4. Geometric Modelling

4.1 REQUIREMENTS OF GEOMETRIC MODELLING

The functions that are expected of geometric modelling are:

Design analysis:

—Evaluation of areas and volumes.
—Evaluation of mass and inertia properties.
—Interference checking in assemblies.
—Analysis of tolerance build-up in assemblies.
—Analysis of kinematics — mechanics, robotics.
—Automatic mesh generation for finite element analysis.

Drafting:

- — Automatic planar cross sectioning.
- — Automatic hidden line and surface removal.
- — Automatic production of shaded images.
- — Automatic dimensioning.
- — Automatic creation of exploded views for technical illustrations.

Manufacturing:

- — Parts classification.
- — Process planning.
- — Numerical control data generation and verification.
- — Robot program generation.

Production Engineering:

- — Bill of materials.
- — Material requirement.
- — Manufacturing resource requirement.
- — Scheduling.

Inspection and Quality Control:

- — Program generation for inspection machines.
- — Comparison of produced part with design.

Requicha and Voelker [1981] specified the following properties to be desired of in any geometric modelling (solids) system.

1. The configuration of solid (geometric model) must stay invariant with regard to its location and orientation.

2. The solid must have an interior and must not have isolated parts.

3. The solid must be finite and occupy only a finite shape.

4. The application of a transformation or other operation that adds or removes parts must produce another solid.

5. The model of the solid in E3 (Euler space) may contain infinite number of points. However, it must have a finite number of surfaces, which can be described.

6. The boundary of the solid must uniquely identify which part of the solid is exterior and which is interior.

4.2 GEOMETRIC MODELS

The geometric models can be broadly categorised into two types:
1. Two-dimensional, and
2. Three-dimensional.

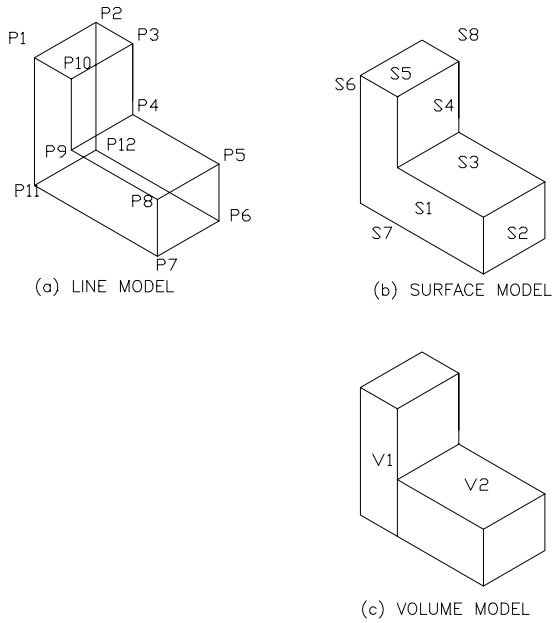


Fig. 4.1 3D geometric representation techniques

The three principal classifications can be

1. The line model,
2. The surface model, and
3. The solid or volume model.

These are represented in Fig. 4.1.

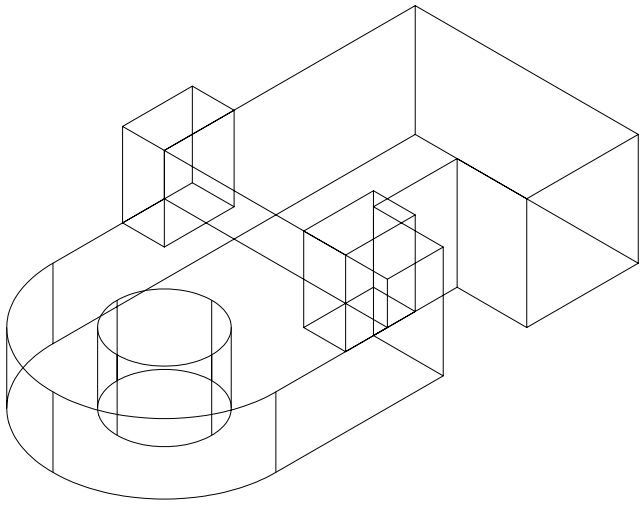


Fig. 4.2 A geometric model represented in wire-frame model

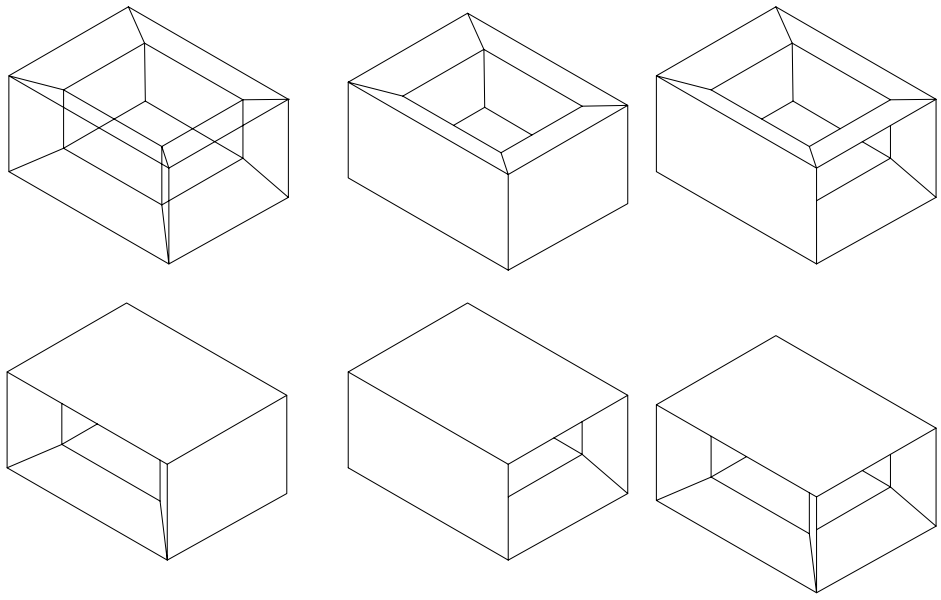


Fig. 4.3 Ambiguities present in the wire-frame model

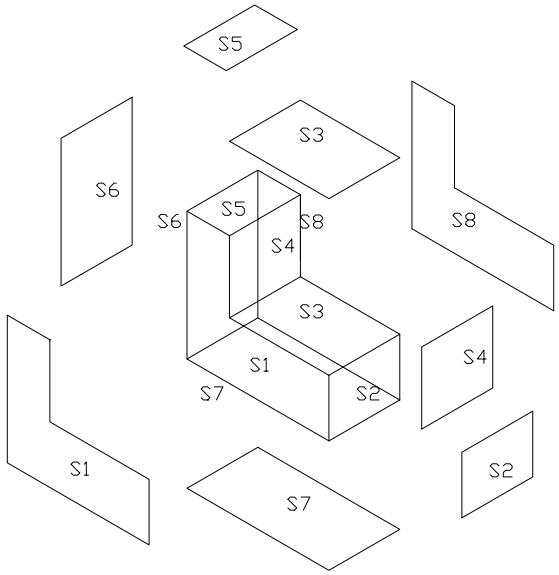


Fig. 4-4 Generation of 3D geometry using planar surfaces

TABLE 4.1 **Comparison of the different modelling methods**

	Line model	*Surface model*	*Volume model*
Automatic view generation (perspective and orthographic)	Impossible	Impossible	Possible
Cross-sectioning	Manually guided	Manually guided	Possible, even automated cross-hatching is possible
Elimination of hidden details	Manually guided	May be possible	Possible
Analysis functions (Geometric calculations)	Difficult or impossible	Difficult or impossible	Possible
Numerical control application	Difficult or impossible	Automatic possible	Automatic possible

