE('',*,*,#136,.F.) ;
#146=ORIENTED_EDGE('',*,*,#141,.T.) ;
#122=EDGE_CURVE('',#119,#121,#117,.T.) ;
#129=EDGE_CURVE('',#128,#121,#126,.T.) ;
#136=EDGE_CURVE('',#135,#128,#133,.T.) ;
#141=EDGE_CURVE('',#135,#119,#140,.T.) ;
#117=LINE('Line',#114,#116) ;
#126=CIRCLE('generated circle',#125,20.) ;
#133=LINE('Line',#130,#132) ;
#140=CIRCLE('generated circle',#139,20.) ;
#241=ADVANCED_FACE('Corps principal',(#236,#240),#232,.T.) ;
#232=PLANE('Plane',#231) ;
#236=FACE_OUTER_BOUND('',#233,.T.) ;
#233=EDGE_LOOP('',(#234,#235)) ;
#234=ORIENTED_EDGE('',*,*,#96,.T.) ;
#235=ORIENTED_EDGE('',*,*,#72,.T.) ;
#96=EDGE_CURVE('',#64,#71,#95,.T.) ;
#72=EDGE_CURVE('',#71,#64,#69,.T.) ;
#240=FACE_BOUND('',#237,.T.) ;
#237=EDGE_LOOP('',(#238,#239)) ;
#238=ORIENTED_EDGE('',*,*,#141,.F.) ;
#239=ORIENTED_EDGE('',*,*,#158,.F.) ;
#141=EDGE_CURVE('',#135,#119,#140,.T.) ;
#158=EDGE_CURVE('',#119,#135,#157,.T.) ;
#255=ADVANCED_FACE('Corps principal',(#250,#254),#246,.F.) ;
#246=PLANE('Plane',#245) ;
#250=FACE_OUTER_BOUND('',#247,.T.) ;
#247=EDGE_LOOP('',(#248,#249)) ;
#248=ORIENTED_EDGE('',*,*,#193,.F.) ;
#249=ORIENTED_EDGE('',*,*,#210,.F.) ;
#193=EDGE_CURVE('',#187,#171,#192,.T.) ;
#210=EDGE_CURVE('',#171,#187,#209,.T.) ;
#254=FACE_BOUND('',#251,.T.) ;
#251=EDGE_LOOP('',(#252,#253)) ;
#252=ORIENTED_EDGE('',*,*,#153,.T.) ;
#253=ORIENTED_EDGE('',*,*,#129,.T.) ;
#153=EDGE_CURVE('',#121,#128,#152,.T.) ;
#129=EDGE_CURVE('',#128,#121,#126,.T.) ;
```

Figure 3: A partial STEP file of the example part of figure 2.

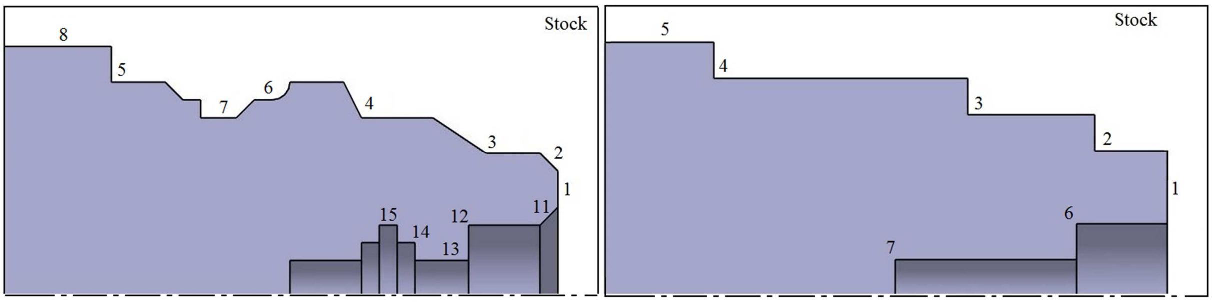
4.2 Features identification and classification

Taking the fact that all features of a workpiece are recognized, features are classified into two groups, simple features and special features. Simple features are cylinders, faces and shoulders. Special features are grooves, recesses, tapers, chamfers and so on. From the point of manufacturing rules applied by experts in the real manufacturing environment, a cylinder-recess-cylinder trio should be unified to establish new features for optimum cutting conditions [9]. Otherwise two cylinders having same diameter will be machined sequentially which causes long tool path and tool crashing into blank diameter of the recess. Which means that a longitudinal turning is performed before recessing.

