UNIT 15 CAPP FOR FORMING PROCESSES

Structure

15.1 INTRODUCTION

Sheet metal parts are widely used in various domestic and industrial products such as mixers, washing machines, utensils, containers, automobiles and aircrafts. These parts are produced on metal forming presses using special tools/dies which perform series of manufacturing operations on flat sheets.

Accuracy, productivity and cost of these parts is primarily governed by the quality of dies which are capital intensive. These complex dies are traditionally designed by human experts who have long experience, expertise and knowledge of the forming operations. Design of dies is more of an art than science.

Manual die design tends to be slow, subjective and often sub optimal. Researchers worldwide are, thus attempting to develop Computer Aided Process Planning and Die Design Systems with an objective to improve agility and shorten lead time from design to manufacturing [1] [2].

In this Unit, salient features of CAPP Systems for sheet metal forming will be discussed.

Objectives

After studying this unit, you should be able to understand

- the need and objectives for developing a CAPP System for sheet metal forming,
- modular architecture of automated Process Planning and Die Design Systems,
- working of typical CAPP Systems for Stamping and Drawing operations, and
- case studies and examples.

15.2 CAPP FOR FORMING

15.2.1 Sheet Metal Forming Processes

Sheet metal parts are produced from flat sheets on metal forming presses which use complex special purpose tools called as dies. Figure 15.1 shows typical sheet metal parts used in various products.

Sheet metal parts have various features such Holes, Cutouts, Bends, Dimples, Ridges, Protrusions, Depressions (Dents), etc. These are commonly produced by various sheet forming operations listed below :

(a) Stamping-Blanking, Piercing

(b) Bending-Single/Multi Axis

(c) Drawing

(d) Roll Forming

(e) Lancing

(f) Dimpling

(g) Coining/Embossing

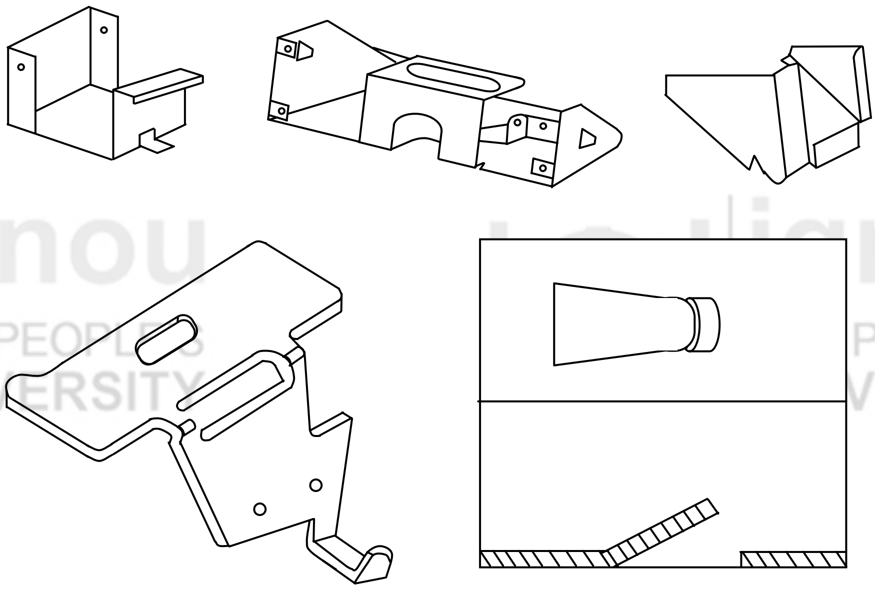


Figure 15.1 : Examples of Sheet Metal Components

15.2.2 Process Planning and Tool Design

In sheet metal forming, Process Planning and Tool Design are closely linked. A process planning engineer essentially carries out the following tasks to decide the strategy for manufacture of a sheet metal component :

(a) Study of part print – part geometry, material, accuracy.

(b) Development of blank geometry.

(c) Deciding sheet forming operations.

(d) Sequencing the forming operations.

(e) Development of Blank, Strip and Die layout.

(f) Design/Selection of Tools/Punches/Dies.

(g) Selection of Standard parts for Dies.

(h) Preparation of Die drawings and Bill of Materials (BOM)

It can be seen that for a specific part geometry, material and production requirement, a customized process sequence is designed [3][4]. The Die is, in fact, a Process Plan realized in hardware.

Since the dies are capital intensive, all decisions in process planning need to be carefully taken. Process Planning is, thus, a very critical design task carried out by human experts having experience, expertise and knowledge.

With frequent product change – a characteristic of today's global manufacturing scenario, it is desirable to automate the process planning and tool design activities for sheet metal parts and link them up with the CAD/CAM activities for enhancing flexibility, productivity and product quality.

15.2.3 Objectives in Developing CAPP

During the last 15 years**,** researchers world wide are developing CAPP systems for sheet metal parts. Many among them are customized in terms of part/process domains and their functional capabilities [3-6].

Broad objectives in developing a CAPP system for sheet metal forming are listed below :

(a) Efficient Computer aided design of sheet metal parts.

(b) Accurate blank development.

(c) Layout planning for efficient material utilisation.

(d) Computer Aided Design of Dies.

(e) Preparation of Die drawings and BOM.

(f) Preparing CNC part programs for Die manufacture.

CAPP systems essentially aim at automating the activities of human process planner/tool designer. Most CAPP systems are based on empirical rules, formulae or data derived from standard handbooks and industry shop practices. Recently some attempts have been made to integrate Finite Element Analysis (FEA) software with CAPP to analyse the stresses developed during forming, particularly at the critical areas on the part where failure may occur. However these studies are at the research level and are out of scope for most general purpose CAPP systems.

In the subsequent sections, CAPP systems for Blanking, Piercing, Bending and Drawing Operations will be presented.

15.3 CAPP FOR STAMPING DIES

First stage in the production of any sheet metal part is to 'Stamp' its outline from a flat sheet. This is done on the presses by Blanking and Piercing Operations performed by the punches and dies. Specific portions of the blank are subsequently Bent to produce bending features on the part. Blanking, Piercing and Bending form three basic operations on most sheet metal components.

Two types of dies are commonly employed to carry out the sequence of operations decided by the Process Planner viz., the Progressive Dies and the Component Dies. [1] In Progressive Dies, the sequence of operations is split over various stages of the die block. The sheet progressively increments through the die stations wherein the different features are successively produced. In contrast, in a Compound die, various features are produced at a single station by carrying out operations successively by a single combination tool. Compound dies are complex to design and costly to produce and maintain compared to Progressive ones.

In industry, Progressive dies are more popular and widely used due to their simplicity of design, manufacture and maintenance. The process planner uses his/her experience in deciding which group of operations should be done in each station/stage and their overall sequence strategy. This is an important decision which governs the die design, part accuracy and productivity [4][6].

15.3.1 Modular Architecture of CAPP System

Figure 15.2 shows the modular architecture of CAPP system for stamping dies. It has various modules to carry out functions listed below :

(a) CAD Modeling of parts

(b) Flat Pattern development

(c) Nesting of Flat Patterns (Blanks)

(d) Die Design

(e) CNC Programming

(f) Output

Die Drawings, BOM, CNC part programs

(g) Database

Materials, Machines, Process capabilities

Error!

