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# A new methodology for recognizing features in rotational parts using STEP data exchange standard

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**Abstract**

Automated feature recognition is considered a critical node for integration of CAD/CAPP/CAM. The CAPP module requires the implementation of a feature recognition procedure, so that decisions relating to steps of process planning activities can be made automatic. STEP is an international standard for geometric and non geometric data transfer between heterogeneous CAD, CAE and CAM systems and it replaces IGES and DXF files. Extracting the necessary information from an exchange file to generate manufacturing parameters becomes an important task. In this paper we present the model of our research effort which is intended to extract the geometric information of rotational parts from STEP file, and utilize this information to recognize the turning features. A generalized Java code has been written to extract the data from STEP file and to recognize the features. The novel approach proposed to extract feature information from STEP files and further integration with STEP-NC file provides as a seamless integration technique of CAD/CAPP/CAM. The approach was tested by several examples for rotational parts.

*Keywords:* STEP, Feature Recognition, Rotational parts.

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## 1. Introduction

Turning is a widely used machining process that is described as removal of material from the surface diameter of a rotating work piece with a single-point tool. Turning operations can be classified as longitudinal turning, facing, angle cutting, and profiling. Owing to the fact that the rotational parts are symmetrical along their axis, designing their processes can be done according to the symmetry axis so the feature recognition process is performed on the symmetry axis. Features including rotational parts could be classified as outside features and inside features according to machining attributes. These features are also classified to sub features by the system such as long turning and grooving according to machining attributes. All of the basic line and arc features obtained from the CAD database are represented independently for all turning operations.

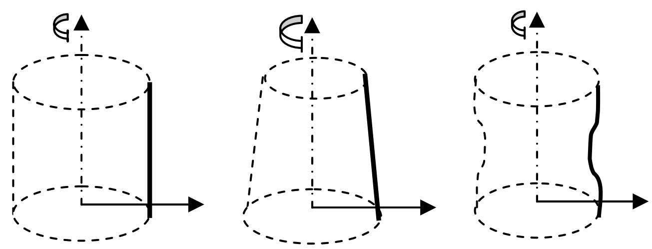
### *1.1 Turning Feature*

A turning feature is a very general term which often indicates certain non-unique shape characteristics that the desired part should possess, realized as a consequence of applying some manufacturing processes to the stock (Li and Shah, 2007). The faces on a rotational part machined by turning are represented as revolved faces in solid modeling. A revolved face's underlying surface is constructed by revolving a planar curve about an axis. Figure 1 shows some examples of revolved surfaces.

### *1.2 Integration of CAD and CAM*

The integration of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) has received significant attention in the recent years according to the development of faster computing power tools. However, the actual integration between CAD and CAM, for the downstream applications such as process planning, can be achieved only when the manufacturing information can be obtained directly from 3D solid model and hence automate the process planning functions (Chang *et.al*, 2002). In spite of using advanced manufacturing and automation technology the link, between CAD and CAM systems, is still not as integrated as desired. The process planning stage, which consists of the explanation of design drawings, is seen as a hindrance in the flow of information between CAD and CAM. An intelligent interface between CAD and CAPP systems is imperative because the CAPP systems depend on correct data obtained from CAD systems to perform precise process planning. Feature recognition techniques provide such a connection between CAD and CAPP.

Part representation in 3D CAD models consists of basic geometric and topological information. This data is not utilized for direct application to process planning because process planning requires part form feature information, not geometric. Hence, a way to extract the required information from the CAD data available is a problem that must be solved in order to achieve an automatic process planning. One of the solutions for these problems between CAD and CAM is the automatic feature recognition technique. This automatic extraction of manufacturing information from CAD systems play an important role to facilitate the concurrent engineering concept in order to achieve the link between the design and manufacturing activities. This successful link can be considered as fundamental step to automate the product development from the design stage all the way to manufacturing and shipping stages. Hence, the total life cycle of the product can be reduces dramatically (Bhandarkar *et.al,* 2000).



(a) Cylinder (b) Cone (c) Surface of Revolution

Figure 1. Revolved surfaces

*1.3 STEP Application Protocols (APs)*

This class defines the resource information models to provide specific functionality. STEP standard is divided into many of APs belonging to the ISO 10303 family of standards (Sharma and Gao, 2002). Each application protocol defines the data exchange standard for defined family of products at defined stage in the life cycle of the product. APs are based on the resource information model but carry specific semantics in the application domain of the AP.
e.g., **Part203**: Configuration controlled design.

In this paper, the authors focused on the development of automatic feature recognition system for the rotational parts by taking STEP file as input. The implementation of CIM in most of the countries is not well developed as compared with those highly industrialized countries. The use of new technologies has been increased, while the CAD/CAM is still seen as an unattainable meta. Recently, the small and medium sized companies have increased in number and play a significant role in production. The feature recognition and process planning is key for any small and medium sized design and manufacturing industries. Therefore the research on integration of CAD/CAM by automatic feature recognition is invaluable. Recent surveys on CAD/CAM system revealed an increasing trend for small and medium sized industries to employ CAPP system for their manufacturing tasks. Lower cost of these systems wills probably increasing the trend. The proposed work can be able to provide additional degree for design and planning industries. Section – 1 given brief introduction to turning feature and integration of CAD and CAM, Section – 2 provides a review of literature on Feature recognition, Section – 3 gives an explanatory note on proposed methodology, Section – 4 presents the development of Geometric Data Extraction (GDE) algorithm from STEP file and Section – 5 constitutes the development of feature recognition system for rotational components. Finally the proposed methodology is implemented with an example in Section – 6.

## 2. Related Work

There have been considerable researches on the feature recognition systems. Automated feature recognition has been an active research area in solid modeling for many years and is considered to be a critical component for integration of CAD and computer-aided manufacturing. Pratt and Regli (2000) gave an overview on the three major algorithmic approaches for feature recognition and mentioned several drawbacks of them also proposed several open research areas. Bhandarkar *et.al.* (2000) proposed a procedure for converting product design data from an Initial Graphic Exchange Specification (IGES) format into Standard for the Exchange of Product Model Data (STEP) format. They also explain the STEP file structure in representing the geometric data like lines, circles etc. Zhang *et.al,* 1989 addressed the need for feature reorganization rules to recognize the features of rotational parts. They also addressed need of Computer Aided Process Planning (CAPP) system in integration of CAD/CAM. This paper gives an overview of CAPP and focuses on the feature-recognition knowledge base. Sheu (1998) developed a computer integrated manufacturing system for rotational parts. Lee and Han (2005) have given reconstruction of 3D interacting solids of revolution from 2D orthographic views.