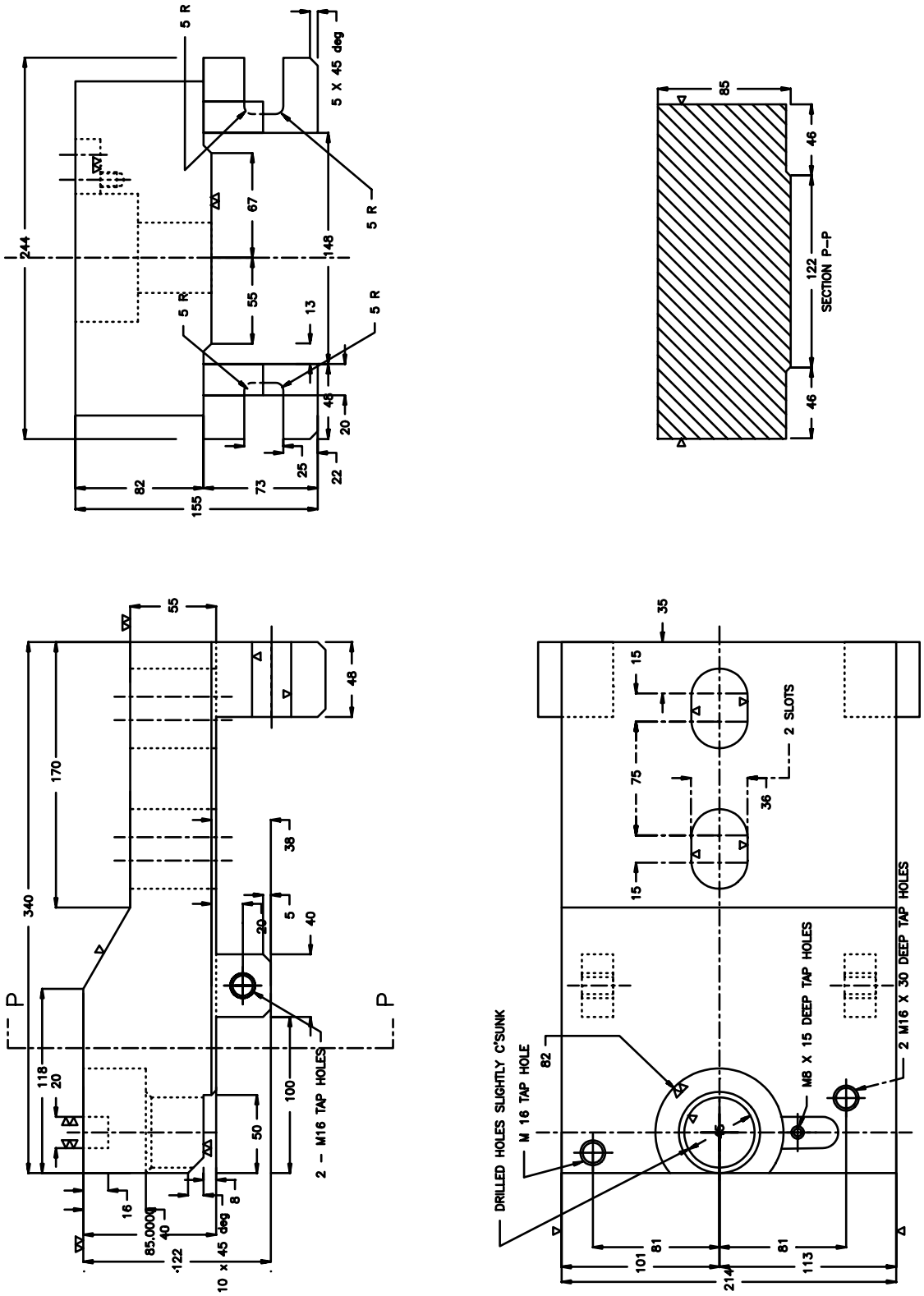


Fig. 4.5 Information present in a 2D drawing (drawing produced using AutoCAD)

4.3 GEOMETRIC CONSTRUCTION METHODS

The three-dimensional geometric construction methods which extend from the 2D that is normally used are:

- Linear extrusion or translational sweep, and
- Rotational sweep.

4.3.1 Sweep or Extrusion

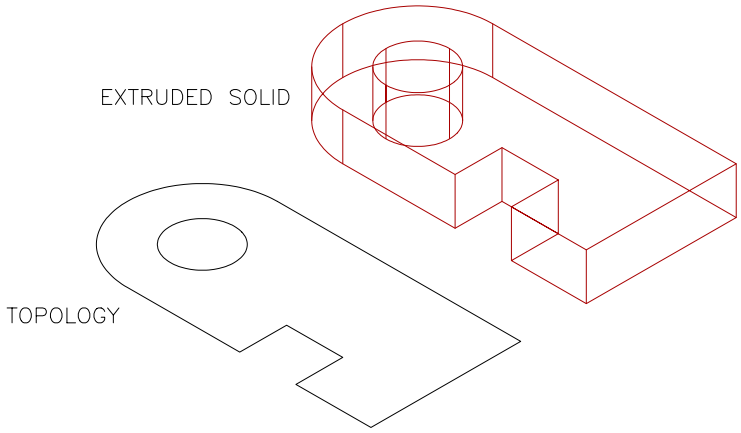


Fig. 4.6 Component model produced using translational (linear) sweep (extrusion)

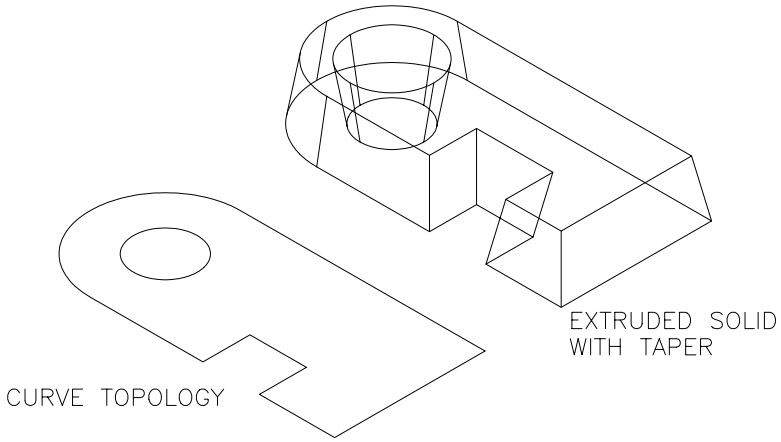


Fig. 4.7 Component model produced using translational (linear) sweep with taper in sweep direction

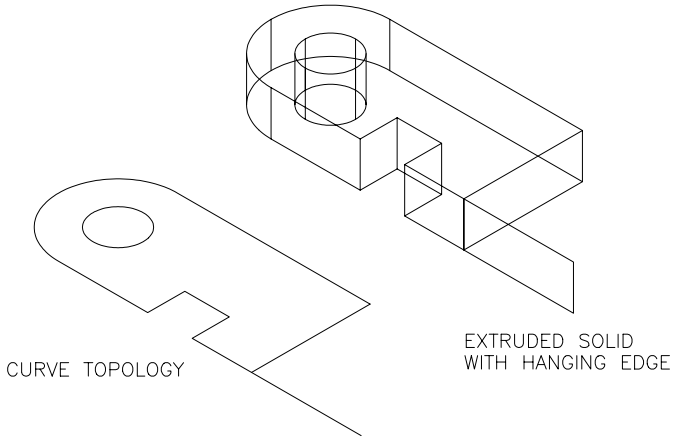


Fig. 4.8 Component model produced using translational (linear) sweep with an overhanging edge