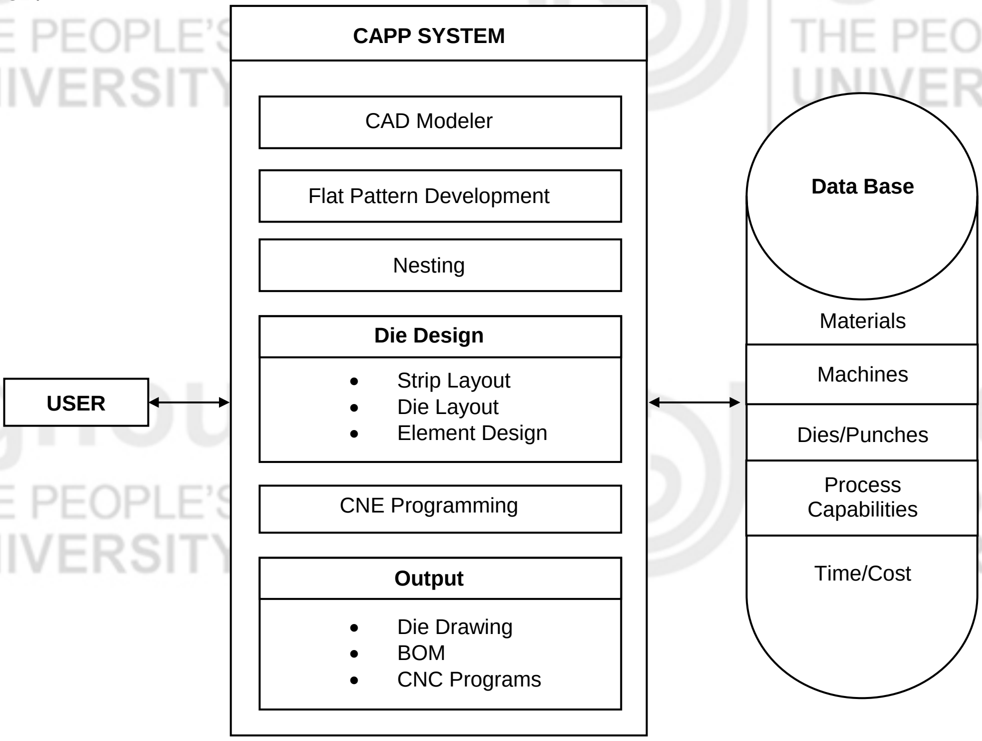


Figure 15.2 : Modular Architecture of CAPP System

Reported CAPP systems have implemented these functional modules to varying degrees to cater different part/process domains, shop practices and outputs desired. Most of the CAPP systems have decision rules based on Heuristics and are in essence, Generative CAPP systems [3-6]. Rule based Expert Systems have also been attempted for specific tasks such as Press Selection, Operation/Process Parameter Selection, Parts/Die selection, etc. [7].

In what follows, features provided by the above modules in CAPP systems are presented in general.

CAD Modeling of Parts

To model a sheet metal part, following data needs to be provided by the user.

- Part Name
- Part Number
- Part Material
- Part Geometry

User is provided with a GUI to input above information. Part geometry data can be inputted by a User friendly CAD modeling interface or imported from a CAD package in the form of standard CAD file in DXF/IGES/STEP format.

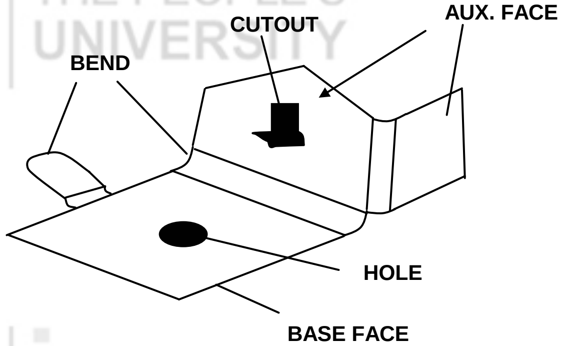


Figure 15.3(a) : Part Modeling Philosophy

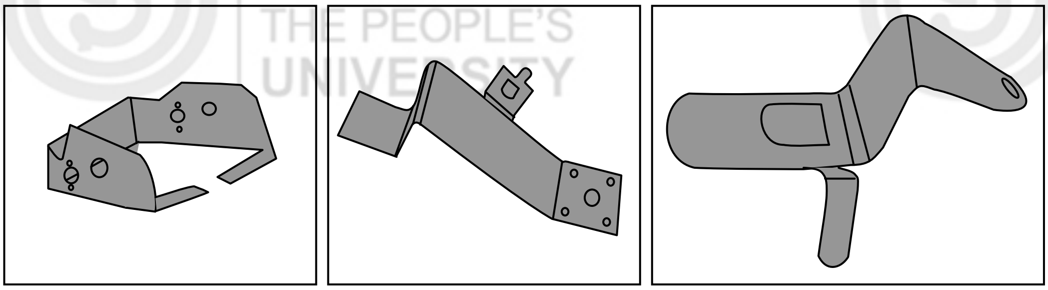


Figure 15.3(b) : Typical Parts Modeled

Figure 15.3 shows the approach followed in CAD modeling of a sheet metal part [2]. The part model is conceived to have a Base Face to which other Auxiliary faces are "Appended". Base Face and the Auxiliary Faces are joined by a "Bend" feature having specific feature parameters like bend radius and bend angle.

Table 15.1 below lists typical part features and the data required for their geometric modeling.

Table 15.1

Sl. No.	Feature	Data needed
1.	Base/Auxiliary Face	Outer Boundary Contour (Edges) Coordinates of vertices and connectivity.
2.	Cutouts	Contour (Edges) Vertex – Edge Data Location on face, Boundary Edge
3.	Bend	Connecting Faces Bend Radius Bend Angle Axis orientation
4.	Protrusion/Depression	Shape Location Consistent Face, Vertex, Edge Data

The geometric data can be provided by the user interactively using mouse or by using custom feature design templates. Figure 15.3 shows typical part models created during the modeling session of a sheet metal CAPP system [2].

The CAD models are internally stored in the form of feature based CAD files following STEP alike data format. These are used in further process planning operations.

Flat Pattern Development

Flat pattern development is the first important step in sheet metal die design and production. Flat patterning essentially means unbending of the 3D sheet metal part onto a flat sheet to determine the blank shape and size, which is produced by blanking operation. For a 3D part, the process of flat pattern development is quite complex as it needs the calculation of bend allowance during the unfolding of part surface (walls) and mapping of features like holes, slots, cutouts, etc. on planes [5].

Traditionally the flat pattern design and drawing is done by process planning engineers using some thumb-rules. It is thus slow, tedious and error prone.