The parametric design and feature-based solid model were used to specify the manufacturing information required to the proposed system. In this system, the boundary profiles were the output to a drawing with the DXF format. Aslan *et.al*. (1999) developed a feature extraction module for rotational parts that are machined at turning centers only. They have also discussed need of neutral file format in CAD data exchange. In this research, DXF file format was used to extract the geometric data of rotational parts in 2D, which was represented by boundary representation (B-rep) data base for rotational parts. Ahmad and Haque (2001) proposed manufacturing feature recognition of a rotational component using DXF file and importance of feature recognition in integration of two independent systems i.e. CAD and CAPP. The geometric information of a rotational part is translated into manufacturing information through a Data Interchange Format (DXF). A feature recognition algorithm has been proposed to recognize different features of the part from its DXF file, where geometric information of the part is stored after respective DXF codes. Finally, using the data extracted from DXF file, each feature of the part is recognized.

Xu and He (2004) reviewed a Striving for a total integration of CAD, CAPP, CAM and CNC. In their review they overviewed and discussed the STEP-NC standard and the G-code that is to be replaced by STEP-NC, the summary of current research activities, the benefits, potentials, challenges and opportunities concerning STEP-NC. Liu *et.al*. (2005) developed a framework and data processing for interfacing CNC with AP238, which represents one of the building blocks for tomorrow's manufacturing workstation. The conceptual controller consists of an interpreting module (interpreter), a planning module (planner), a simulation module and a CNC kernel. The interpreter reads an AP238 file and converts it into internal data, which the planner utilizes to sequence the specific machining operations and processes. From the review of feature recognition authors may conclude that the literature on feature recognition is vast among those very few were addresses the issues like intersecting features, recognition of features in rotational parts and most of the authors were addressed by IGES, DXF files. The lack of information from those files was identified and STEP file was used in this work.

## 3. Proposed Methodology

Feature recognition (FR) is done through the processing of a geometric model from a CAD system and find portions of the model matching the characteristics of interest for a given application. There are several approaches suitable for recognition of 2D rotational features, however if 2D edge and profile patterns of the rotational parts are having feature interactions, then some of the 2D rotational features are not recognizable with current methods. Moreover if the rotational part does not have symmetry, then the so called 2D feature recognition is not at all suitable (Liu, 2004). Hence this research aimed to extract different types of features that the rotational part is having irrespective of its symmetry. Different steps in the methodology for recognizing turning features are shown in Figure 2.

The main objective of the work presented in this paper for recognizing features in rotational parts is development of an integrated methodology comprising of the following algorithms. They are as follows

- Development of geometric data extraction algorithm to extract geometry and topology information from STEP file.
- Development of Turning Feature Recognition algorithms (two algorithm), which identifies primary turning features like cylindrical surface, conical surface, toroidal surface etc.
- Development of an algorithm to recognize holes along radial and axial direction in rotational parts.
- Development of an algorithm to recognize special turning features like threading. (both internal and external threading)

In all these algorithms a specific geometry/topology configuration is searched in the STEP file of the part model and identifies the presence of a particular type of feature. The algorithms are developed for recognition of features with ease in 3D CAD systems which are fairly complex in nature. These algorithms were implemented in JAVA environment since it is having flexibility while reading a data base.

### *3.1 Frame Work of the Proposed Methodology*

Figure.2 shows the frame work of the proposed methodology of SFPS for integration of CAD and CAM. The frame work constitutes three major modules.

***Module 1:*** Modeling and Geometric Data Extraction from STEP file

***Module 2:*** Recognition of features in both rotational and prismatic parts.

### *3.2 The Main Objectives of the Proposed Methodology*

- Use of STEP standard to exchange CAD information and exploitation of such information for identification of features in rotational and prismatic parts and further generation of CAPP output
- To develop Algorithms to extract the geometric information from STEP files.
- To develop an algorithm to recognize turning features like cylinders, cones, toroidal surfaces, threads and holes on a cylindrical surface etc.

## 4. Geometric Data Extraction from STEP File

STEP is a new International Standard (ISO 10303) for representing and exchanging product model information. It includes an object-flavored data specification language, EXPRESS, to describe the representation of the data. STEP also defines implementation methods, for instance, a physical transfer file, and offers different resources, e.g. geometric and topological representation. Implementation methods are used for data exchange. The development of STEP started in 1984 as a worldwide collaboration. The goal was to define a standard to cover all aspects of a product (i.e. geometry, topology, tolerances, materials, etc.), during its lifetime (Pratt, 2001).

*4.1 Structure of STEP (AP-203) File*

The STEP file structure is language based and is described by an unambiguous context free grammar to facilitate parsing by software. The grammar is expressed in Wirth Syntax notation (Ma .S, *et.al,* 2001) The information contained with the file is in free format and thus not column dependent. The STEP file is begun by the keyword ISO-10303-21and is terminated by keyword END-ISO- 10303-21, and in similar fashion sections are delimited by keywords. The contents of the sections are limited to the entity instances, i.e., the description of the object of interest. Briefly the data format is as follows. Each entity instance has an identifier of the form #N. where N is a unique integer. Each individual entity has a name. The data for an entity instance follows the type name and is enclosed in parentheses. A datum can be either "primitive" like integer, real or string, etc., or it may be a reference to another entity instance within the file. Such a reference has the form #N where N is the entity number of the reference instance. Entities may be referenced before they are defined within the file.

The **advanced brep shape representation** (it is a typical representation of face in STEP file) ABSR is STEP consists of a set of representation items. This set contains an entity of the type **manifold solid brep**. The **manifold solid brep** entity or its subtype namely brep with voids contains the complete definition of the geometry and topology of the solid in the B-Rep format. The manifold solid brep is a finite, arcwise connected volume, bounded by one or more surfaces, each of which is a connected, oriented, finite, closed manifold (Bhandarkar and Nagi, 2000; Hamri *et al*., 2004).