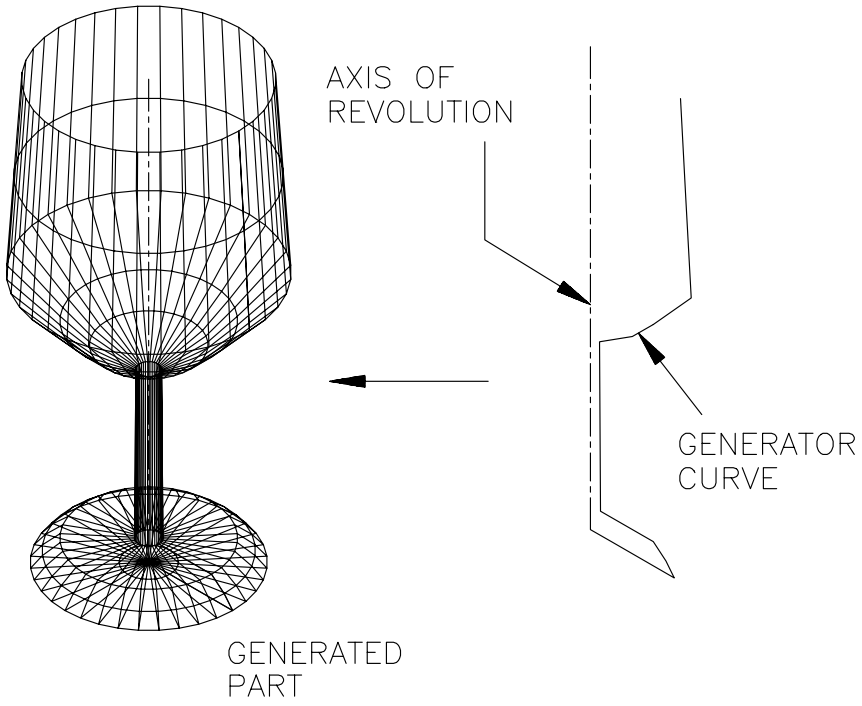


Fig. 4.9 Component produced by the rotational sweep technique

4.3.2 Solid Modelling

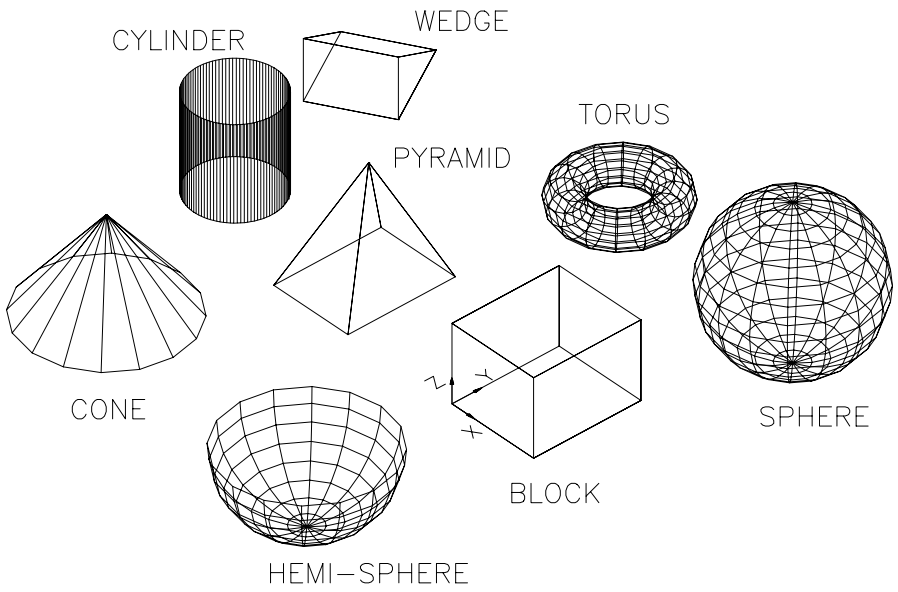


Fig. 4.10 Various solid modelling primitives

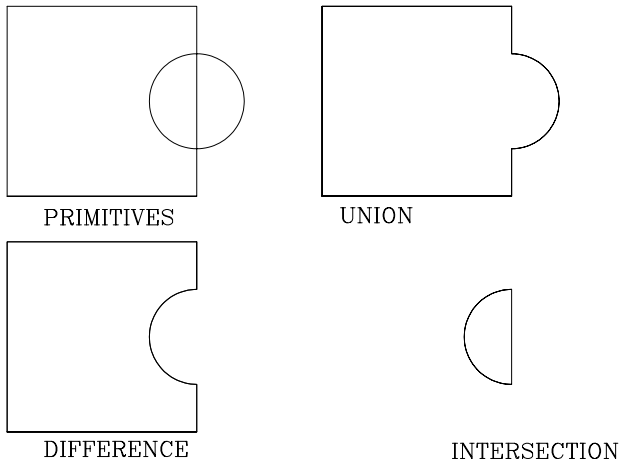


Fig. 4.11 The Boolean operators and their effect on model construction

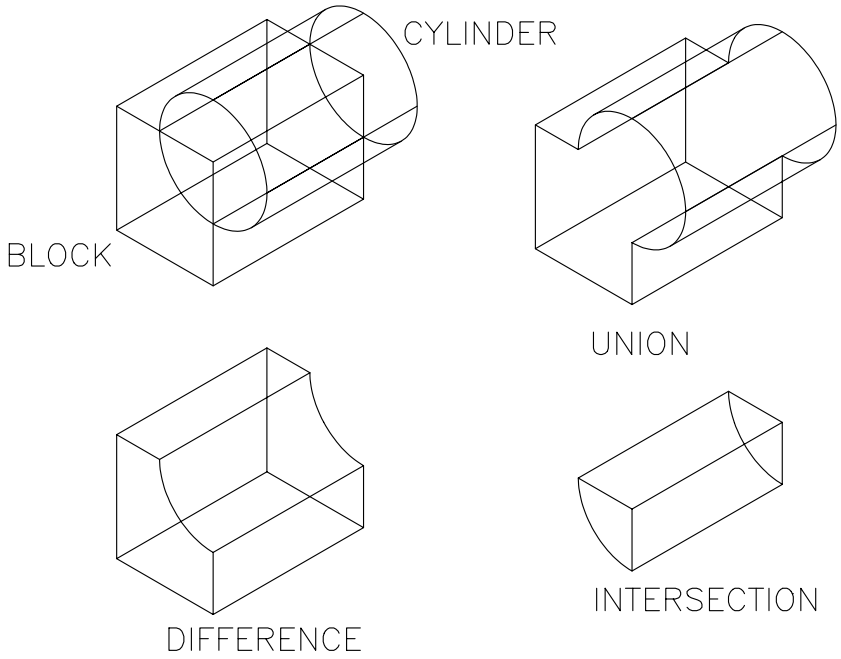
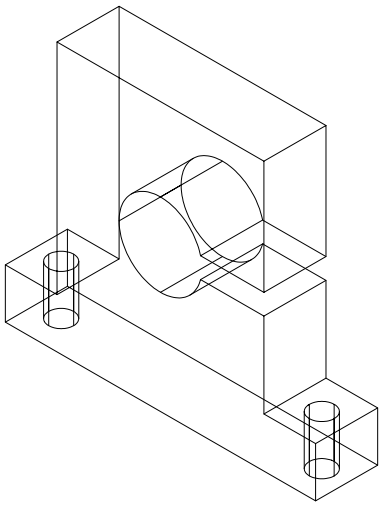