For this reason, special features will be added as material rings to the part since they are performed after simple features. This method will be advantageous since multiple interpretations resulting by interactions between special features and simple features will be deleted. The next section describes how special features are eliminated from the part by adding material rings, and how the number of all combinations to machine the part can be reduced.

4.3 Special features elimination according to manufacturing rules and metal removal principles

The system we have developed for special features elimination is based on the work already done by Ersan [9], which treats unification of machining parameters for rotational parts according the manufacturing rules. The method consists in defining priority of the processes based on analyzing neighborhood between features. As cited above, when a recess or a groove occurs between two cylinders having the same diameter, these cylinders are unified and a new cylinder length record is stored. And then, the recess is stored to be the performed after machining that new cylinder. In a topological point of view, the new cylinder can be obtained by adding a material ring corresponding to the recess topology and geometry. This can be done by creating a virtual cylindrical surface to link the two cylinders. The left circular loop of this virtual surface is the same right circular loop of the left cylinder, and the right circular loop of this virtual surface is the same left loop of the right cylinder. The virtual surface diameter and both cylinder diameters are same. By this way, a ring which is composed by three material surfaces and the virtual surface is considered as a closed shell and can be added to the part. This procedure is valid for nested recesses and nested grooves in condition that these features must be added from inner to upper level. Author [9], has described how to create a new cylinder based on neighborhood between cylinder and taper. However, the cylinder may interact with other neighbor features. Features interactions generate multiple interpretations of features and then, the length of that new cylinder may take many values (see taper 6 and neighbor cylinder 5 in Fig.4a). Thus, it is preferable to build a material ring from the taper in such a way that the neighbor cylinder to the taper becomes a simple shoulder feature that can interact easily with other simple features. The material ring in this case is formed by three surfaces sharing three circular loops. The first surface is the material surface of the taper. The second surface is a virtual cylinder having the same length of the taper, the same diameter of the bigger circle diameter of taper and delimited by end circles centers of taper. The third surface is a virtual plan bounded by two loops. The inner loop of that plan is the same loop of taper formed by circle with minor diameter. It is known that adjacent surfaces of a chamfer are almost a plan and a cylinder. Author [9], has explained to, how to create a cylinder neighbor to a chamfer for which the length is calculated by the sum of the old cylinder length and the first chamfer length. However, author has not treated the neighbor face to the chamfer. Adding to that, the face (1) and the cylinder (3) adjacent to the chamfer can interact between each other and with other features (see Fig.4a). Thus, it is advantageous to add a material ring from the chamfer in such a way that the adjacent cylinder to the chamfer is extended by the first chamfer length, and the adjacent face to the chamfer is extended by the second length of the chamfer. By this way, the ring composed by the intersection of the extended surfaces and the material surface of the chamfer, can be added to the workpiece. The example part of figure Fig.4 explains the methodology of rings addition.



(a):Before adding material rings

(b) After adding material rings

Figure 4: Methodology of material rings addition.

In our system for feature recognition, a shoulder can be defined by many types of surfaces. For example, a shoulder can be obtained by joining a cylindrical surface and a planar surface along a circular loop. Or, by joining a taper (conical surface) and a cylindrical surface along a circular loop. The system is able to distinguish between internal and external features. In the example part of Fig.4, the workpiece in divided into two regions, internal region and external region since the maximum diameter for both internal and external features lies in one end of the part [10]. Each region must be treated separately. Taking the fact that features such as chamfers and filled are covering features, they can be excluded from features interactions. Thus, in the example part of Fig.4a, seven external features are interacting, and four internal features. This means that there are 7! combinations resulting by external features and 4! combinations resulting by internal features. By applying the method of material rings addition, these numbers of combinations can be reduced to 5! combinations for external features and 2! combinations of internal features. According to metal removal principles, workpiece zero point is generally taken on the face in CNC machining operations. Operations are put into order depending on their confident factors. The number of factors starts with 100, which belongs to facing [9]. The bigger confident factor describes the first process to be machined. So, facing is considered to be the first operation in any turning process. The second operation is considered as the operation from stock diameter to the maximum diameter of the finished product [11]. So it will be necessary to remove the face and the cylinder features from the stock cylindrical bar. This can be done by extending the face until the stock, and followed by extending the cylindrical surface with the bigger diameter until the extended face. And then, a cylinder to the face which is formed by the extended face and two stock surfaces (planar and cylindrical), and a hollow cylinder to the cylinder with maximum diameter, which is formed by the extended cylindrical surface with most diameter, and three stock surfaces (two plans and one cylinder), are removed from the stock. Thus, the length of the new cylindrical stock bar becomes smaller by the length of the removed cylinder to the face, and the diameter of the new stock becomes smaller by the difference between the old stock bar diameter and the maximum diameter of the part. By this way, in the example part of Fig.4, the face and cylinder features (features 1 and 5 in Fig.4b) are excluded from simple features that will be addressed in the feature generator system, and the new stock will be used to generate possible interpretations of interacting features. As a result, after excluding the face and the cylinder feature that are considered as interacting features, the number of combinations for the machining of external features for the example part of Fig.4b is reduced from 5! combinations to 3! combinations.