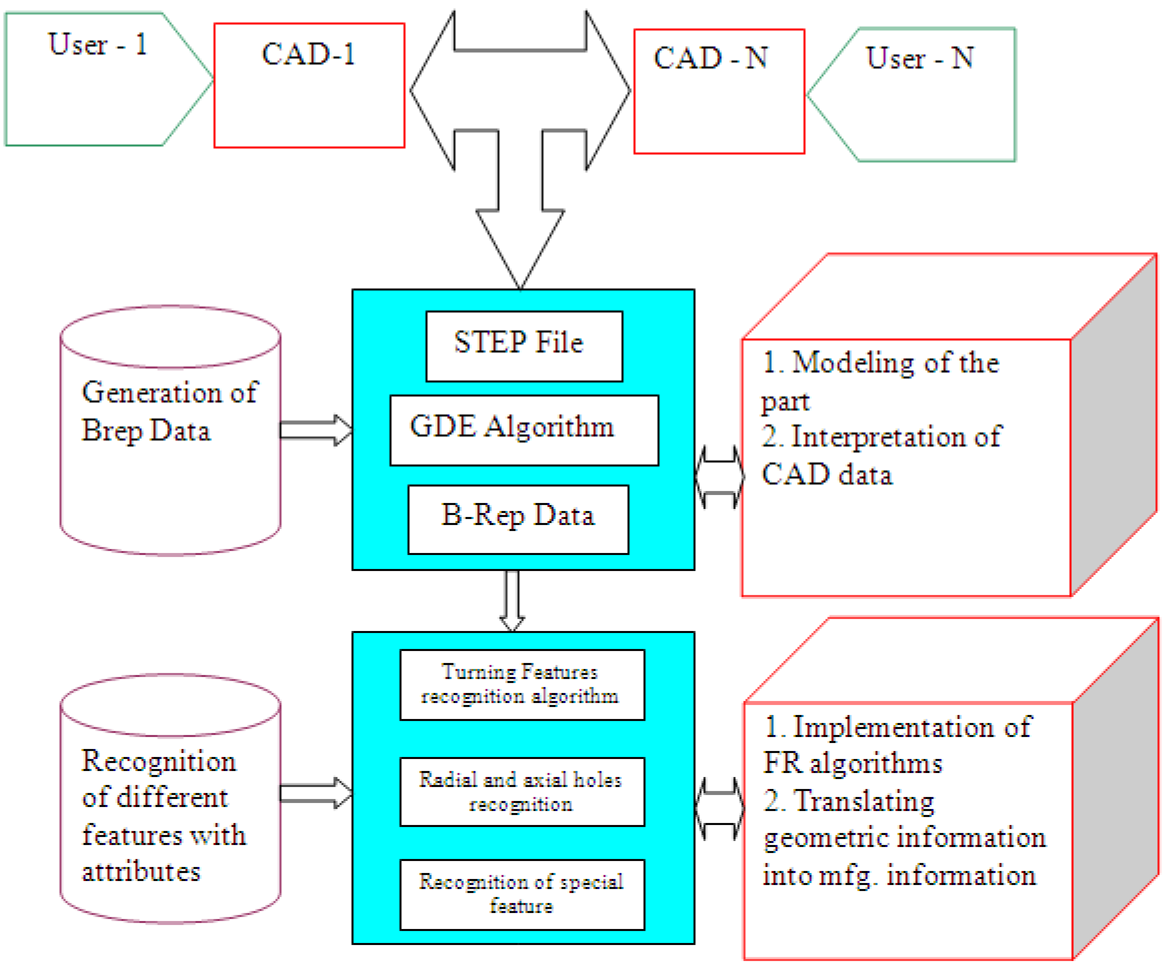



Figure 2. Methodology to recognize different turning features

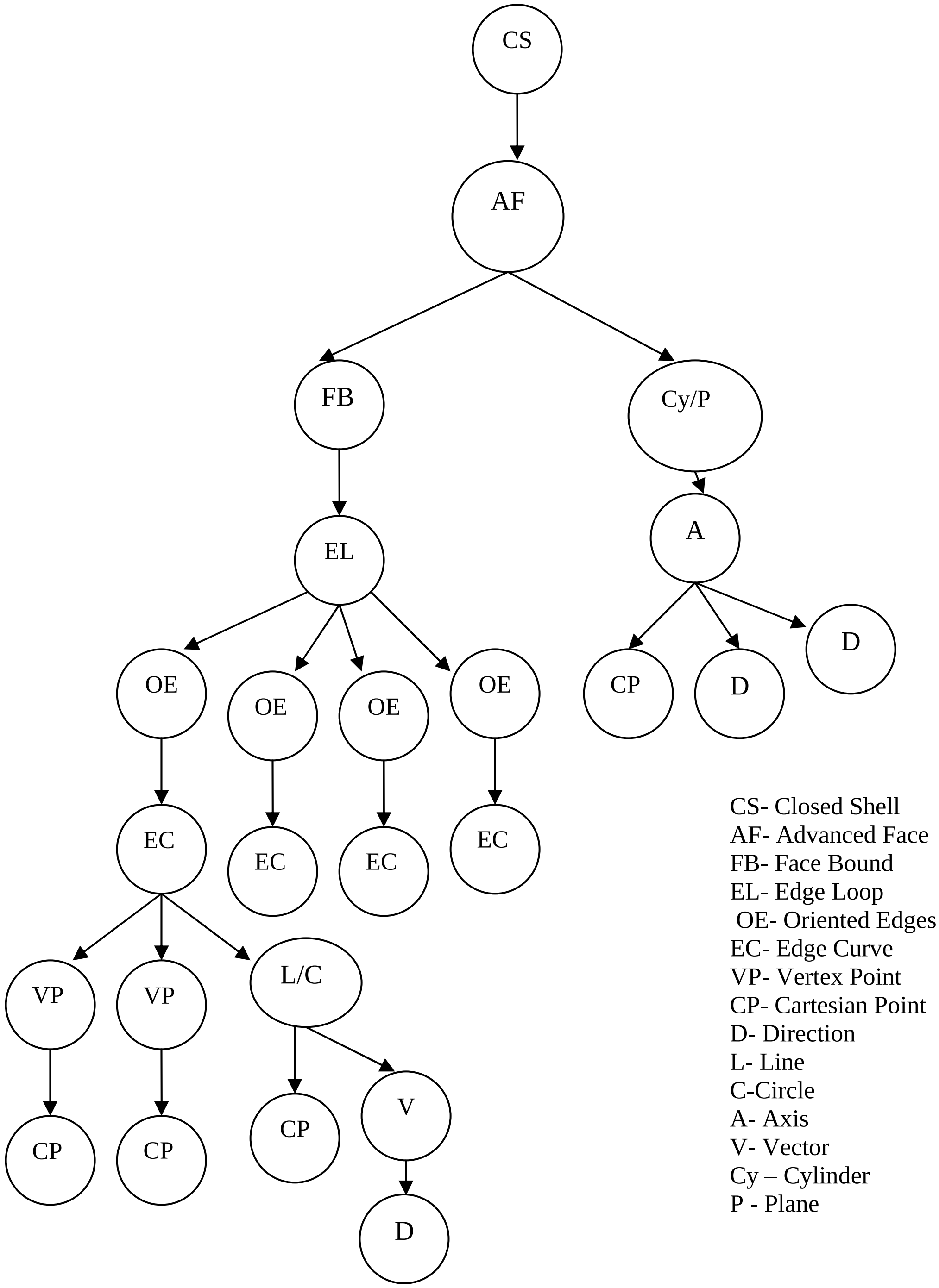



Figure 3. Structure of STEP file

A brief description of some of the important STEP data elements are given below.

***Closed-Shell*****:** A collection of one or more faces which bounds a region in three dimensional space and divides the space into two regions, one finite and the other infinite.

***Face-Surface:*** A type of face in which the geometry is defined by the associated surface, boundary and vertices

***Face-Bound****:* A loop used for bounding a face.

***Edge-Loop****:* A path in which the start and end vertices are the same.

***Oriented-Edge:*** An edge constructed from another (original) edge and containing the direction (orientation) information. The ORIENTED-EDGE will be equivalent to the original edge if the orientation information is not included.