Fig. 4.12 The Boolean operators and their effect on model construction



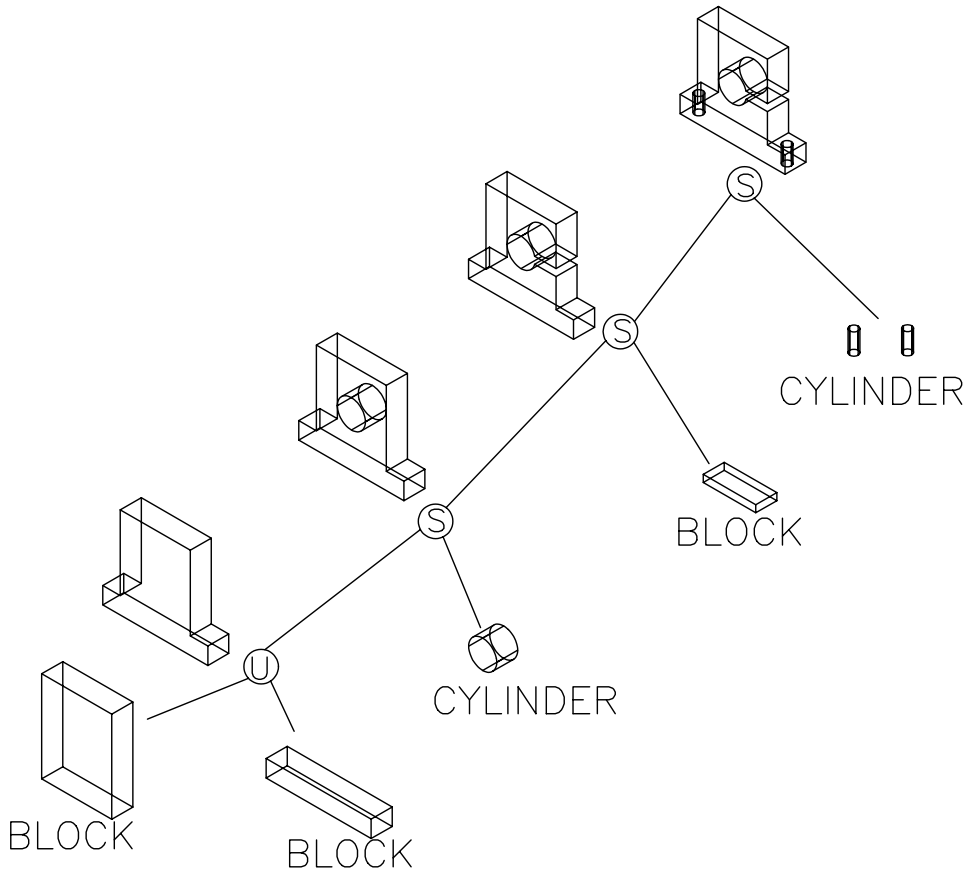


Fig. 4.13 Creating a solid with the 3D primitives in solid modelling and the model shown in the form of Constructive Solid Geometry (CSG)

4.3.3 Free Form Surfaces

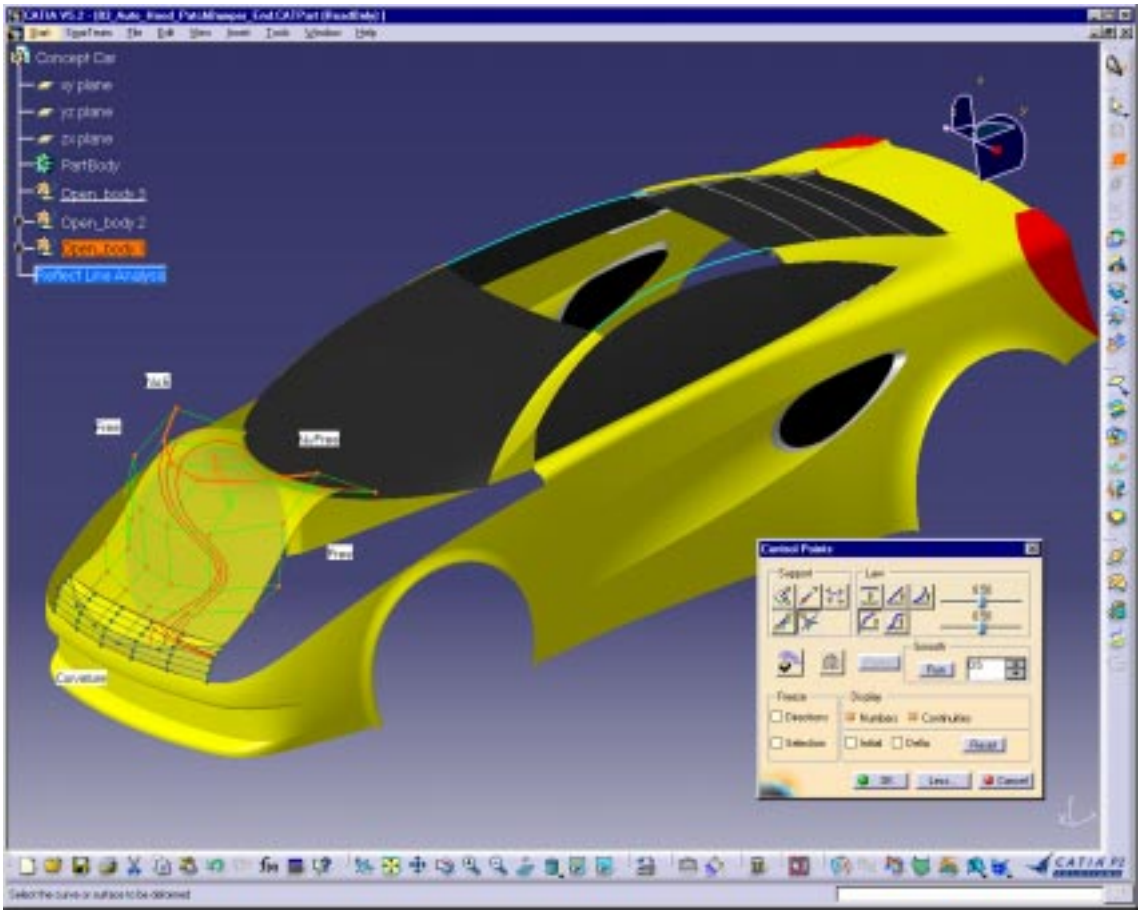


Fig. 4.14 Model generated using the sculptured surfaces (Image appears with the permission of IBM World Trade Corporation/Dassault Systems - Model generated using CATIA)