CAPP packages provide a module for automated flat pattern development from the 3D CAD part model. It involves the following steps [2] :

(a) Retrieval of feature based CAD part model

(b) Identification of base face and other faces to be unbent

(c) Gathering parameters of bend from the part database

  (i) Constituent faces

  (ii) Basic feature length

  (iii) Bend angle

  (iv) Bend radius

  (v) Material

(d) Calculating bending allowances (BA) and Bending Compensation (BC)

(e) Computing sizes of flat pattern blanks

(f) Creating CAD model of flat patterns

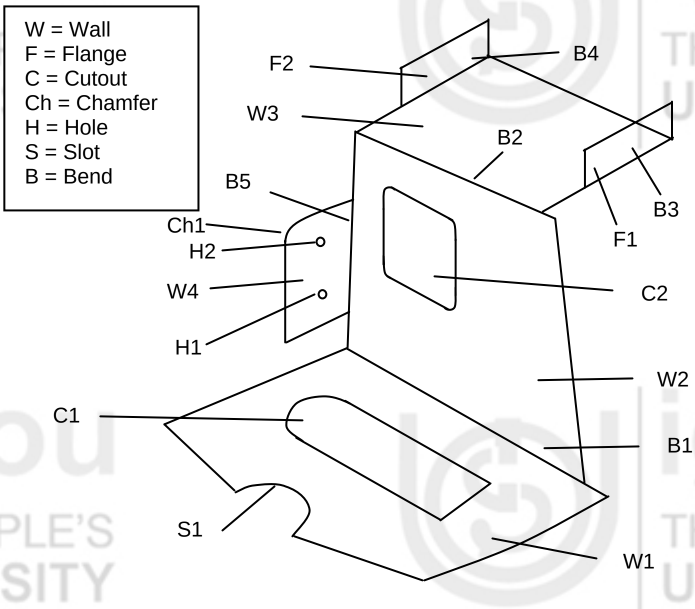


Figure 15.4 : A Sample Part [5]

Figure 15.4 shows a typical 3D model of the sheet metal part with Base Face and other bent faces with relevant data. The CAPP system uses Sach's Rule [5] for computation of Bend Allowance using the empirical equation as under

Bend Allowance (BA) = $\theta\,(r + kt)$

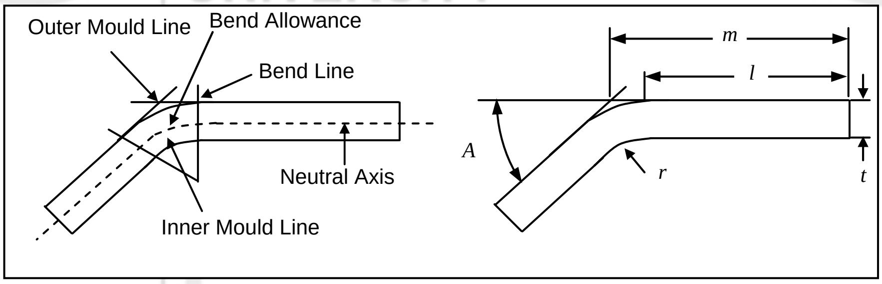
where θ = Bend Angle in radians,

r = inner radius of the bend,

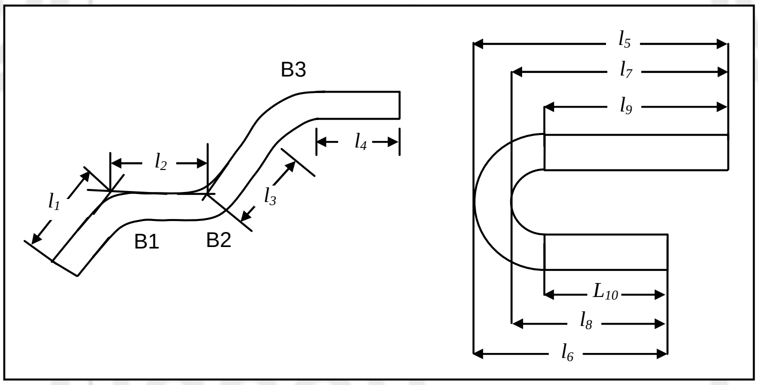
k = empirical constant, and

t = sheet thickness.

The constant K varies between 0.2 to 0.5 based on material type, hardness, inner radius of the bend and stock thickness. It is stored in the CAPP database.



Bending Nomenclature : r = bend radius, t = stock thickness, l = length of straight section, m = mould line dimension, and A = bend angle.



(a) Part Measurements (Except of a 180-degree bend). "Outer" (l_1 and l_2) for bend "B1", "Inner" (l_2 and l_3) for bend "B2" and; "Straight" (l_3 and l_4) for bend "B3", and (b) Part Measurements for a 180-degree Bend. "Outer" (l_5 and l_6); "Inner" (l_7 and l_8) and; "Straight" (l_9 and l_{10})

Figure 15.5 : Bend Feature Nomenclature

Bend Compensation (BC) is the length to be subtracted from the specified lengths of the connected sections when calculating the blank length. Figure 15.5 shows the nomenclature for specifying section lengths and type of bending viz., 'Outer', 'Inner' and 'Straight' [5]. For example, the blank length for sections with l_1 and l_2 is (Figure 15.5).

$$\text{Blank Length} = l_1 + l_2 - B2$$

CAPP system will automatically compute BC based on cases enumerated below :

(a) BC is calculated as per the three cases – outer, inner and straight bond.

(b) BA is calculating by earlier.

Outer Bend

$$BC = 2\,(r + t)\tan\left(\frac{\theta}{2}\right) - BA$$

Inner Bend

$$BC = 2\tan\left(\frac{\theta}{2}\right) - BA$$

Straight Bend

$$BC = -\,BA$$

Figure 16.6 shows the flat pattern developed from the CAD model of the part shown in Figure 15.4.

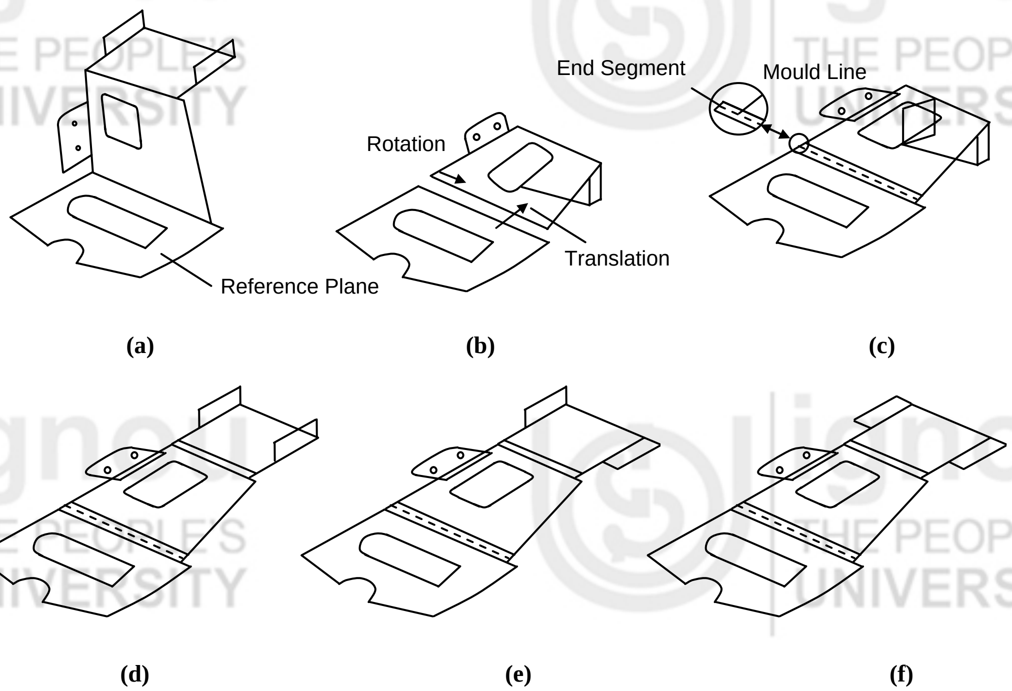


Figure 15.6 : The Unfolding Steps for the Sample Part

Nesting of Flat Patterns (Blanks)

Nesting of flat patterns is important in sheet metal CAPP as it directly governs material utilization, productivity and cost of production. Nesting is the placement of several similar/dissimilar flat patterns (blanks) on a larger sheet/strip to maximize material utilization and minimise scrap.