***Edge-Curve:*** A type of edge which has its geometry fully defined.

***Vertex-Point:*** A point defining the geometry of a vertex.
***Cartesian-Point:*** Address of a point in Cartesian space.
The hierarchy of the different elements of STEP file starting from Closed_Shell to move towards the Cartesian_Point is shown in Figure 3.

*4.2. Geometric Data Extraction (GDE) Algorithm*

After a thorough study of the STEP file an attempt has been made to develop an algorithm to extract the geometric information (B-Rep database) from the STEP file. The algorithm will determine the type and orientation of each face using the B-Rep data base including all topological and geometrical information for the object and the B-rep data base is modified accordingly. Algorithm for extracting the geometric information from STEP file is shown in Figure 4.

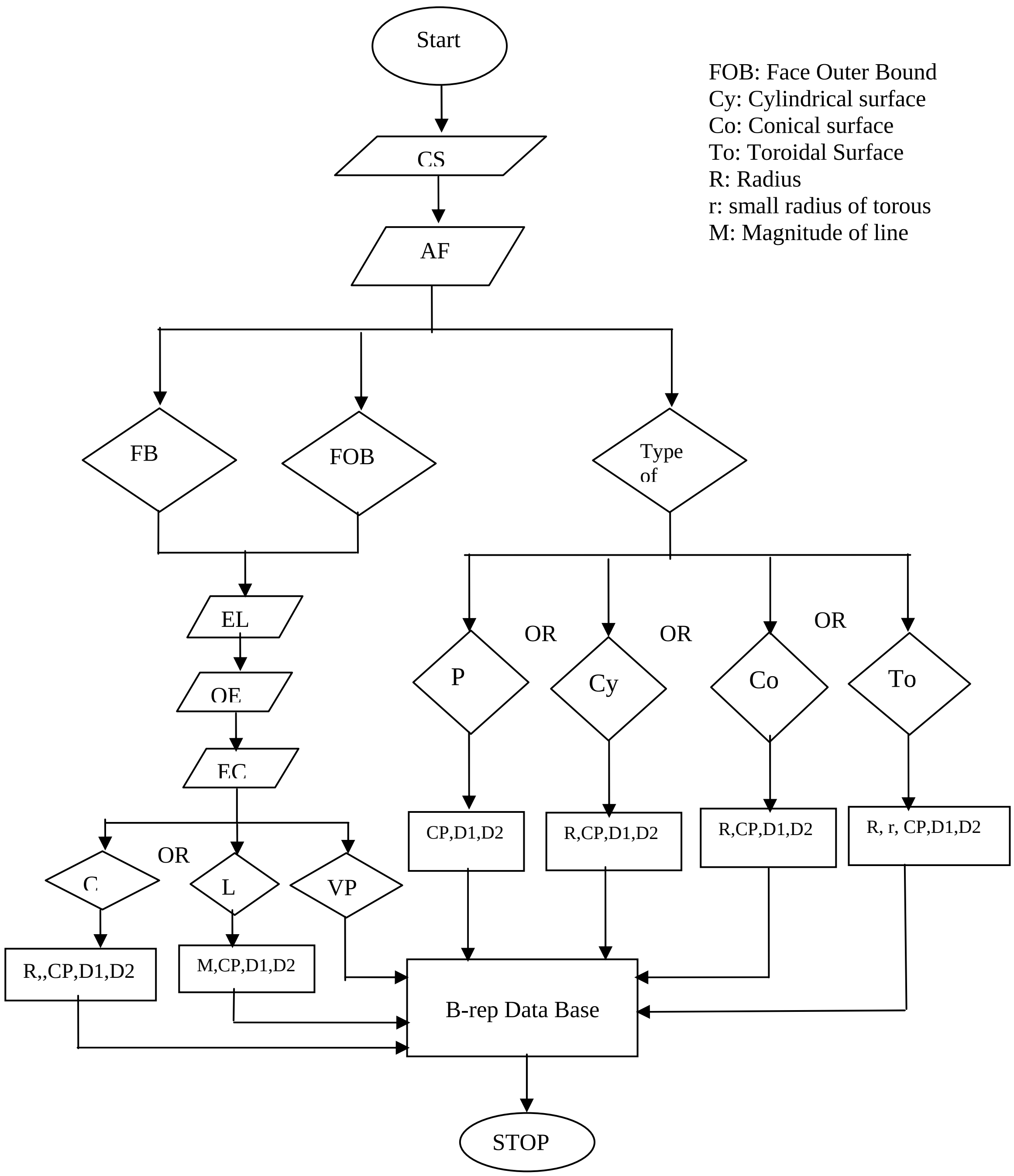



Figure 4. Geometric Data Extraction (GDE) Algorithm

A generalized JAVA program has been written to extract the geometric information from STEP file of any part which has been modeled on any platform. JAVA is having grater flexibility for handling of files (like STEP files) having huge data.

*Limitations of GDE algorithm*

- The proposed GDE algorithm is developed only for extracting data from STEP AP – 203.
- Cylindrical hole and cylindrical projection (protusion) are represented in samilar fashion and hence it is difficult to interpret one from other.

## 5. Algorithms to Identify the Turning Features

Different algorithms were proposed in this work to extract features from rotational parts.

*5.1 Recognition of Primary Turning Features*

Based on the details that the B-Rep data contains, which is obtained from the GDE algorithm, an attempt has been made to develop a turning feature recognition algorithm, to recognize the different primary turning features like cylinder, cone and toroidal surface. These features exist in most of the turned components with nomenclature like stepped to one end, taper turning, cylindrical turning, form turning etc.

*5.1.1 Algorithm for Identifying Primary Turning Features*

The schematic representation of the algorithm for recognizing different turning features is shown in Figure 5. B-Rep data obtained from GDE algorithm is given as input to the proposed algorithm.

The following steps will explain a functioning of the primary turning feature recognition algorithm.

**Step 1:** Read the data from the B-Rep database.

**Step 2:** If the row of the B-Rep Database contains

(a) "CYLINDRICAL_SURFACE" read the radius (R) and cartesian point (CP) of that particular surface

(b) "CONICAL_SURFACE" read the R, CP and semi cone_angle ($\theta$) of that particular surface

(c) "TOROIDAL_SURFACE" read the R, r and CP of the torus

**Step 3:** match the above data with the other set of data i.e., (since each cylindrical, conical and toroidal surface is represented by two sets of similar data)

For CYLINDRICAL_SURFACE, The radius and Cartesian point of $i^{th}$ face with $j^{th}$face i.e., $R_i$ with $R_j$ and $CP_i$ with $CP_j$

For CONICAL_SURFACE, The radius, angle of cone and Cartesian point of $i^{th}$ face with $j^{th}$face i.e., $R_i$ with $R_j$ and $\theta_i$ with $\theta_j$ and $CP_i$ with $CP_j$

For TOROIDAL_SURFACE, The major radius, minor radius and Cartesian point of $i^{th}$ face with $j^{th}$face i.e., $R_i$ with $R_j$ and $r_i$ with $r_j$ and $CP_i$ with $CP_j$

**Step 4:** if the match found store the data into their corresponding arrays.

If match not found read another set of data and repeat the *Step 2 to Step 3*.