4.3.4 Skinning or Lofting

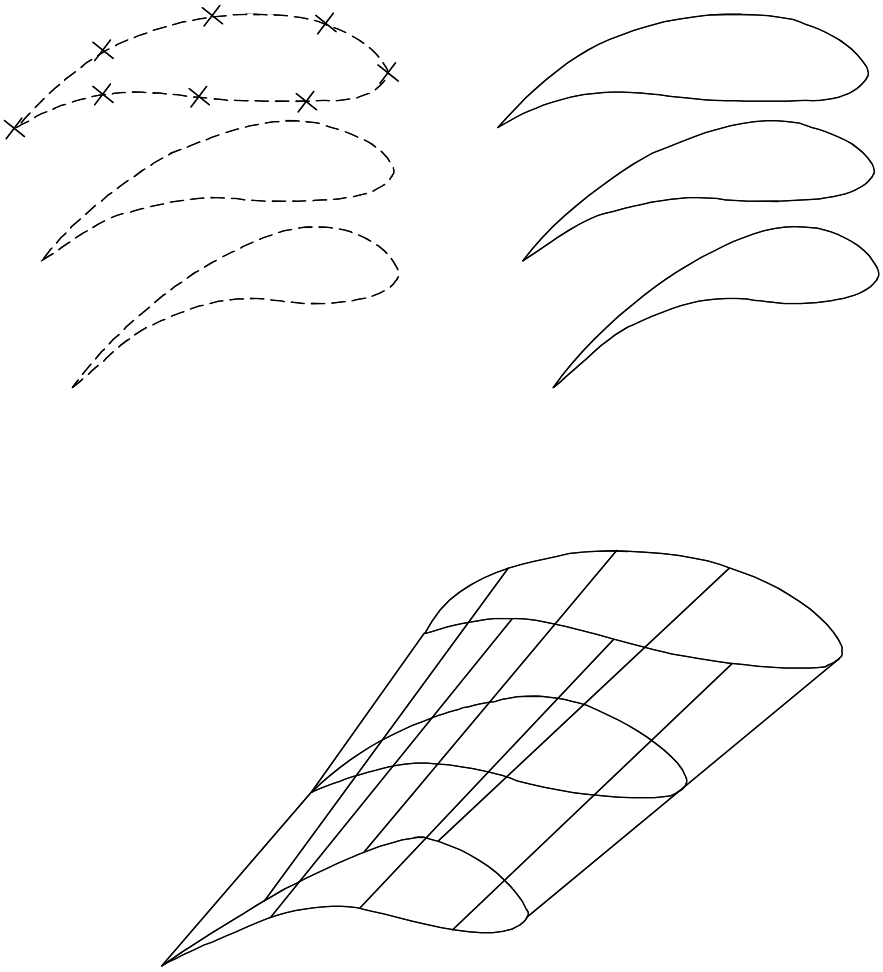


Fig. 4.15 Example of skinning method for model generation

4.3.5 Miscellaneous Construction Methods

Filleting

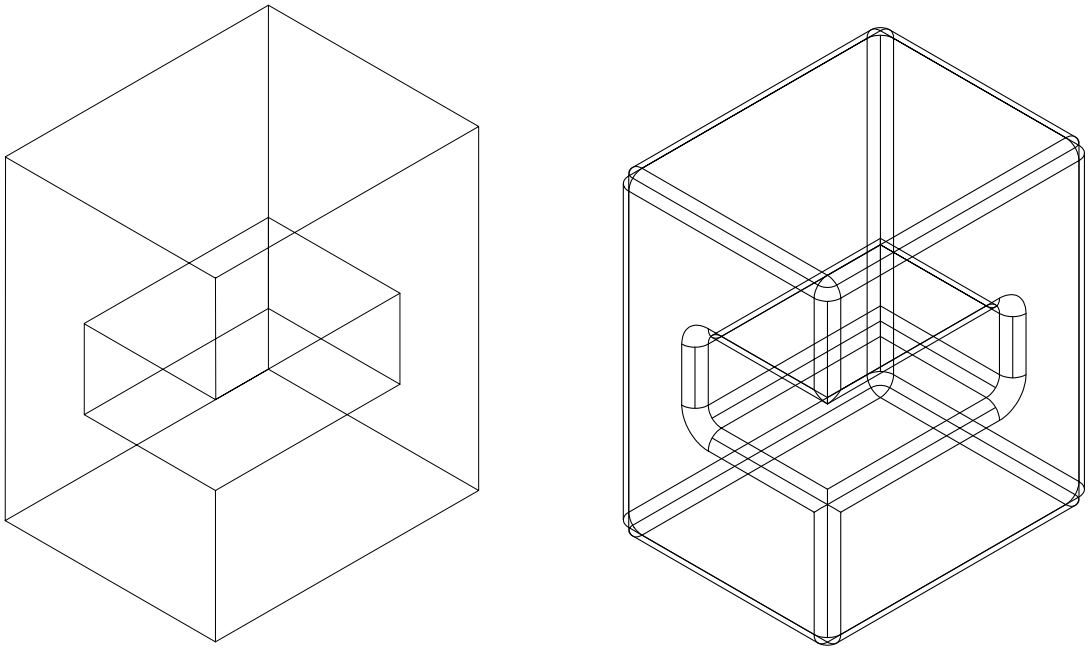


Fig. 4.16 Example of filleting or blend method for model generation

Tweaking

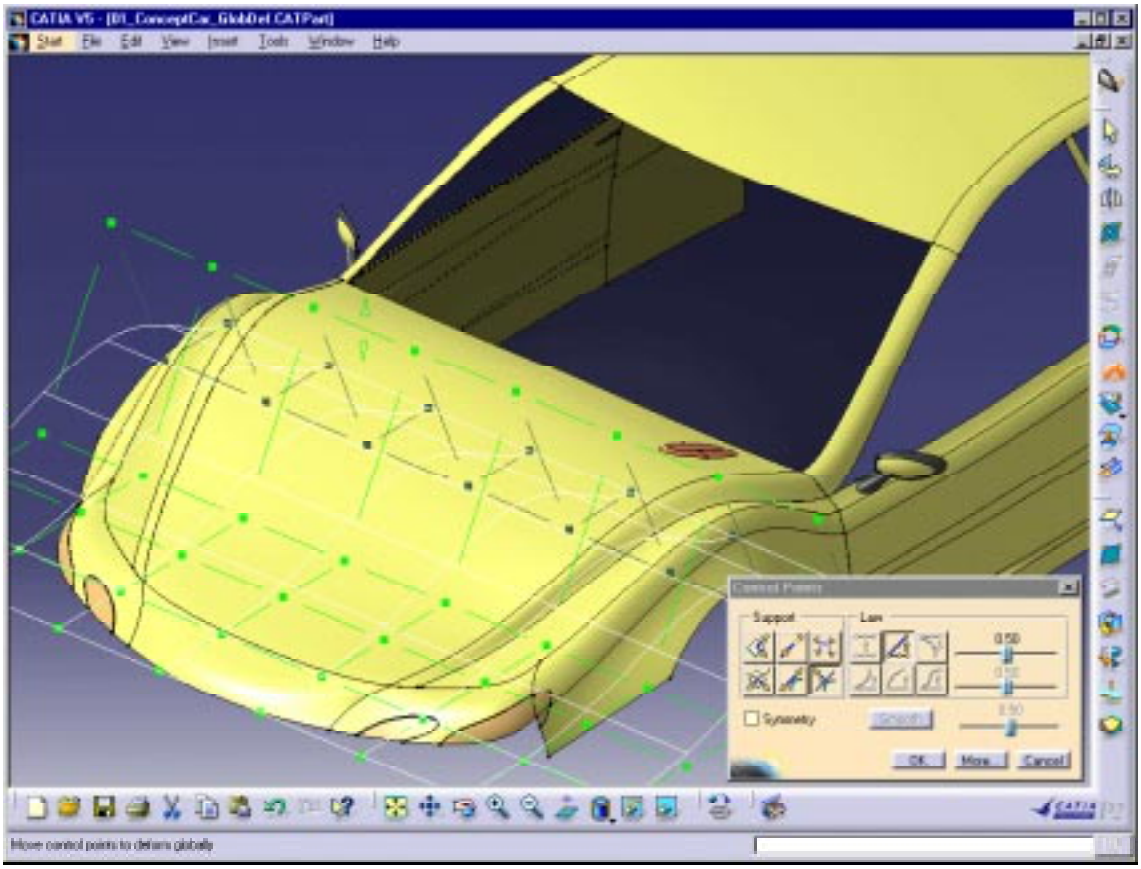


Fig. 4.17 Example of tweaking method for surface modification ((Image appears with the permission of IBM World Trade Corporation/Dassault Systems - Model generated using CATIA))

4.4 OTHER MODELLING METHODS

4.4.1 Variant Method

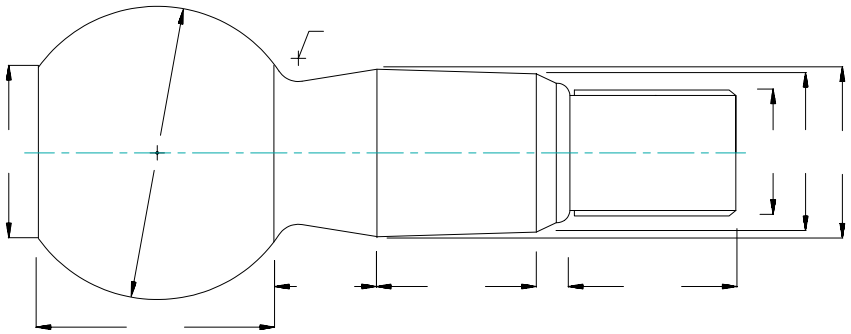


Fig. 4.18 Typical drawing for the variant method of modelling

4.4.2 Symbolic Programming

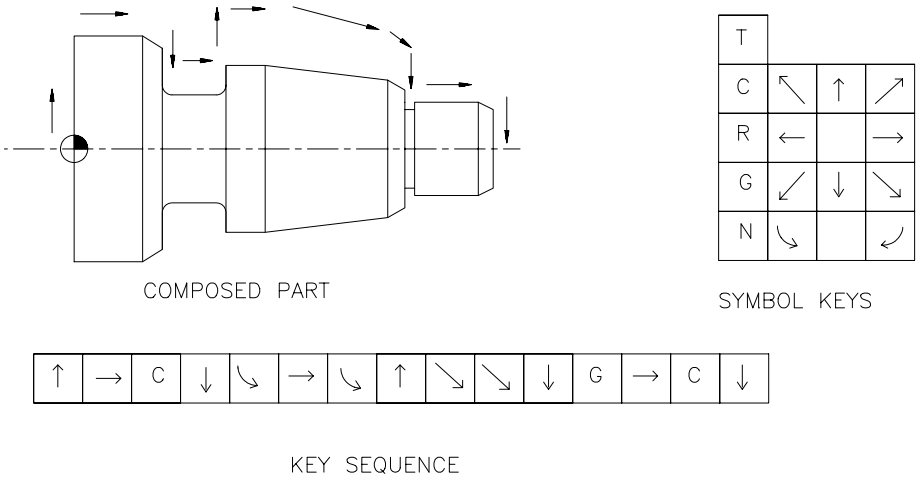


Fig. 4.19 Part model produced using the symbolic programming

4.4.3 Form Features

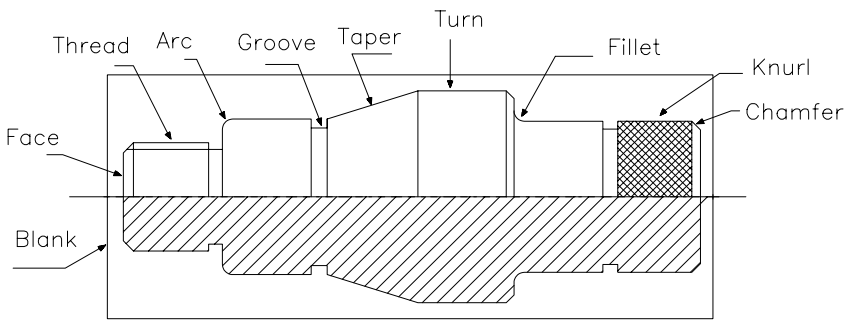


Fig. 4.20 Examples of form elements used for model generation in the case of axi-symmetric components