5 FEATURES GENERATOR (FG)

Feature extraction and classification becomes complex in the case of interacting features [12, 13]. Some surfaces of features are lost by interactions. Thus, a system for generating new features based on interacting features is required. Before describing the methodology followed for construction of new manufacturing features it will be important at this stage to define the following terms: Perfect Manufacturing Feature PMF and Imperfect Manufacturing Feature IMF.

<u>A MF is considered as PMF if:</u>

a) All surfaces that constitute the feature are material surfaces.

b) All edges shared by its adjacent surfaces are material edges.

c) The topological and geometrical conditions between the surfaces that define the feature are valid.

d) All faces except those for defining MF are blank (stock) surfaces.

<u>A MF is considered as IMF if:</u>

e) It exists a MF for which the topologic and geometric criterions are satisfied but it exists at least one adjacent surface of that MF which is not a blank surface.

f) Conditions a to c of PMF are also satisfied for the MF concerned.

To explain the methodology for construction of interacting (imperfect) manufacturing features, the following procedural rules must be known:

- A blank surface is a surface that can be a cylinder having the same radius as the raw cylinder radius, or a plan having the same coordinates as two circles coordinates of the raw cylinder.
- An adjacent (frontier) surface to the blank is a surface for which a circular edge loop has the same radius as the raw cylinder radius, or circle centers coordinates of that loop and circles centers coordinates of the raw cylinder are same.

Taking the fact that surfaces that form each feature are known, the Feature Generator system consists in analysing adjacent (frontier) surfaces of each simple manufacturing feature obtained by upstream systems, to distinguish between PMF and IMF. Remember that some features such as recesses and nested recesses are not treated by the Feature Generator, they are added to the part as material rings to facilitate construction of IMF. Construction of a new MF is based on extending its material surfaces until the blank (stock) surfaces. By this way, an IMF is transformed to a PMF. Once a feature is built, it is removed from the blank, and after, material surfaces of a following feature are extended until the last new stock surfaces. The operation is repeated according to the number of IMF. If the number of IMF is N, there are N! ways (combinations) to build N features. Otherwise, there are N! manners to machine N features. The flowchart of Fig. 5 shows the methodology of features classification and generation. It must be noticed that a workpiece can be machined in two set-ups if the maximum diameter lies in the middle of the part [12]. The maximum number of regions that a part can be subdivided in is four, left exterior region, right exterior region, left interior region, and right interior region, each region must be treated separately by the Features Generator. Thus, if Ni! is the number of ways to build N features of the ith region, the total number of manners to machine the workpiece is equal to the product of Ni!. At a second stage, and after construction of new perfect manufacturing feature, which are considered as isolated features, the features library is called and feature recognition is applied another time in order to extract new dimensional, geometrical and topological information of the modified features.