***Nomenclature used in this algorithm***

Cyl-sur: Cylindrical surface

Con-sur: Conical surface

Tor-sur: Toroidal Surface

$R_i$: Radius of $i^{th}$ Cylindrical/Conical/Toroidal surface

$r_i$: Minor radius of $i^{th}$ Toroidal surface

$\theta_i$: Semi cone angle of $i^{th}$ Conical surface

CYL-array: Cylinder array

CON-array: Conical array

TOR-array: Torus array

$CP_i$: Cartesian point of $i^{th}$ Cylindrical/Conical/Toroidal

*5.2 Recognition of Secondary Turning Features*

This section presents development of different algorithms to recognize secondary turning features i.e. C-axis and special turning features (threads).

*5.2.1 Recognition of C-axis Features*

Irrespective of symmetry of the part, different algorithms have been developed to recognize the C-axis features like radial and axial holes. The proposed algorithms for recognizing those features are given below.

*(I) Radial Holes Recognition Algorithm*

Normally a cylindrical surface or conical surface contains two circles and two lines in its data. The first circle gives starting point of the cylinder and second circle gives ending point of the cylinder. The length of cylinder is given by length of the line. There may be some holes on lateral surface of cylinder (Cylindrical_Surface), for these holes the data of cylindrical surface contains a B_SPLINE curve, one circle and two lines. Based on this information an algorithm has been developed to recognize the radial holes in rotational parts. The schematic representation of that algorithm is shown in Figure 6. and this algorithm was also implemented in JAVA environment

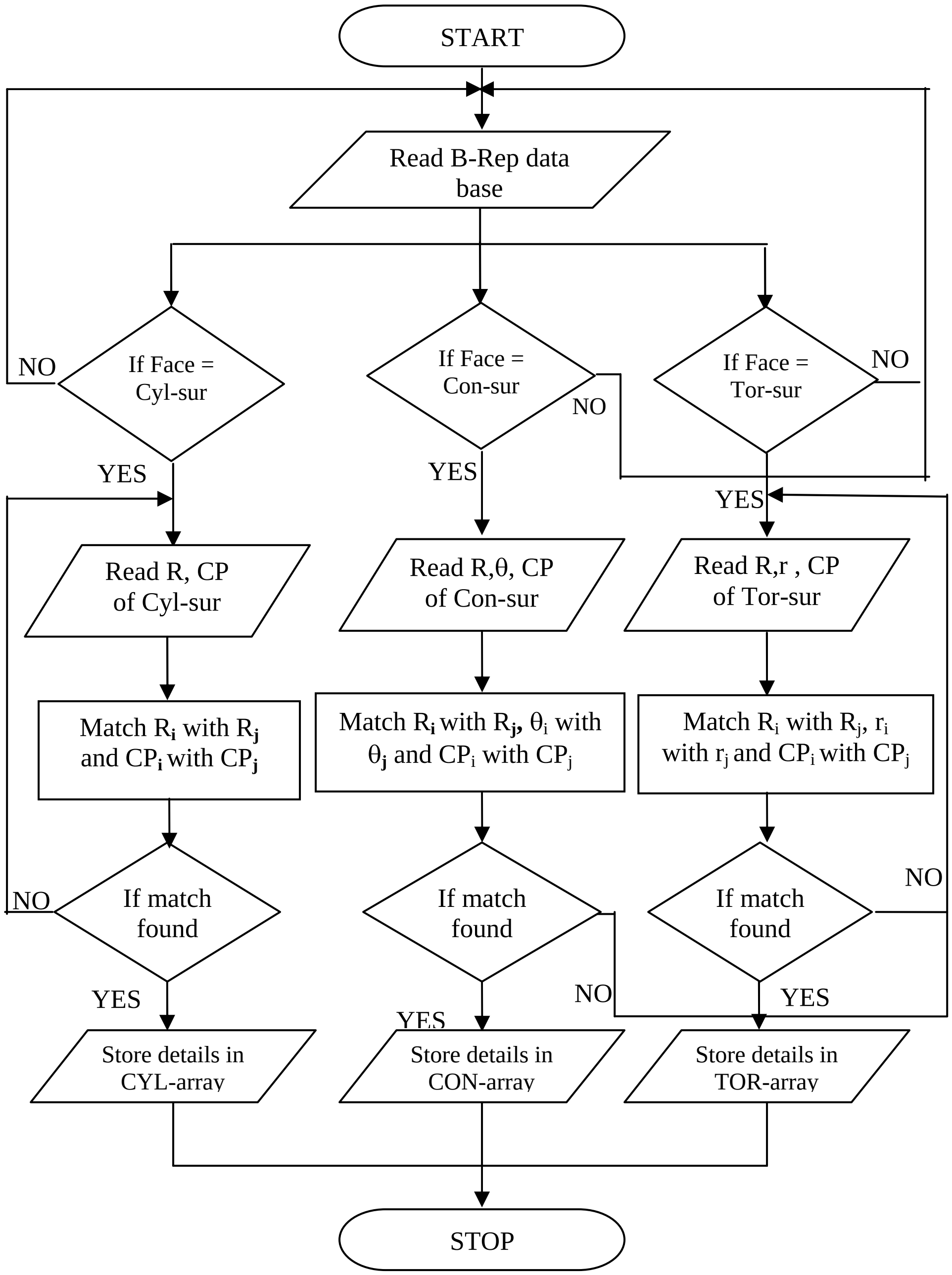



Figure 5. Algorithm for recognizing primary turning features

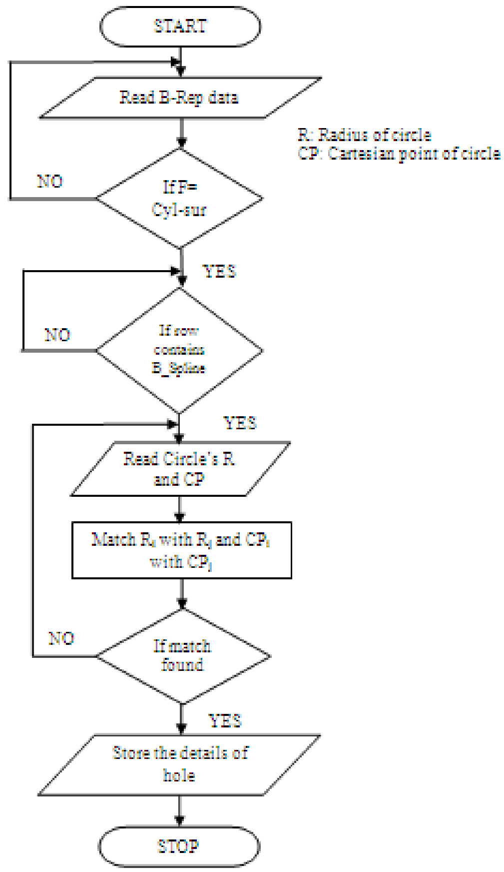



Figure 6. Radial hole recognition algorithm

The following steps will describe the procedure of extracting radial holes.
**Step-1:** Read the B-Rep database for which the row contains CYLINDRICAL_SURFACE
**Step-2:** If the same row contains B_SPLINE then read the circle data i.e., radius (R) and cartesian point (CP).
**Step-3:** Compare the circle data with the circle on another cylindrical surface.
**Step-4:** If match found, store them in an array. If match not found repeat the *steps from 2 to 4.*