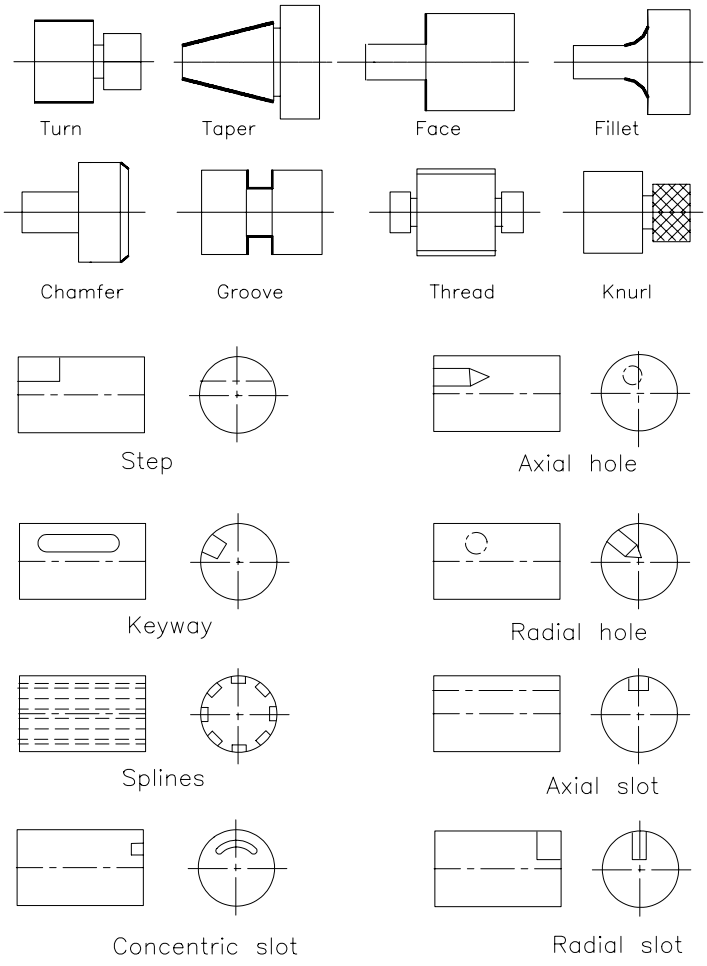


Fig. 4.21 Examples of form features for modelling axi-symmetric components with milled features

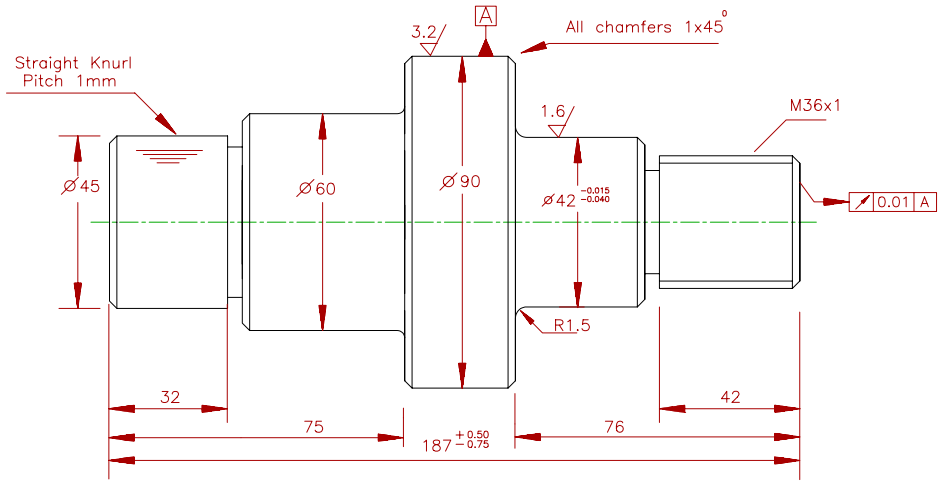


Fig. 4.22 Example component modelled using the features shown in Fig. 4-21

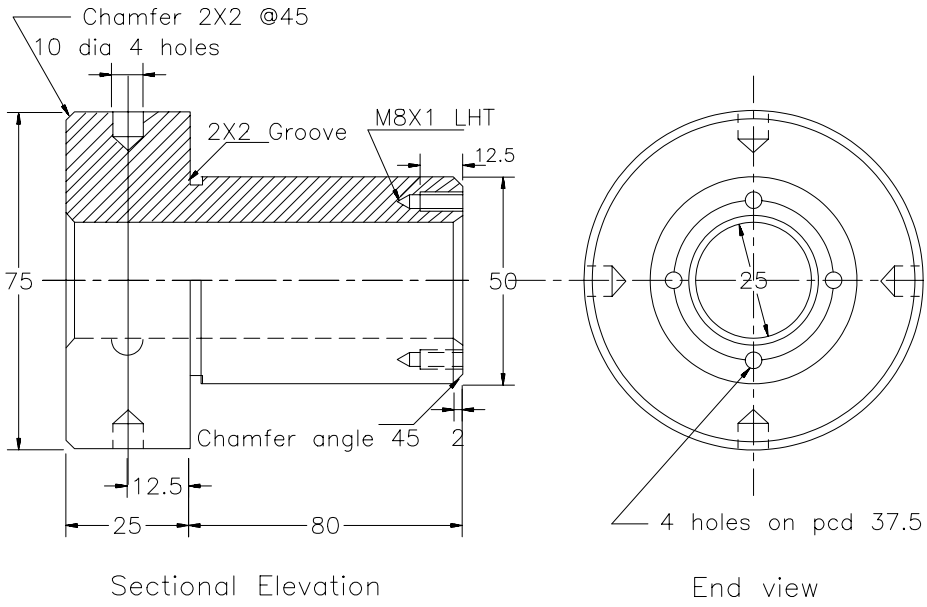


Fig. 4.23 Example component modelled using the features shown in Fig. 4.21

4.5 Curve representation

Representation of curve geometry can be carried out in two forms:

Implicit form, and
Parametric form.