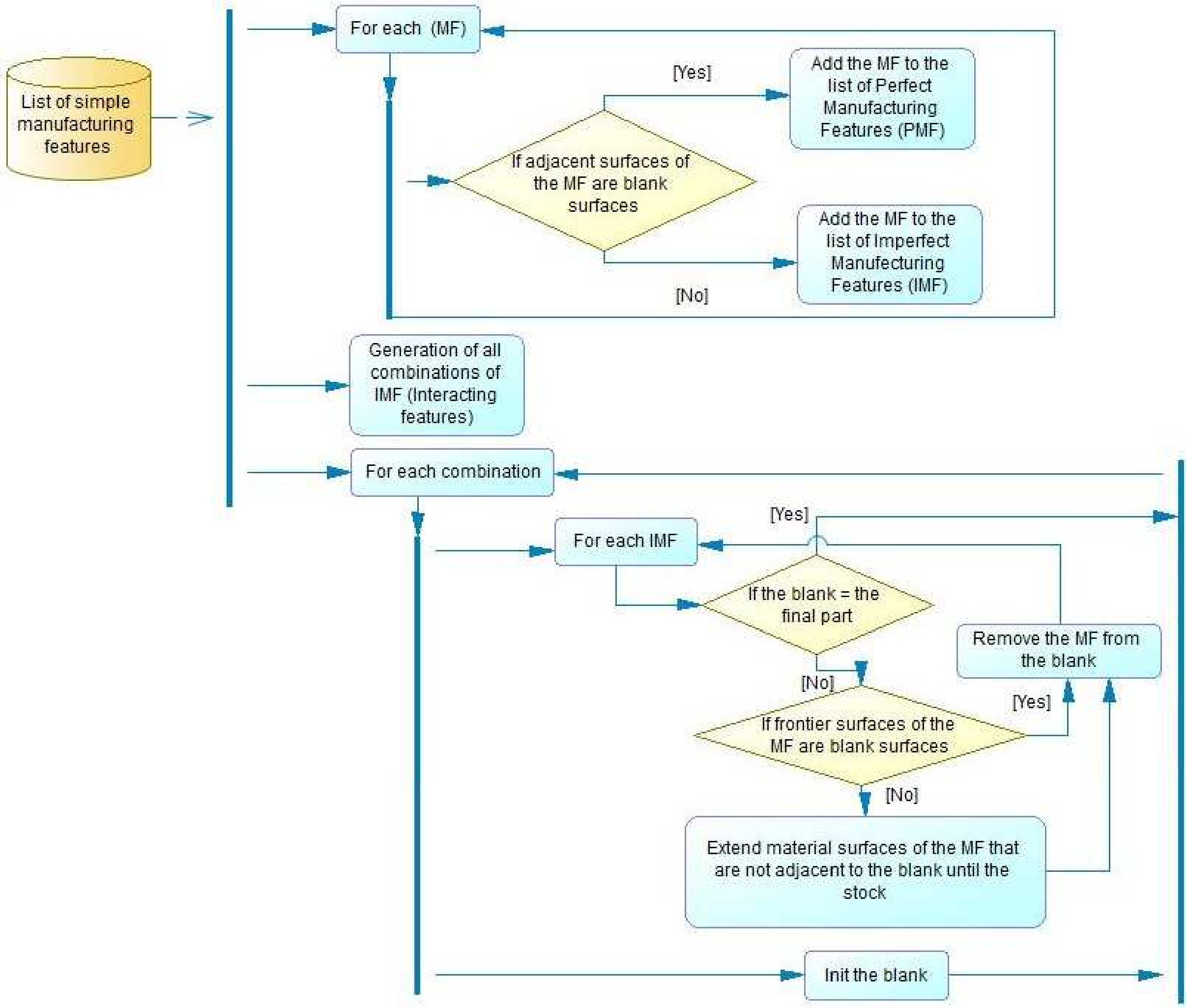


Figure 5: Flowchart of feature classification and generation

It must be known that special features such as radial and axial holes and threads are not treated by the feature generator since threading is the last operation after a turning process, and holes for being Non-axisymmetric features.

6 CASE STUDY

In this section, we have taken the same example part shown in Fig. 4b. This part is used only to clarify the method for generating new manufacturing features based on interaction between features, and not to test its limitations. After extraction of geometric and topological data of the part shown of Fig.4a from STEP APA203 data file by the GTDE module, these data are analyzed by the feature recognition system to extract features and to classify them into simple and special features. Special features are eliminated by adding material rings to the part as shown in Fig.4, and the workpiece is modified. Then, simple features (1 and 5 in Fig.4b) corresponding to facing and longitudinal turning that represent the first and the second operation respectively, are removed from the stock and a new one is generated. The face can be found by comparing the final length of the part with stock bar length, and the cylinder with bigger diameter can be found by comparing its diameter with the diameter of the stock bar. The feature generator module takes the extracted simple features (three shoulders) and the new stock as input, and distinguishes between PMF and IMF. Material surfaces of IMF are used to build new PMF. Taking the fact that three shoulders are recognized, the possibilities to machine external shape of the part follow six orders (3!), which is the same order in which features are modified and their surfaces are extended to form PMFs. Two possibilities are similar since features are the same in a dimensional point of view, thus, only five possibilities remain. To machine the internal shape, two possibilities are generated. This means that the total number of combinations to machine the part of Fig.4b is equal to the product of numbers of combinations for external turning and internal turning. Thus, ten combinations are generated and illustrated in Fig.6. At a last stage, the feature recognizer module is applied to extract the new parameters of features.