*(II) Axial Holes Recognition Algorithm*

Recognition of axial holes is different from radial holes, since both the cylinders and holes are in axial direction and both are represented in a similar way in STEP file, it is difficult to recognize axial holes in rotational components.

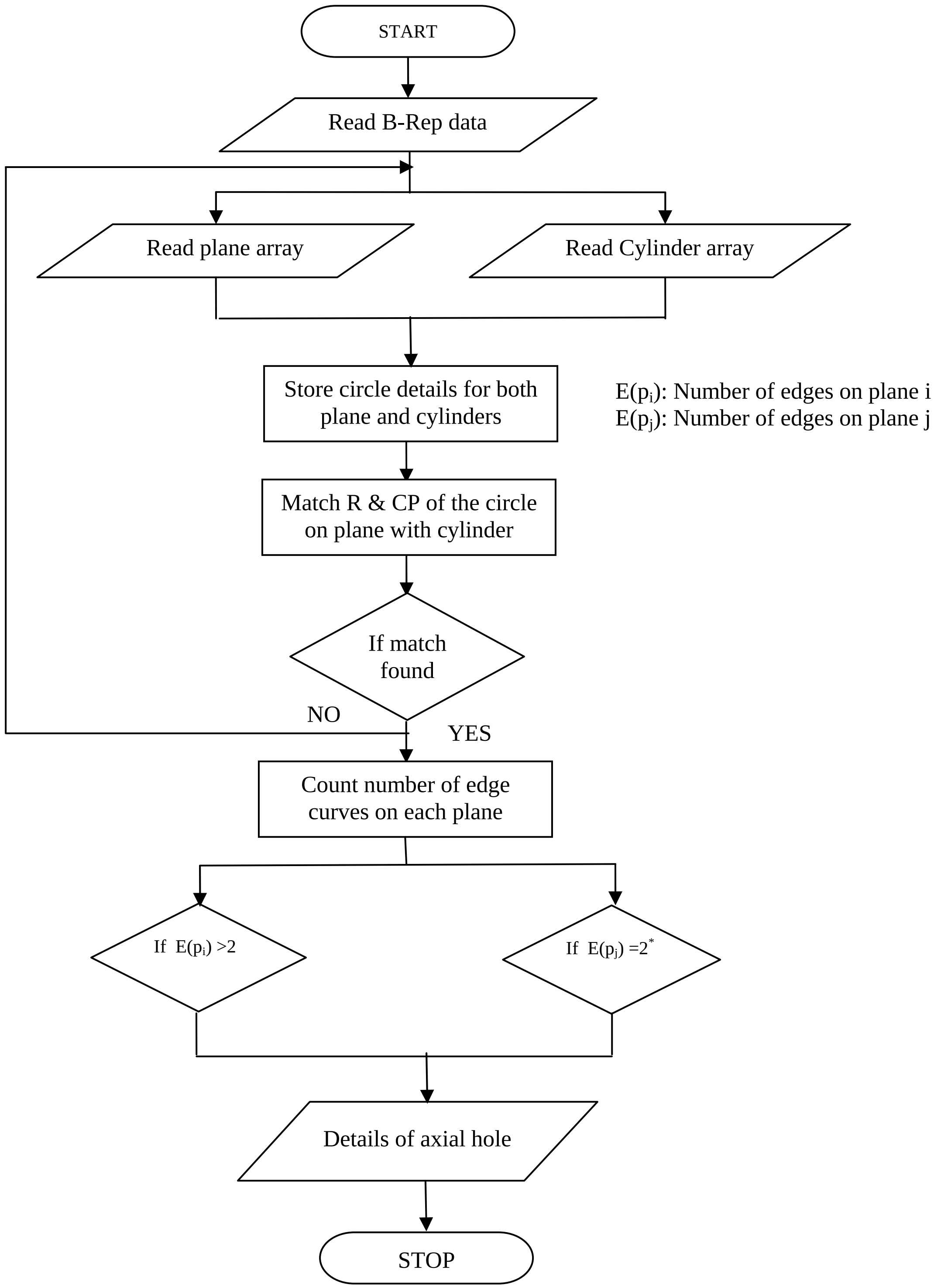



Figure 7. Algorithm for recognizing axial holes in rotational parts

A procedure is described in the form of an algorithm to recognize axial holes in rotational components is given in following steps. Figure 7 shows schematic representation of such algorithm.

**Step-1:** Read the B-Rep data line by line.
**Step-2:** If it contains a PLANE read the circle details i.e., radius (R), cartesian point (CP)
**Step-3:** Read the circle details of cylinder i.e., radius (R), cartesian point from the cylinder array.
**Step-4:** Match the radius (R) and cartesian point (CP) of circle on the plane with R and CP of circle of cylinder.
**Step-5:** If the match found store them in an array. If match not found repeat the *steps from 2 to 4.*
**Step-6:** Count the number of edges on each plane.

**Step-7:** If the number of edges one plane is grater than 2 and on another plane is equal to two (exclude starting and ending planes), the corresponding two cylindrical surfaces will form an axial hole.

*5.2.2 Recognition of Special Feature like Threading*

Whenever there is a special feature like Threading on any cylindrical surface, the cylindrical surface is represented in CLOSED_SHELL (actual representation of STEP file), but these features will be represented in OPEN_SHELL of STEP file with its attributes like minor diameter and length of the threaded portion etc. The GDE algorithm developed for extracting the B-Rep data can also be used to extract the geometry information of such features by small modification i.e. by replacing Closed_Shell with Open_Shell in GDE algorithm and by using turning feature recognition algorithm proposed in the above section special features are also recognized**.**

*Limitations of the proposed algorithms*

- It is difficulty to differentiate features like treaded and knurled portions, since those are represented in open_shell of a STEP file instead of Colsed_Shell.
- With the proposed algorithms, it is difficult to identify ineer slots if any in a cylindrical holes. (Since slot on cylindrical portion comes under curve on B-spline curve)

## 6. Implementation of Above Algorithms

An example part is shown in Figure 8, has been modeled in Pro/Engineer. This example consists of 24 (8 for cylinders + 16 for axial and radial holes) cylindrical surfaces and 13 planes (5 for cylinders + 8 for holes) and all combined together are 37 faces. All these faces are represented in Closed_Shell of STEP AP203 file of the example part-2. Threaded portion having two cylindrical surfaces and one plane are represented in Open_Shell of STEP AP203 file.