In parametric form, the curve is represented as
X = x(t)

Y = y(t)
Z = z(t)

Circle:

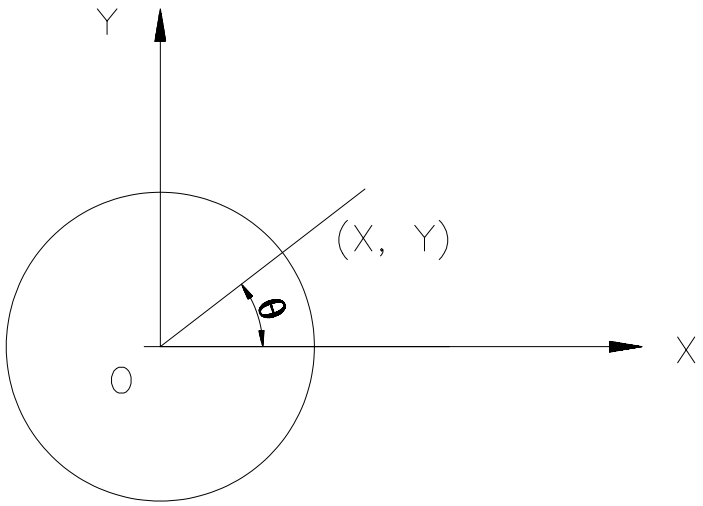


Fig. 4.24 Circle

Ellipse:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

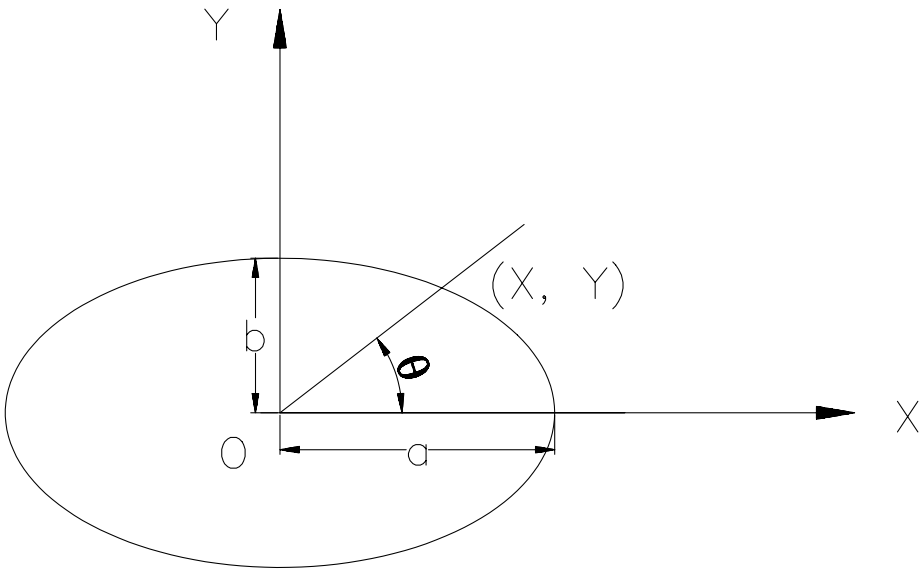


Fig. 4.25 Ellipse

Splines:

Bezier curves:

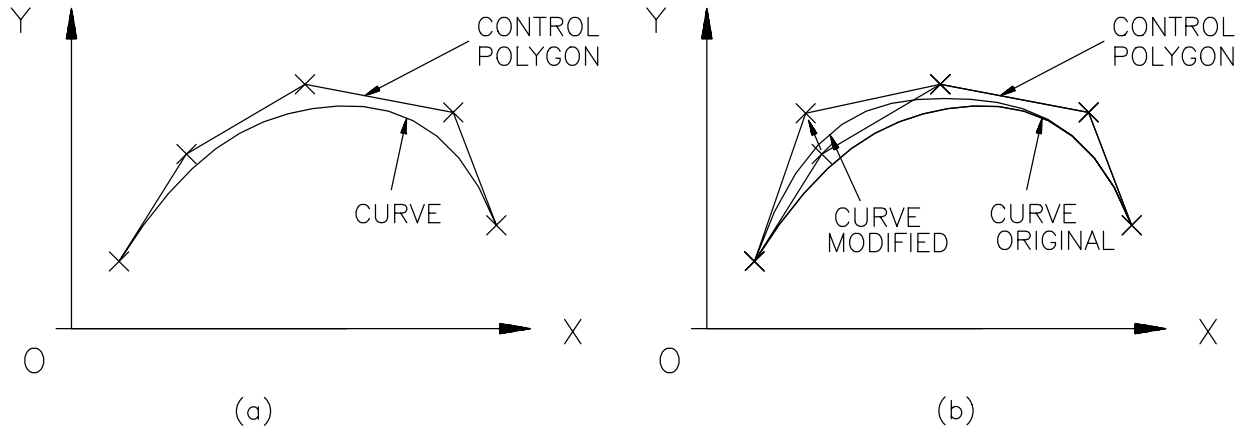


Fig. 4.26 Bezier curve

B-splines:

4.6 MODELLING FACILITIES DESIRED

The total modelling facilities that one would look for in any system can be broadly categorised as follows:

- The geometric modelling features.
- The editing or manipulation features.
- The display control facilities.
- The drafting features.
- The programming facility.
- The analysis features.
- The connecting features.

4.6.1 Geometric modelling features

4.6.2 Editing or Manipulation Features

4.6.3 Display control facilities

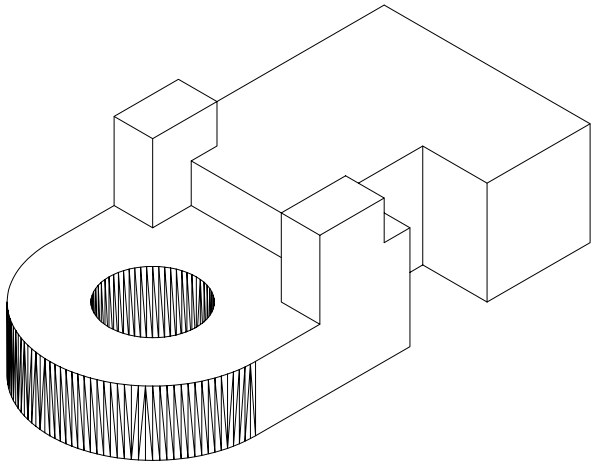


Fig. 4.27 Elimination of hidden lines in display

Fig. 4.28 **Shaded image of a CAD geometric model** ((Image appears with the permission of IBM World Trade Corporation/Dassault Systems - Model generated using CATIA))

4.6.4 Drafting Features

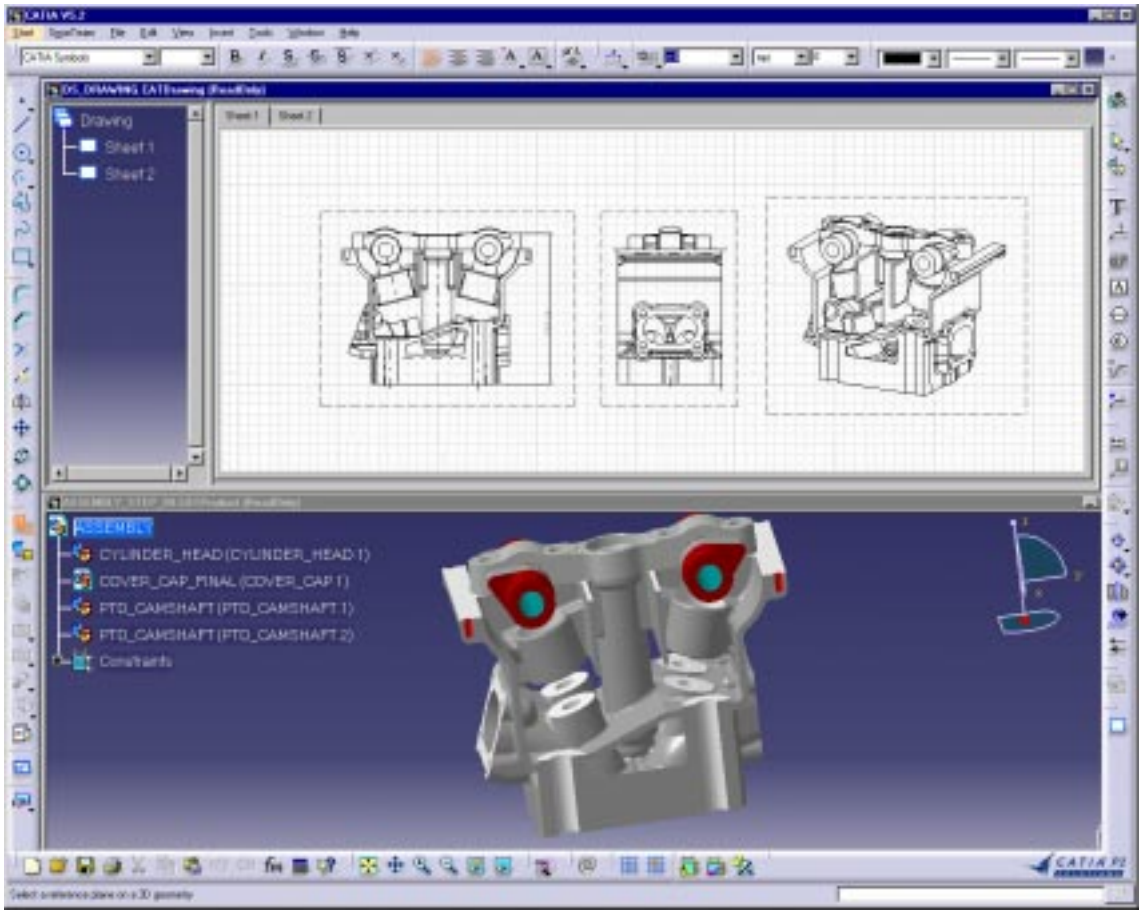


Fig. 4.29 **Orthographic views from a geometric model** ((Image appears with the permission of IBM World Trade Corporation/Dassault Systems - Model generated using CATIA))

