CHAPTER 3

METHODOLOGY - FEATURE EXTRACTION AND RECOGNITION PROCESS

3.1 INTRODUCTION TO FEATURE TYPES

A product model can have any number and types of features. In order to prove the concept, general types and combinations of features have been considered in the present work. The STEP files of all these components with features were analyzed and the logic developed for different feature types.

The feature analysis has been carried out by grouping the extracted features into categories like

1. **Prismatic features**
2. **Rotational features**
3. **Complex features**
4. **Feature Interactions or Combination of features**

The Prismatic features have been further classified into

a. Rectangular slot
b. Square slot
c. Dovetail slot
d. Rectangular pocket
e. Square pocket
f. General Contour

The prismatic features have been shown in Fig 3.1 to 3.4.

The Rotational features have been further classified into

a. Plain through hole
b. Plain blind hole

c. Array of holes - Circular or Rectangular

d. Cylindrical component

e. Taper component

The rotational features have been shown in Fig 3.5 to 3.7.

The Complex feature include

a. Complex cavities developed by axisymmetric rotation of a spline about a central axis. This component requires 3-axis milling operation for machining. (as shown in Fig 3.11)

The Feature Interactions or Combination of features include

a. T-slot feature comprising of a combination of 2 rectangular slots.

b. Feature comprising of a combination of slot or pocket along with a number of holes in random or in an array.

c. Feature comprising of a combination of cylindrical and taper components.

d. Feature comprising of a combination of cylindrical component and a plain hole.

The feature interactions have been shown in Fig 3.8 to 3.10.

The sample components containing the above mentioned features considered in the thesis have been shown in the figures to follow.
• **Prismatic Features**

Fig 3.1 Plate with Rectangular slot

Fig 3.2 Plate with Dovetail slot

Fig 3.3 Plate with Pocket
• **Rotational Features**

Fig 3.4 Plate with a standard Contour

Fig 3.5 Plate with a Hole

Fig 3.6 Plate with 'n' Holes
• **Feature Interactions**
Fig 3.9 Taper Component

Fig 3.10 Plate with T-Slot
• **Complex cavity feature**

![Complex cavity feature diagram](image)

Fig 3.11 Plate with Complex cavity

The system deals with a unique, novel and exhaustive method to identify and extract required data from all the above depicted features. The logic and the algorithms used in the system development have been briefly explained in the following sections.

### 3.2 PRISMATIC FEATURE RECOGNITION

Here each feature is made up of "edges", hence the name given to the proposed logic being the **Edge Relationship Logic**. The concept has been shown in the table 3.1.
The logic, coded in the system recognizes the features in the following manner.

- Searching for the string representing an EDGE CURVE in the STEP file of the CAD model.
- Analysis of the string, character-by-character to find the hash codes corresponding to Vertex points thereby leading to the Cartesian points.
- Identification of the edges forming part of the feature. This is done by eliminating the edges which have minimum and maximum coordinate values in X, Y and Z directions.
- Identification of the line type viz. horizontal, vertical or inclined.
- Inferring the relationship between the lines e.g. parallel or perpendicular, equal or unrelated.
- Recognition of the prismatic feature is carried out by the Edge theory.
- The Maximum values of X, Y and Z indicate the length, width and height of the plate.
- If length of slot = Length of Plate, it is a through slot, else blind.

3.3 ROTATIONAL FEATURE RECOGNITION

Here each feature is assumed to be made up of "cylinders" or "tapers", i.e., the cylinder has equal radius at both ends whereas the taper has unequal radius at each end.

3.3.1 Cylindrical Feature Recognition

The "Cylindrical Feature Identification Logic" has been proposed to analyze the rotational features. The cylinder parameters include a radius and length. The concept and the coded logic have been briefly explained in this section.
Searching for the string representing a GENERATED CYLINDER in the STEP file of the CAD model. The number of the strings gives the count of the cylinder features in the model.

Analysis of the string, character-by-character to find the hash code and radius value of the cylinder.

Finding the Centre point coordinates (X, Y, Z) and Direction vector (Z values) from hash codes.