Apart from material utilization, many technological constraints need to be taken into consideration during nesting [4][6]. Important among them are as under :

- Manufacturing process, Machine
- Blanking press, Flame cutting, Laser/Water jet cutting
- No. of dies for blanking Presses
- Sheet/Strip size – (Length, Width)
- Orientation of bend with grain direction
- Clearances (bridge) between band sheet edges.
- Types of blanks – similar/different geometry.
- Preferred shop practices.

Figure 15.7 shows a typical blank placement on sheet indicating the clearances (Bridge) between blanks, sheet edges, pitch of the layout and orientation of blanks. The bridge allowances are selected by the CAPP system database created from handbook recommendation and heuristics. The values are dependent upon the material of the part, hardness of sheet, grain orientation and sheet thickness [4][6].

The problem of optimal placement of parts on sheet (Nesting) is a very complex mathematical problem. Researchers world wide have developed several computer algorithms to solve this problem using various techniques like heuristics, knowledge based (Expert System), statistical techniques and recently the genetic algorithms [2].

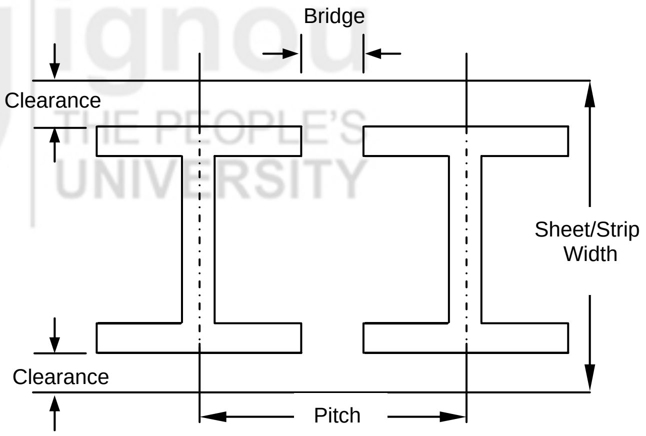
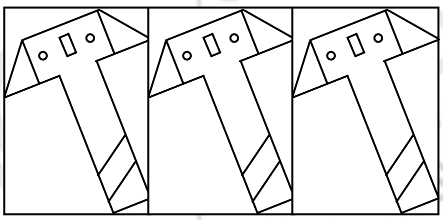


Figure 15.7 : Blank Layout Parameters

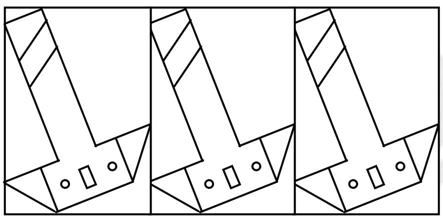
Problems of nesting rectangular sheet is relatively simple but nesting of irregular geometry blank parts onto rectangular sheet is very complex.

Given the parts to be nested, their CAD models, number and sheet size, the CAPP system automatically designs and displays optimal nesting layout. Various cases can broadly fall into four categories [4].

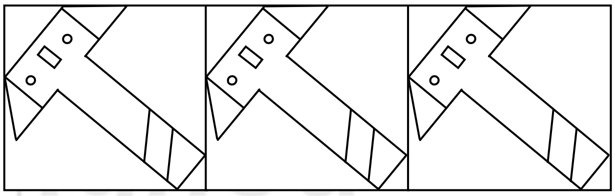
- Single Product, Single Row (SPSR)
- Single Product, Multi Row (SPMR)
- Multi Product, Single Row (MPSR)
- Multi Product, Multi Row (MPMR)



Tilting Angle : angle = 20^{o}
Slitting Width = 157.793
Pitch = 105.326
Utilisation Ratio = 0.4272



Tilting Angle : angle = 204^{o}
Slitting Width = 157.254
Pitch = 110.300
Utilisation Ratio = 0.4094



Tilting Angle : angle = 60^{o}
Slitting Width = 119.663
Pitch = 155.020
Utilisation Ratio = 0.3828

Figure 15.8 : Typical Part and its Layouts

Figure 15.8 shows a typical part and its various layouts generated with reported material utilization ratio [6]. The user can select the desired layout based on the machine and shop constraints.

Die Design

The optimal blank layout generated by the nesting module of CAPP software is used further for the die design. There are three important sub stages in automated die design.

- Strip Layout
- Die Layout
- Design/Selection of Punch/Die elements

CAPP system has some rules derived from practice which carry out technological checks at every stage to ensure the feasibility of die design. These essentially include data range checks and production constraints.

In the strip layout module, the type of die is selected depending upon sheet thickness, product accuracy, production quantity and complexity of the part/blank. Strip layout is automatically created by the CAPP system considering number of stages in the progressive dies; pitch, slitting width and the punch profile details in each stage. For compound dies, such splitting of geometric data over stages is not required. Based on the strip layout, the die layout module of CAPP system carries out various tasks such as computation of force and center of pressure, selection of die and punch material, stripper, punch holders, back up plates, springs, etc. [4].

The next stage is to design/select standard punches, die blocks, check them for strength (feasibility), etc. The die design module converts the strip layout into actual die (Tool) by generating an assembly of punches and dies and creating the actual die solid model in the CAD system. CAD model of the die is automatically generated by the system by Virtually Assembling CAD models of various die components. Die drawings and bill of material are the outputs generated by the CAPP system.

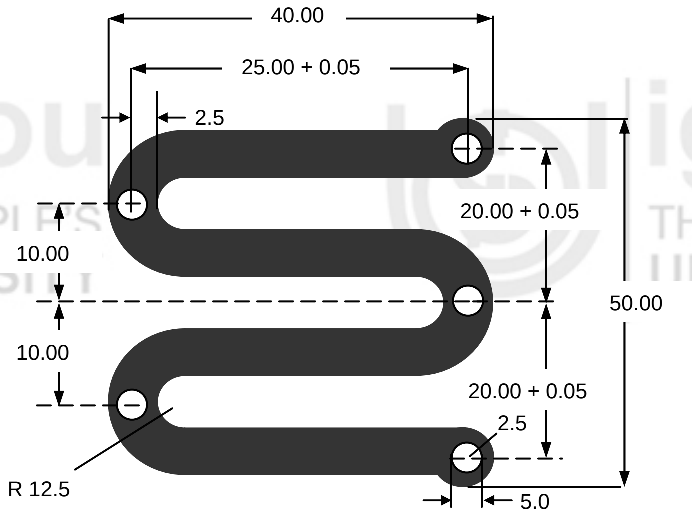


Figure 15.9 : Component for Die Design [4]