7 CONCLUSION

In the present work, we have introduced a new methodology to interlink CAD and CAPP systems based on features recognition for rotational parts, by analyzing the extracted geometric and topological data of the part from STEP AP203. The system recognizes and classifies features into two categories, simple features and special features. According to manufacturing rules, some special features such as grooves and recesses can be excluded from downstream activities and added as materiel rings to the part. Others such as an end face and a cylinder with the bigger diameter are excluded according to metal removal principles and removed from the stock. The new stock and the remaining simple features are transferred to the feature generator system which analyses the recognized features and build new features from material surfaces of interacting features by extending their material surfaces. Finally, feature recognition is applied a second time to extract the new dimensional parameters of features. It is clear that despite the fact that the Features Generator system can reduce the number of combinations of interacting feature at the feature recognition stage, it can give multiple combinations of interacting features to machine a same workpiece, which can lead to a computational combinatorial explosion, and time consuming at the tool selection stage. Thus it will be preferable to take into consideration Geometric dimensioning and tolerancing GD&T and economical and technological constraints at the feature recognition stage.

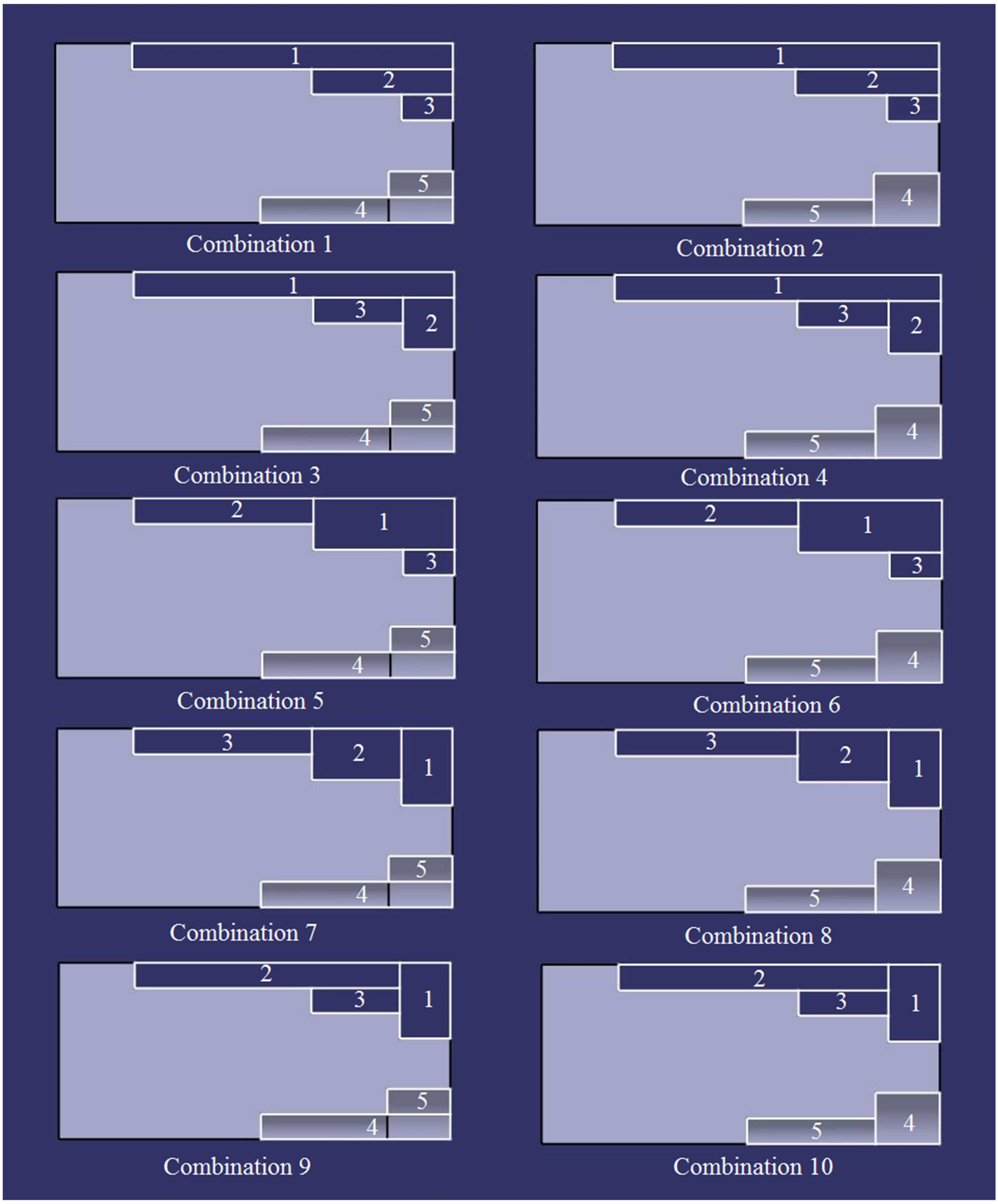


Figure 6: combinations of features generated by the Feature Generator system

Taking the fact that surfaces of each feature are known, GD&T, economic and technological constraints create precedence between surface of the part and then, between features. By this way, some combinations of feature that violate these constraints will be deleted and only the remaining combinations will be transferred to downstream activities such as automatic tool selection. It must be noted that some combinations seem to be the same if we compare dimensional parameters of their features (Combination 5 or 6 in Fig.6), but the order to machine these features is different. Considering that these features can be machined with a single tool, traveling distance of the tool may be different. Through these issues, an automatic and an optimized tool selection, and a sequence optimisation are required to pick out the optimal combination, which will be the objective of the next work.