If the Z value of the Direction vector of a cylinder = -1, the cylinder is a Hole (subtracted volume).

If the Z value of the Direction vector of a cylinder = +1, the cylinder is a Protrusion (added volume).

Height or length of protrusion = difference between the maximum Z and minimum Z coordinates.

Depth of hole = difference between Average Z coordinate value of 1st & 2nd "Circle" strings and Average Z value of 3rd & 4th "Circle" strings.

The Maximum values of X, Y and Z indicate the length, width and height of the plate (if the component is a plate with holes).

If depth of hole = height of Plate, the hole is a through hole, else it is a blind hole.

3.3.2 Taper Feature Recognition

The "Taper Feature Identification Logic" has been proposed to analyze the taper features. Here each feature is assumed to be made up of "tapers" having a major and minor radius along with a length.
The concept and the coded logic have been briefly explained in this section.

- Searching for the string representing a CONICAL SURFACE in the STEP file of the CAD model. The number of the strings divided by 3 gives the count of the taper features in the model.
- Analysis of the string, character-by-character to find the hash code of the taper.
- Finding the Centre point coordinates (X, Y, Z) and Radius "R" of the start of the cone i.e major radius side, from hash codes.
- Finding the Radius values of "Circle" strings, if Radius is equal to R value, R is major radius and the other radius value of the "Circle" strings will be the minor radius.
- The Length of taper = difference between Maximum X coordinate of "Circle" string corresponding to major radius and Minimum X coordinate of "Circle" string corresponding to minor radius.

### 3.4 COMPLEX FEATURE RECOGNITION

The complex feature is in the form of a cavity which is created by rotating a spline by $360^0$ about a central axis. The cavity is circular at the top surface and gradually changes shape as it reaches the bottom surface. The cavity has been created in a rectangular plate. The spline is made up of Control points placed at regular intervals.

The "**Complex Feature Identification Logic**" has been proposed to analyze the cavity feature.
- Searching for the string representing a Cartesian Point "CONTROL POINT" in the STEP file of the CAD model and store the Coordinate values (X, Y, Z).
- The depth of cavity = Difference between Z coordinate of topmost control point and lowest control point.
- The other coordinate values of the control points along the spline are calculated for each quadrant of the full circle depending on the decreasing values of (X or Y) and Z coordinates (in steps), thereby defining the limits of the cavity.
- From Max values of (X,Y,Z) i.e. the first control point, constant reduction in X and Z coordinates in steps (of say 0.1mm) and checking whether the coordinate values coincide with a point on the spline helps determining the other points on the spline in regular steps thereby aiding in the calculation of the cavity volume.
- Since the cavity is axisymmetric in nature, the coordinates in all 4 quadrants can be calculated by suitably negating X values, adding Y values and decreasing Z values (0.1 mm step), thereby helping in determining the toolpath.

### 3.5 RECOGNITION OF FEATURE INTERACTIONS OR COMBINATION OF FEATURES

The combination of features includes the coexistence of prismatic and cylindrical features, cylindrical and taper features, prismatic and prismatic features or cylindrical and cylindrical
features. The logic discussed in the earlier sections is combined with some modifications in the logic for recognizing combined features.

The input/output parameters along with the logic used are briefly highlighted in this section.

Fig 3.12 Input/output parameters for Prismatic features & Prismatic Feature-Interactions

Fig 3.13 Input/output parameters for Rotational features & Rotational Feature-Interactions
Fig 3.14 Input/output parameters for Prismatic/ Rotational features & Feature-Interactions

The flowcharts in the ensuing sections provide the logic flow in the feature recognition process for all types of features and feature-interactions/ combinations.
Fig 3.15 Flowchart showing Feature Recognition Logic for Prismatic features & Prismatic Feature-Interactions
Fig 3.16 Flowchart showing Feature Recognition Logic for Cylindrical features & Cylindrical/ Taper Feature-Interactions
The features have been identified and extracted using complex and meticulously designed algorithms and logic. A wide variety of features and interactions have been considered and the logic has been tested on all the individual features and feature-interactions yielding good results.