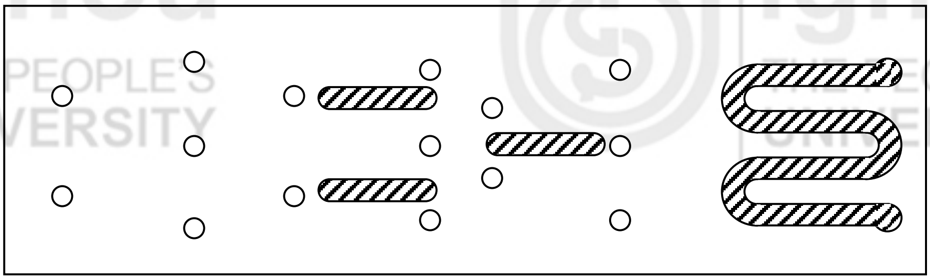
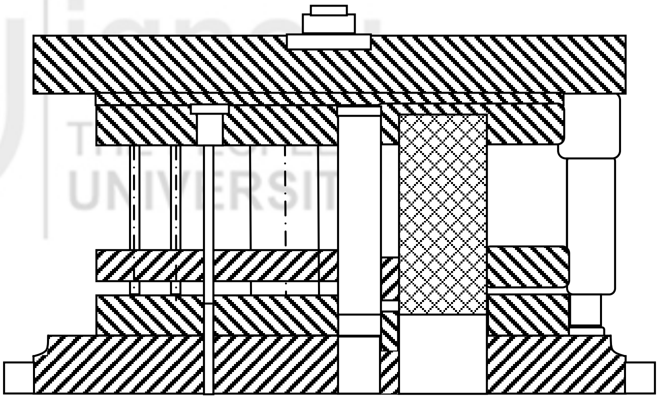
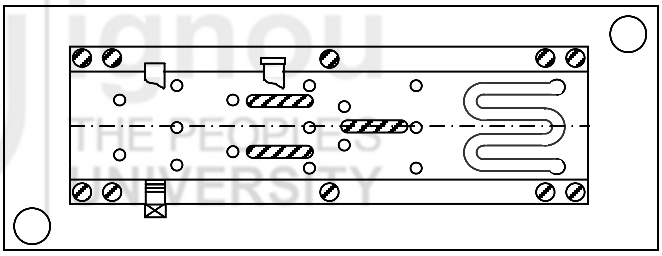


Figure 15.10 : Strip Layout [4]

Figure 15.9 shows a typical sheet metal part to be produced. Figure 15.10 shows the strip layout for the progressive die. Figure 15.11 shows the die drawing and BOM for the progressive die to manufacture this component [4].





Sl. No.	Description	Catalogue Number	Material	Quantity
21	Flat spring	9-1204-11	Special steel	3
20	Intermediate stop	Standard	Standard	2
19	Stripper bolt	M16 × 100	10.8 steel	6
18	Guide bush	DR 19	Standard	2
17	Pilot	D5-6 × 11	Tool steel	2
16	Dowels	PR 65	Standard	2
15	Spring for stop	M5 × 30	Special steel	3
14	CS screw	M8 × 40	12.9 steel	8
13	HSHG screw	PR 65	12.9 steel	6
12	Dowel pin	Standard	Standard	2
11	Pin stop	DR 19	Standard	3
10	Lower die shoe	Standard	Cast iron	1
9	Die block	Standard	Tool steel	1
8	Piercing punch	Standard	Col. Steel	5
7	Stripper	Standard	CR steel	1
6	Blanking punch	Standard	Col. Steel	3
5	Punch pate	Standard	1040 SAE steel	1
4	Back-up plate	Standard	Hrd steel	1
3	Guide pillar	DR 19	Standard	2
2	Upper die shoe	DR 19	Cast iron	1
1	Shank	Standard	Semi steel	1

Figure 15.11 : Die Design and BOM [4]

Data Base

Database for the CAPP system has various layers which store the following information :

- Part material, hardness, strength
- Empirical constants/Tables for bend allowance
- Design check rules
- Press/Die specifications

- Standard punch/die elements
- Vendor data, costs

Various sheet metal CAPP systems for blanking, piercing, bending have been developed by industries/academic researchers which cater to differing capabilities, specifications and part/process domains.

It has been generally reported that compared to manual process planning and die design, CAPP systems significantly reduce the lead time from months to weeks and provide optimum die design. CAPP systems provide output in terms of Die drawings, BOM, cost estimation [4][6]. CNC part programs help in the rapid productionisation of dies required for today's competitive manufacturing scenarios.

15.4 CAPP FOR DRAWING DIES

15.4.1 Deep Drawing Process

Deep drawing is an important sheet metal forming process to produce a wide variety of axi-symmetric and non axi-symmetric hollow shapes such as cups, domes and shallow cavities. Deep drawn products are produced on presses using special dies which could be Single stage, Progressive or Transfer types. Single stage dies are generally used for batch production of low accuracy products while Progressive and Transfer dies are used for mass production of products requiring higher accuracy [1].

Deep drawing process is a complex capital intensive process. A well designed die offers benefit of high productivity, low scrap rate, excellent mechanical properties after forming, good surface quality and high accuracy of drawn parts.

15.4.2 Need For CAPP

Process planning for drawing involves the determination of sequence of operations and the die design parameters which convert the raw material into the finished shape. Process Planning is quite involved as it has to take into account several complex factors such as material properties, lubrication between the die and work material, press rigidity, punch and die geometry, die material and processing methods. The quality of drawn products naturally depends on the experience, skill, knowledge and judgment of the die designer/methods engineer. Traditionally this task is done by human process planners/die designers having knowledge accumulated over years of experience. Manual process planning and tool design however, tend to be slow, subjective and sub optimal.

During the last decade, researchers have tried to develop CAPP systems for drawing. However compared to CAPP systems for machining, CAPP system for drawing are still in their infancy. Reported systems are often Semi-generative/Variant CAPP systems for specialized material, part and shop domains.

The architecture and working of a knowledge based CAPP system for deep drawing is presented in the sections to follow [7].

15.4.3 Knowledge Based CAPP System for Drawing

The architecture of a knowledge based CAPP system for drawing is quite similar to one discussed earlier for stamping (Figure 15.2). It essentially has the following functional modules :

(a) CAD modeling of parts

(b) Blank development

(c) Die Design

  (i) Planning stages in drawing

  (ii) Developing intermediate geometry

  (iii) Die Layout

(iv) Design/Selection of punch/Dies

(d) Output

(i) Die Drawings

(ii) BOM

(e) Data Base

(i) Materials

(ii) Press/Tool Specifications

(iii) Decision Rules/Tables

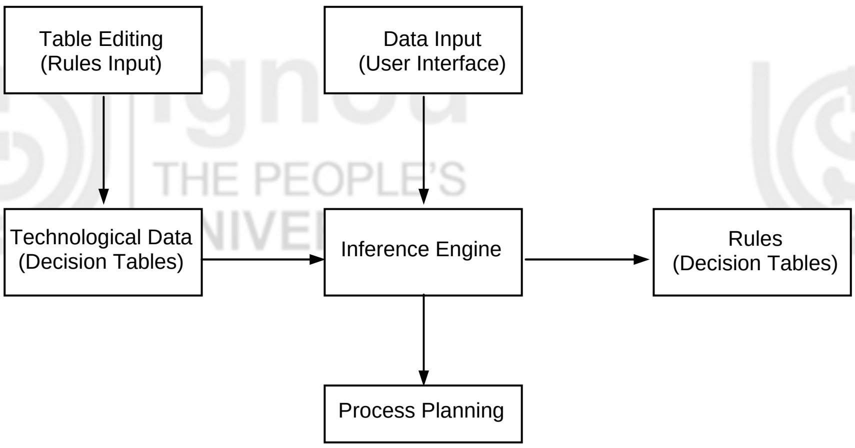


Figure 15.12 : Knowledge Based CAPP System for Drawing [7]

The CAPP system is knowledge based having an Inference engine and Rule/Data base as shown in Figure 15.12. The overall working of the knowledge based CAPP system is shown in Figure 15.13. It essentially is a two stage process as under.