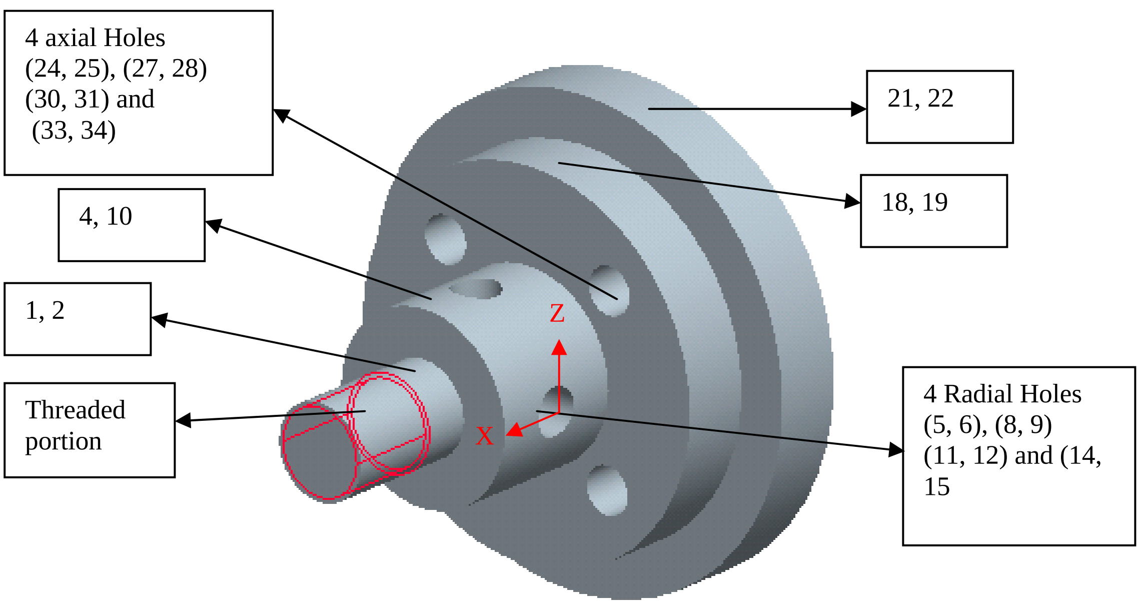



Figure 8. Example part

The STEP AP-203 file is given as input to the GDE algorithm (as given in section 4), the output of this algorithm in B-Rep data format is shown in Figure 9. The information of 3 faces is only shown in this figure.

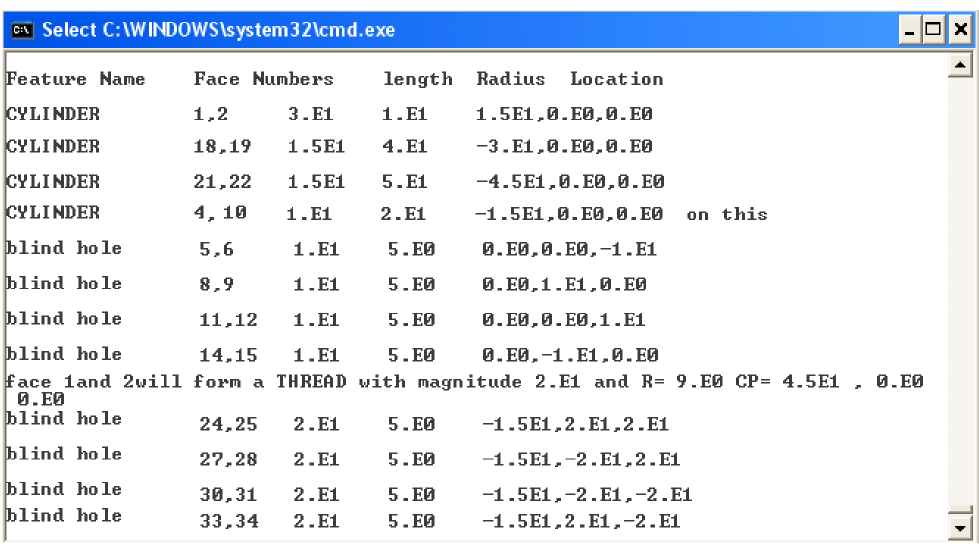
```
0||1||4.5E1||1.E1||0.E0||4.5E1||-1.E1||0.E0||CIRCLE||1.E1||4.5E1||0.E0||0.E0 ||-1.E0||0.E0||0.E0||0.E0||1.E0||0.E0||
PLANE||0||4.5E1||0.E0||0.E0||1.E0||0.E0||0.E0||0.E0||-1.E0||0.E0
0||2||4.5E1||1.E1||0.E0||4.5E1||-1.E1||0.E0||CIRCLE||1.E1||4.5E1||0.E0||0.E0 ||1.E0||0.E0||0.E0||0.E0||1.E0||0.E0||
PLANE||0||4.5E1||0.E0||0.E0||1.E0||0.E0||0.E0||0.E0||-1.E0||0.E0
1||1||4.5E1||1.E1||0.E0||1.5E1||1.E1||0.E0||LINE||3.E1||4.5E1||1.E1||0.E0 ||-1.E0||0.E0||0.E0|||||||
CYLINDRICAL_SURFACE||1.E1||-4.95E1||0.E0||0.E0||1.E0||0.E0||0.E0||0.E0||-1.E0||0.E0
1||2||1.5E1||1.E1||0.E0||1.5E1||-1.E1||0.E0||CIRCLE||1.E1||1.5E1||0.E0||0.E0 ||-1.E0||0.E0||0.E0||0.E0||1.E0||0.E0
1||3||4.5E1||-1.E1||0.E0||1.5E1||-1.E1||0.E0||LINE||3.E1||4.5E1||-1.E1||0.E0 ||-1.E0||0.E0||0.E0|||||
1||4||4.5E1||1.E1||0.E0||4.5E1||-1.E1||0.E0||CIRCLE||1.E1||4.5E1||0.E0||0.E0 ||-1.E0||0.E0||0.E0||0.E0||1.E0||0.E0
2||1||4.5E1||1.E1||0.E0||1.5E1||1.E1||0.E0||LINE||3.E1||4.5E1||1.E1||0.E0 ||-1.E0||0.E0||0.E0|||||||
CYLINDRICAL_SURFACE||1.E1||-4.95E1||0.E0||0.E0||1.E0||0.E0||0.E0||0.E0||-1.E0||0.E0
2||2||4.5E1||1.E1||0.E0||4.5E1||-1.E1||0.E0||CIRCLE||1.E1||4.5E1||0.E0||0.E0 ||1.E0||0.E0||0.E0||0.E0||1.E0||0.E0
2||3||4.5E1||-1.E1||0.E0||1.5E1||-1.E1||0.E0||LINE||3.E1||4.5E1||-1.E1||0.E0 ||-1.E0||0.E0||0.E0|||||
2||4||1.5E1||1.E1||0.E0||1.5E1||-1.E1||0.E0||CIRCLE||1.E1||1.5E1||0.E0||0.E0 ||1.E0||0.E0||0.E0||0.E0||1.E0||0.E0
```

Figure 9. B-Rep Data of Example part

The output from the GDE algorithm is B-Rep data. Each row of the B-Rep data having 31 fields.