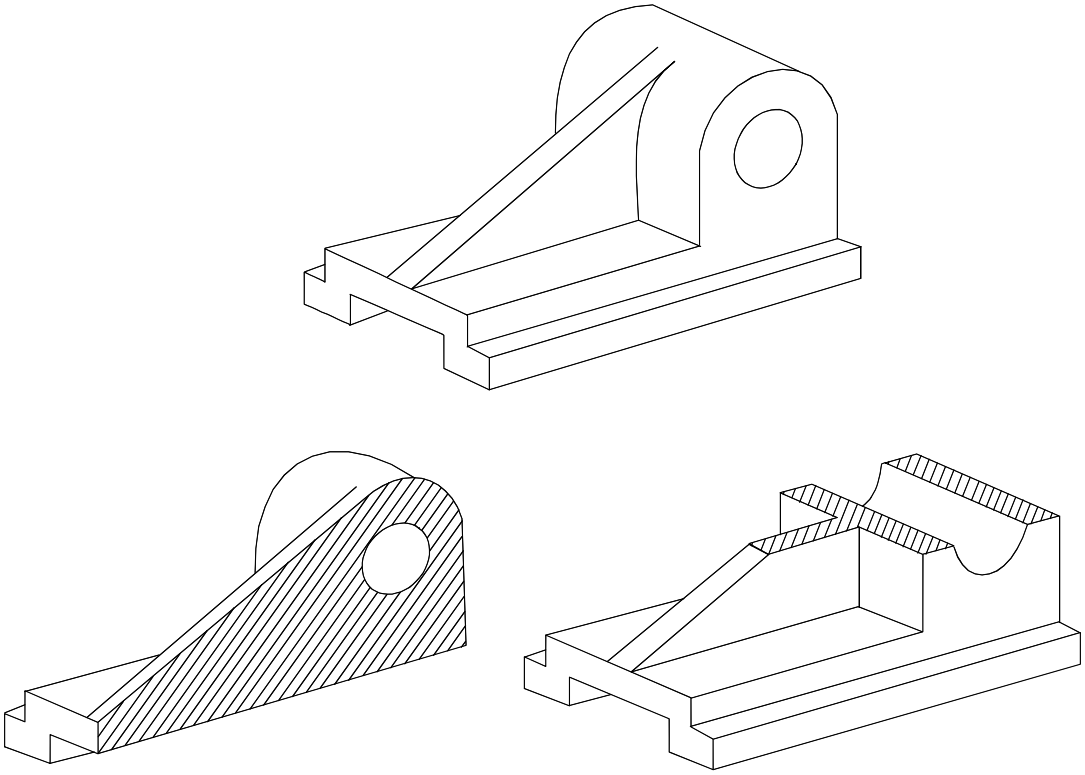


Fig. 4.30 Section view generation from a geometric model

4.6.5 Programming Facility

4.6.6 Analysis Features

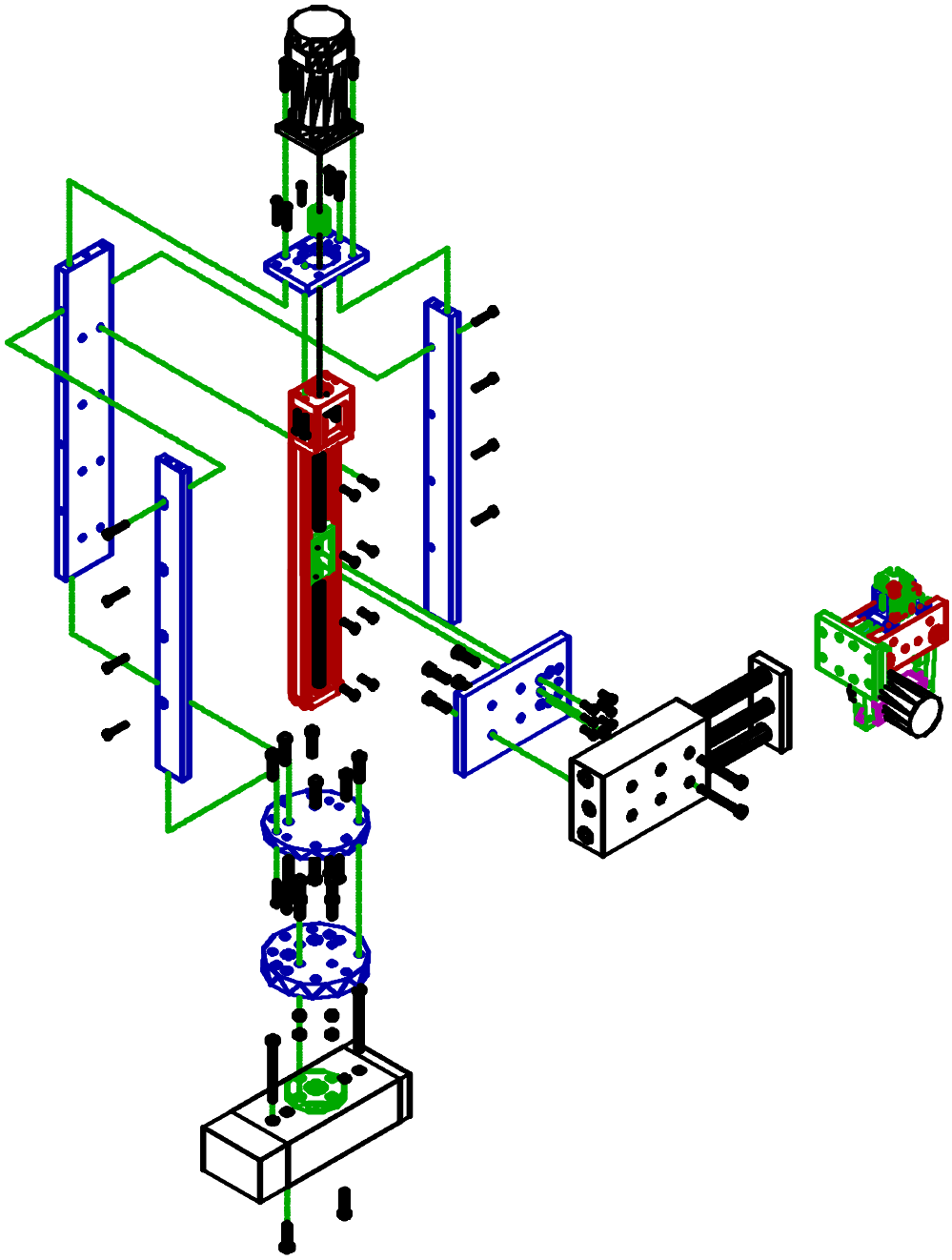


Fig. 4.31 Exploded view and bill of materials of an assembly modelled

4.6.7 Connecting features

4.7 Rapid prototyping (RP)

The technologies involved are:

Stereolithography

Selective Laser Sintering

3-D Printing

Solider Process

Fused Deposition Modelling

Laminated Object Manufacturing

Some of the uses of rapid prototyping are:

- Check the feasibility of new design concepts
- Conduct market tests/evaluation
- Assess the fit of complex mechanisms
- Promote concurrent product development
- Make many exact copies simultaneously
- Make moulds for wax cores in castings
- Use as a master for silicon and epoxy moulds