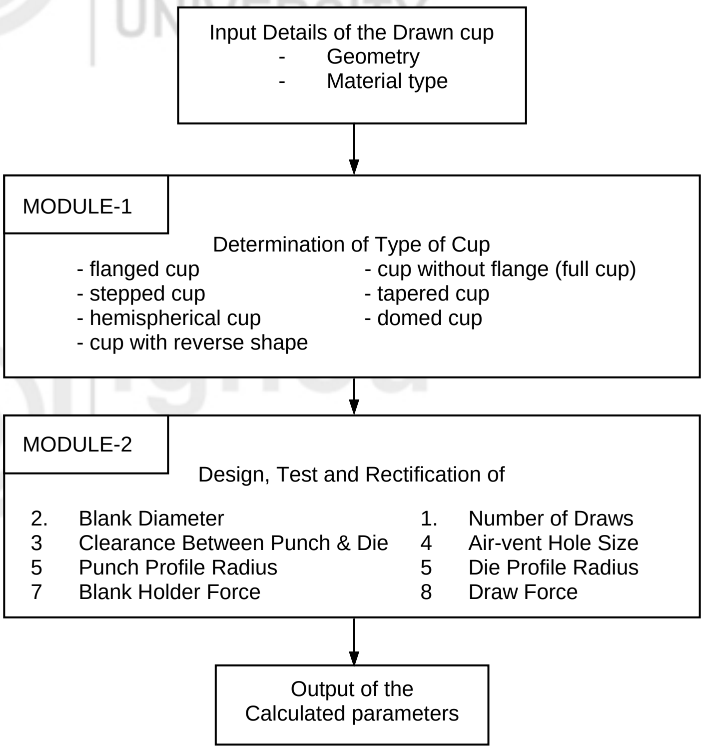


Figure 15.13 : Working of Knowledge Based CAPP System [7]

Stage 1

Identification of the type of cup geometry to be formed from the CAD part model.

Stage 2

Design of Die Stages.

In what follows, important functional modules of the CAPP system are discussed.

CAD Modeling of Parts

Using CAD package, the user can model the geometry of axisymmetric drawn cup (final shape) as shown in Figure 15.14. Geometry of the cup is described in terms of seven types of geometric primitives viz., Horizontal, Vertical, Tapered, Concave, Convex, Reverse-Tapered and Fillet [7].

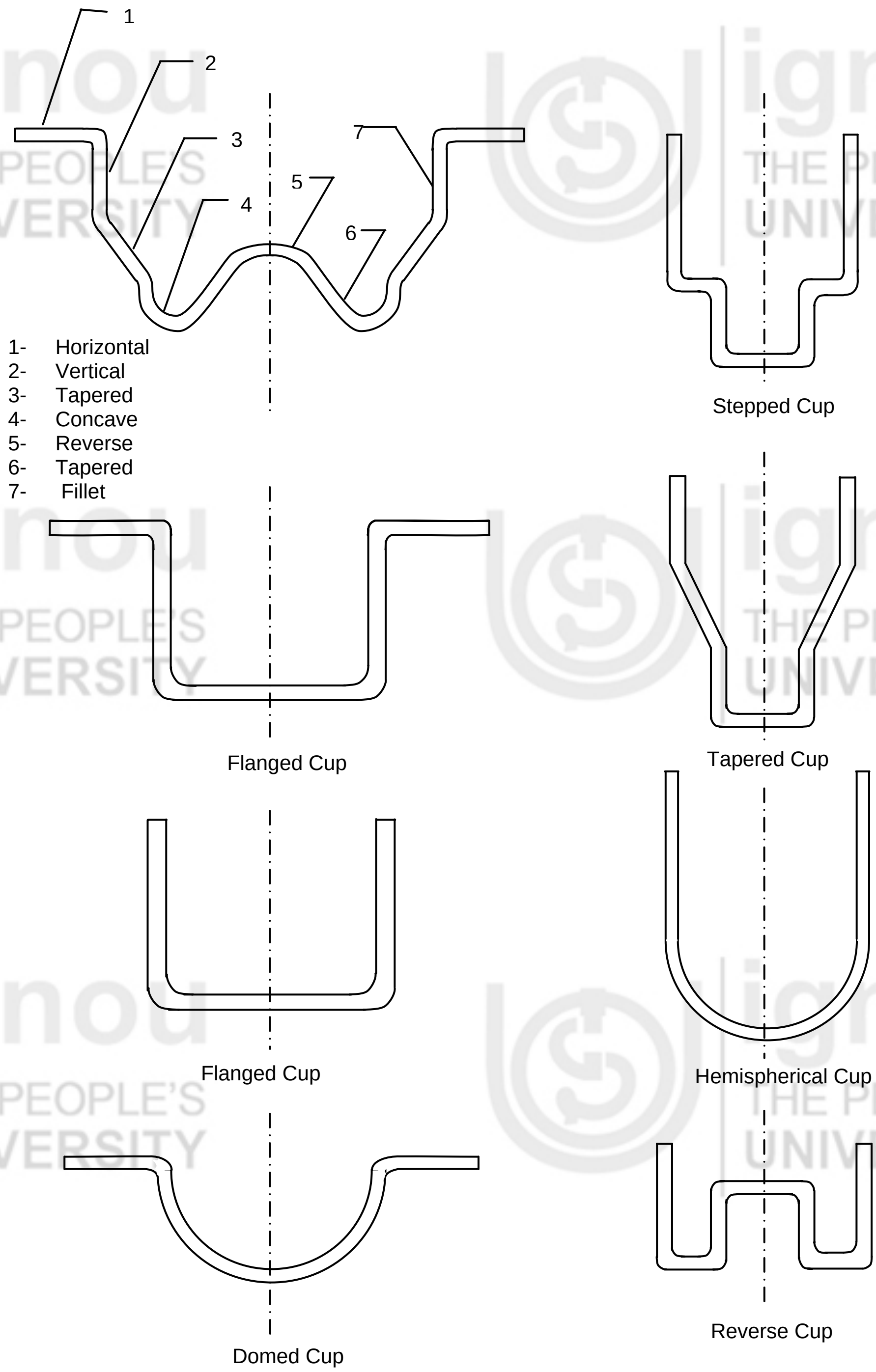


Figure 15.14 : Various Geometric Elements and Drawn Cup Shapes [7]

CAPP system has knowledge represented in the form of Decision Table/Rules of the form

IF

<condition>

THEN

<action>

Table 15.2 shows the Decision Table/Rules for Automatic identification/ recognition of the type of cup (forming type) from CAD model geometry primitives [7].