- ❖ Field 1 indicates face number.
- ❖ Field 2 indicates edge number.
- ❖ Field 3, 4 and 5 indicates starting point the edge curve i.e., starting cartesian point.
- ❖ Field 6, 7 and 8 indicates ending point of the edge curve i.e., ending cartesian point.
- ❖ Field 9 indicates type of edge i.e. CIRCLE or LINE.
- ❖ Field 10 indicates radius or magnitude of the corresponding edge.
- ❖ Field 11, 12 and 13 indicates center point or starting of the corresponding edge.
- ❖ Field 14, 15 and 16 gives the direction-1 of the corresponding edge.
- ❖ Field 17, 18 and 19 gives the direction-2 of the corresponding edge. (if the edge type is line then there is no second direction).
- ❖ Field 20 indicates the type of face i.e. CYLINDRICAL_SURFACE or CONICAL_SURFACE or TOROIDAL_SURFACE.
- ❖ Field 21 indicates radius of corresponding face.
- ❖ Field 22 gives semi cone_angle of CONICAL_SURFACE or radius of TOROUS. It is ZERO for CYLINDRICAL_SURFACE.
- ❖ Field 23, 24 and 25 indicates center point of corresponding face.
- ❖ Field 26, 27 and 28 gives the direction-1 of corresponding face.
- ❖ Field 29, 30 and 31 gives the direction-2 of corresponding face.

This B-Rep data is given as input to the different algorithms developed for recognizing secondary turning feature. After the execution as per the flow charts shown above and the output obtained from these algorithms is shown in Figure 10.



```
Select C:\WINDOWS\system32\cmd.exe
Feature Name    Face Numbers    length  Radius   Location
CYLINDER        1,2     3.E1    1.E1    1.5E1,0.E0,0.E0
CYLINDER        18,19   1.5E1   4.E1    -3.E1,0.E0,0.E0
CYLINDER        21,22   1.5E1   5.E1    -4.5E1,0.E0,0.E0
CYLINDER        4, 10   1.E1    2.E1    -1.5E1,0.E0,0.E0  on this
blind hole      5,6     1.E1    5.E0    0.E0,0.E0,-1.E1
blind hole      8,9     1.E1    5.E0    0.E0,1.E1,0.E0
blind hole      11,12   1.E1    5.E0    0.E0,0.E0,1.E1
blind hole      14,15   1.E1    5.E0    0.E0,-1.E1,0.E0
face 1and 2will form a THREAD with magnitude 2.E1 and R= 9.E0 CP= 4.5E1 , 0.E0
 0.E0
blind hole      24,25   2.E1    5.E0    -1.5E1,2.E1,2.E1
blind hole      27,28   2.E1    5.E0    -1.5E1,-2.E1,2.E1
blind hole      30,31   2.E1    5.E0    -1.5E1,-2.E1,-2.E1
blind hole      33,34   2.E1    5.E0    -1.5E1,2.E1,-2.E1
```

Figure 10. Output window of JAVA program for example part-2

Face 1 and 2 will form cylindrical feature having length of 30 mm, radius of 10 mm and centre point of one end of the cylinder is (15, 0, 0). Faces 5 and 6 will form an axial hole of length of 10 mm, radius of 5 mm and centre point of one end of the hole is (0, 0, -10). Face 24 and 25 will form hole on cylindrical surface i.e. radial hole having length of 20 mm, radius of 5 mm and centre point of one end of the hole is (-15, 20, 20). A threaded portion is identified on cylindrical feature formed by face 1 and 2 having length of 20 and minor radius of 9 mm and one end of the centre point of threaded portion is (45, 0, 0).

Total four cylindrical features, four axial holes, four radial holes on cylindrical feature formed by faces 4 &10 and one threaded portion were fond in example part-2 and all these features are tabulated in Table 2. Column -2 of the table shows the type of feature, column -3 indicates the corresponding faces of a feature (These faces are shown on example part in figure 7) and column -4 gives the attributes of the feature.

Table 1: List of features for the example part

| **S.No** | **Feature** | **Face Nos.** | **Attributes** | | |
|---|---|---|---|---|---|
| | | | **Length/ Semi cone angle** | **Radius** | **Centre point of one end of feature** |
| 1 | Cylindrical | 1, 2 | 30 | 10 | (15, 0, 0) |
| 2 | Threaded portion | 1, 2 | 20 | 9 (minor) | (45, 0, 0) |
| 3 | Cylindrical | 4, 10 | 10 | 20 | (-15, 0, 0) |
| 4 | Cylindrical | 18, 19 | 15 | 40 | (-30, 0, 0) |
| 5 | Cylindrical | 21, 22 | 15 | 50 | (-45, 0, 0) |
| 6 | Radial Hole | 5, 6 | 10 | 5 | (0, 0, -10) |
| 7 | Radial Hole | 8, 9 | 10 | 5 | (0, 10, 0) |
| 8 | Radial Hole | 11, 12 | 10 | 5 | (0, 0, 10) |
| 9 | Radial Hole | 14, 15 | 10 | 5 | (0, -10, 0) |
| 10 | Axial Hole | 24, 25 | 20 | 5 | (-15, 20, 20) |
| 11 | Axial Hole | 27, 28 | 20 | 5 | (-15, -20, 20) |
| 12 | Axial Hole | 30, 31 | 20 | 5 | (-15, -20, -20) |
| 13 | Axial Hole | 33, 34 | 20 | 5 | (-15, 20, -20) |

## 7. Conclusion

The methodology proposed in this work is a practical approach to the total integration of CAD and CAPP for the rotational parts by feature recognition from STEP file. The Feature recognition methodology discussed in this work has several advantages over other methods suggested in the literature. The STEP file has the ability to provide a good a generic representation of the simple and compound product data in which the feature, geometry, topology, and manufacturing data are associated. The algorithm for geometric data extraction from STEP file gives the full details of the geometry including the normal and edge direction of the plane, which reduces the complexity while implementing the turning feature recognition algorithm. The turning feature recognition algorithm has the ability to recognize the different features like Cylindrical, Toroidal, Conical, Threading, radial and axial holes etc. with attributes of the features.

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