REFERENCES

[1] S. Sivakumar and V. Dhanalakshmi, A feature-based system for CAD/CAM integration through STEP file for cylindrical parts, *Indian Journal of Engineering & Material Sciences*, vol. 20, February 2013, pp. 21-26.

[2] D. Sreeramulu and C.S.P.Rao, A new methodology for recognizing features in rotational parts using STEP data exchange standard, *International Journal of Engineering, Science and Technology*, Vol. 3, No. 6, 2011, pp. 102-115.

[3] V. N. Malleswari, Dr. P. M.Valli and Dr. M. M. M. Sarcar, Automatic Recognition of Machining Features using STEP Files, *International Journal of Engineering Research & Technology (IJERT)*, ISSN: 2278-0181, Vol. 2 Issue 3, March – 2013.

[4] STEP Application Protocol (AP) 203 editions 1 & 2, Configuration Controlled 3D Designs of Mechanical Parts and Assemblies, ISO10303 1994, (2007) & (2009).

[5] N. Ismaila, N. Abu Bakar and A.H. Juri, Recognition of cylindrical and conical features using edge boundary classification, *International Journal of Machine Tools & Manufacture* 45 (2005) 649–655.

[6] Mohamed El-Mehalawi and R. Allen Miller, A database system of mechanical components based on geometric and topological similarity. Part I: representation, *Computer-Aided Design* 35 (2003) 83-94.

[7] Emad S. Abouel Nasr and Ali K. Kamrani, A new methodology for extracting manufacturing features from CAD system, *Computers & Industrial Engineering* 51 (2006) 389–415.

[8] G. Nawara, M. A. ELBaz and A. M. Attia, Parts Classification Based on Solid Model and Neural Networks, *Contemporary Engineering Sciences*, Vol. 3, 2010, no. 8, 395 – 417.

[9] Ersan ASLAN, Process unification and frame preparation of machining parameters for rotational parts, *Journal of Engineering Sciences*, 137-145 (2005).

[10] Ali Oral and M. Cemal Cakir, Automated cutting tool selection and cutting tool sequence optimisation for rotational parts, *Robotics and Computer-Integrated Manufacturing* 20 (2004) 127–141.

[11] MC. KAYACAN., I.H. FILIZ., A.I. SIJNMEZ., A. BAYKASOGLU and T. DERELI., OPPS-ROT: An optimised process planning system for rotational parts, *Computers in Industry* 32 (1996) 181-195.

[12] Tobias Dipper, Xun Xu and Peter Klemm, Defining, recognizing and representing feature interactions in a feature-based data model, Robotics and Computer-Integrated

Manufacturing 27 (2011) 101–114.
[13] A. Elmesbahi , A new methodology for recognition of interacting features using Frontier Faces of Base Face, CPI 2009, 19-21 octobre 2009, Fès, Maroc.