Table 15.2 : Decision Table for the Determination of Drawn Cup Type

		Rules							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Sl. No.	**Condition Stubs**	**Conditions Entries**							
1	The first element is horizontal	N	Y	N	Y	–	–	–	–
2	Horizontal elements included	Y	Y	Y	Y	Y	–	Y	–
3	Vertical elements included	Y	Y	Y	Y	–	Y	Y	N
4	Vertical elements more than one	N	–	Y	Y	–	–	–	N
5	Taper elements included	N	N	N	N	Y	N	–	N
6	Convex elements included	N	N	N	N	N	N	–	N
7	Reverse convex elements included	N	N	N	N	N	N	–	N
8	Concave elements included	N	N	N	N	N	Y	–	Y
9	Reverse tapered elements included	N	N	N	N	N	N	Y	N
	Action Stubs : Drawing Type	**Action Entries**							
1	Flanged cup	N	Y	N	Y	N	N	N	N
2	Full cup	Y	N	N	N	N	N	N	N
3	Stepped cup	N	N	Y	Y	N	N	N	N
4	Tapered cup	N	N	N	N	Y	N	N	N
5	Hemispherical cup	N	N	N	N	N	Y	N	N
6	Cup with reverse shape	N	N	N	N	N	N	Y	N
7	Domed cup	N	N	N	N	N	N	N	Y

Blank Development

Blank development is the first important stage which governs the strip layout and die stages. For axisymmetrical shapes, CAPP systems use analytical computation methods to determine the blank sizes from the final draw geometry [1].

The algorithms are based on the principle of constancy of volume between the blank and drawn cup, neglecting the material thinning/thickening during the deformation. The exact blank shapes are difficult to calculate as the material thinning/thickening varies due to material properties, heat treatment, punch/die geometry and surface texture. To account for these factors, some stock allowance is provided on the calculated blank sizes for subsequent trimming operations [7].

To compute the blank size, the drawn cup is broken down into standard shapes such as a Circle, Annular disc, Cone, Cylinder etc and the surface area of each primitive element is computed. The blank diameter is calculated as under

$$D_{\text{blank}} = \left[\frac{4}{\pi}\sum_{i=1}^{n} Ai\right]^{\frac{1}{2}}$$

where D_{blank} = Blank Diameter, and

A_i = Area of primitive element i.

This method is illustrated further in this Unit under Examples.

Die Design

This involves several steps like deciding number of stages (draws), finding intermediate shapes, die layout and finally the design of die elements. Important steps are explained as follows.

Deciding Number of Draws

This is an important decision taken by the CAPP system based on sheet metal type, sheet thickness, punch/Die clearance and radii and the type of drawing.

The CAPP system has a Knowledge Base which stores this knowledge in the form of Decision Tables and Inference Rules. To ensure that a cup can be drawn smoothly without failure, suitable drawing rate needs to be chosen based on the LDR-Limiting Draw Rate.

Table 15.3 shows the decision table data showing relationship between sheet thickness range and the LDR for mild steel full cup deep drawing for different stages in drawing [7].

Table 15.3 : Determination of Limit Drawing Rate for Full Cup Drawing

Sheet Thickness Range	**Rules**					
	1	**2**	**3**	**4**	**5**	**6**
t/D_n **(%)**	**0.08 ~ 0.15**	**0.15 ~ 0.30**	**0.30 ~ 0.60**	**0.60 ~ 1.0**	**1.0 ~ 1.5**	**1.5 ~ 2.0**
Drawing Rate	**Action Entries**					
m_1	0.63	0.60	0.58	0.55	0.53	0.50
m_2	0.82	0.80	0.79	0.78	0.76	0.75
m_3	0.84	0.82	0.81	0.80	0.79	0.78
m_4	0.86	0.85	0.83	0.82	0.81	0.80
m_5	0.88	0.87	0.86	0.85	0.84	0.82

CAPP system contains many such Decision Tables in knowledge base to cater to various materials, drawing conditions and cup geometrics (simple cup, flanged cup, etc.)

Punch/Die Clearances

Clearance between Punch and Die determines the severity of draw, i.e. ironing or no ironing. Various rules and data based on experience/shop practices are stored into the CAPP system to design clearance between Punch and Die.

$$\text{Clearance gap } = t \,.\, \sqrt{\frac{D}{d}}$$

where t = sheet thickness,

D = Blank Diameter, and

d = Punch Diameter.

Punch/Die Profile Radii

The sizes of punch and die radii govern occurrence of fracture and wrinkling of part. Its selection is again based on the Decision Tables stored in Knowledge Base of the CAPP system.

Design/Selection of Punch/Die

CAPP system selects standard punch/die elements from the database based on some thumb rules stop practices. CAD models of Punch/Die elements are retrieved and the Die drawings and BOM are created as explained earlier (Section 15.3).

15.4.4 Case Study

Figure 15.15 shows a flanged cup product as a typical example run on the knowledge based CAPP system for drawing operation [7].

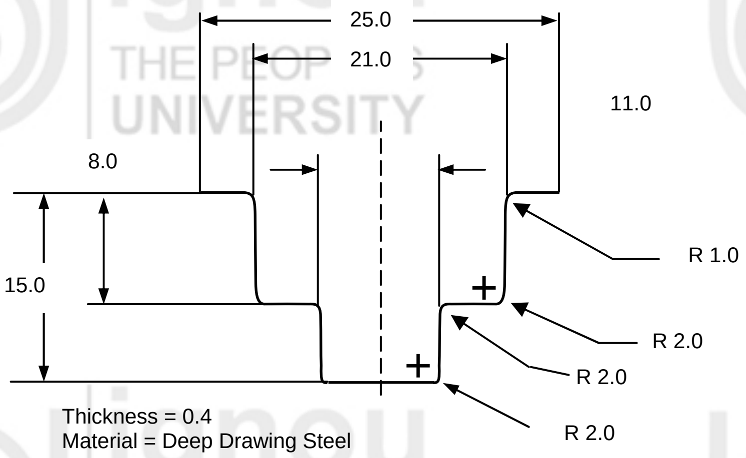


Figure 15.15 : Flanged Cup used in the Case Study [7]

Figure 15.16 shows the strip layout for progressive die to produce the flanged cup. The layout shows developed blank geometry, single row layout, sequence of drawing, associated stages and intermediate pinch and die shapes. The knowledge base stored in the CAPP system, provides very robust and reliable decision support, and ensures efficient and defect free drawing of final shape from blank geometry.

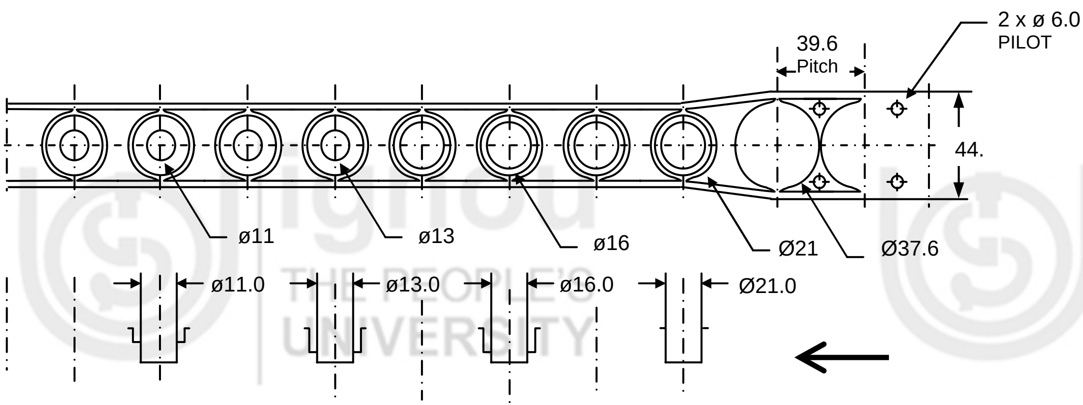


Figure 15.16 : Strip Layout Generated by CAPP System [7]

15.5 EXAMPLES

Example 15.1

A flanged cup shown in Figure 15.17 is to be produced by deep drawing. Calculate the size of the blank required for drawing.

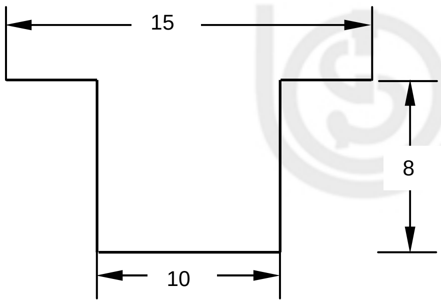


Figure 15.17

Solution

Neglecting sheet thinning/thickening,

Area of flanged cup = Area of blank

The cup shape is divided into 3 primitives as under

Annular Disc

$$\text{Area } A_1 = \frac{\Pi}{4}(15^2 - 10^2)$$

$$= \frac{125\,\Pi}{4}\text{ mm}^2$$

Cylindrical Part

$$\text{Area } A_2 = \Pi\, DL$$

$$= \Pi \times 10 \times 8 = 80\,\Pi\text{ mm}^2$$

Circular Disc

$$\text{Area } A_3 = \frac{\Pi}{4} D^2$$

$$= \frac{\Pi}{4} \times 100\text{ mm}^2$$

$$\text{Area of flanged cup } A = A_1 + A_2 + A_3$$

$$= \frac{545\,\Pi}{4}$$

$$\text{Area of blank } = \frac{\Pi}{4} D_b^2 = A$$

$$= \frac{545\,\Pi}{4}$$

$$\text{Diameter of blank, } D_b = \sqrt{545} = 23.35\text{ mm}$$

Diameter of blank can be chosen to be 25.00 mm to account for material properties, die clearances and trimming allowances.

Example 15.2

Part shown in Figure 15.18 is to be produced from flat sheet by bending operation. Calculate the length of the developed blank. Assume $k = 0.3$.

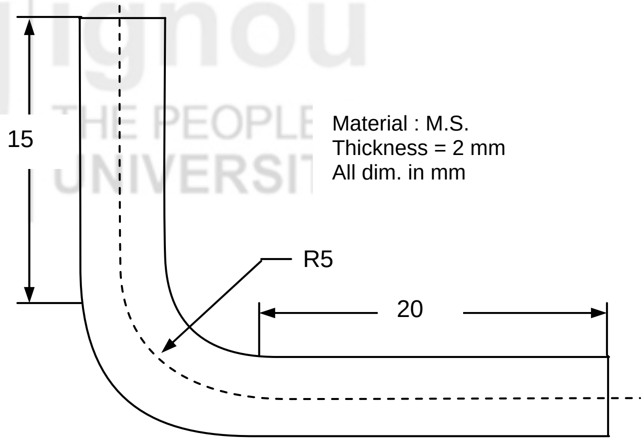


Figure 15.18

Solution

Reference to Figure 15.5 the part is a case of straight Bend with the following parameters :

Bend Angle : 90 degree

Bend Radius : 5 mm

Lengths L_1 : 20 mm

L_2 : 15 mm

Bend Allowance = θ ($r + kt$)

$$BA = \frac{\Pi}{2}(5 + 0.3 \times 2)$$

$$= 8.796 \text{ mm}$$

Bend Compensation = – BA

$$BC = -8.796 \text{ mm}$$

Blank Length = $L_1 + L_2 - BC$

$$= 20 + 15 - (-8.796)$$

$$= 43.796 \text{ mm.}$$

SAQ 1

(a) Arrange the following operations to generate a logical process plan.

P : Strip Layout

Q : Nesting

R : Die Layout

S : Blank development

(i) *S-P-Q-R*

(ii) *S-Q-P-R*

(iii) *P-R-S-Q*

(iv) *Q-P-R-S*

(b) In deep drawing LDR refers to

(i) Limiting Design Range

(ii) Limiting Design Rate

(iii) Limiting Draw Rate

(iv) Limiting Draw Range

(c) Ironing during drawing is governed by

(i) Blank Layout

(ii) Strip Layout

(iii) No. of stations in Progressive Die

(iv) Clearance between Punch/Die

(d) Which one among the following is a critical constraint during Nesting (Blank Layout)?

(i) Clearance between Punch/Die

(ii) No. of forming stages in die

(iii) Orientation of Bend with grain direction

(iv) Type of die-Progressive/Compound

Exercise 15.1

(a) With the help of a flow chart, explain the functions carried out by various modules in a sheet metal CAPP system.

(b) Bring out the fundamental difference between a Blank layout and strip layout for a Progressive Die.

(c) For the layout shown in Figure 15.19, calculate the material utilisation ratio. [**Hint :** Ratio of area of blank to strip in one pitch].

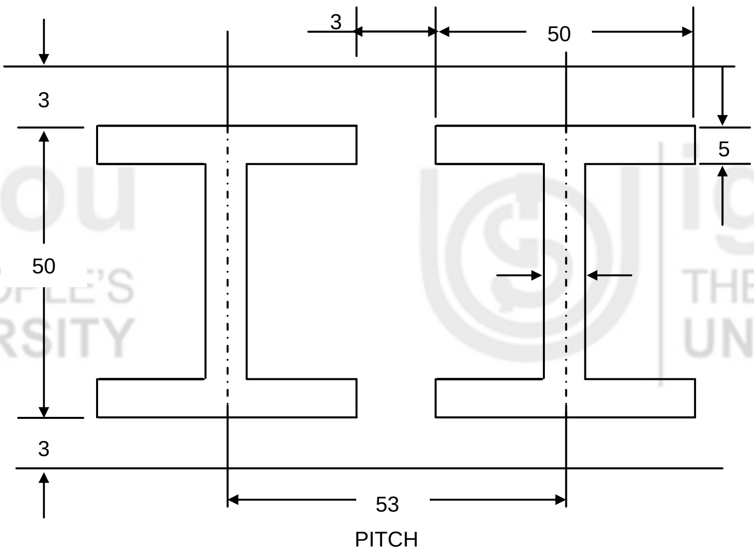


Figure 15.19

(d) Part shown in Figure 15.20 is to be produced from flat sheet by bending. Calculate the length of the developed blank. Assume $k = 0.3$.

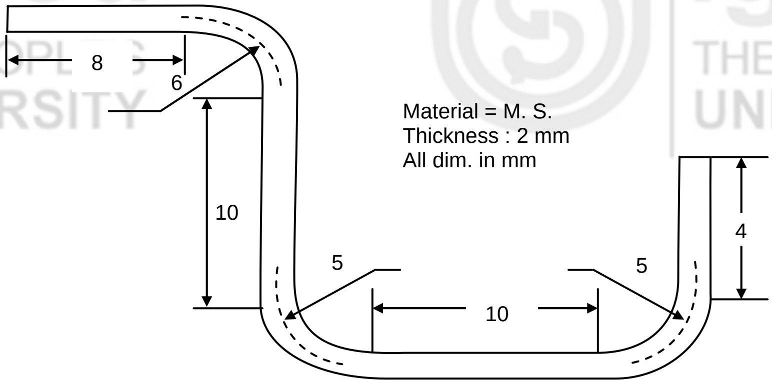


Figure 15.20

(e) A funnel shown in Figure 15.21 is to be produced by deep drawing. Calculate the size of the blank required.

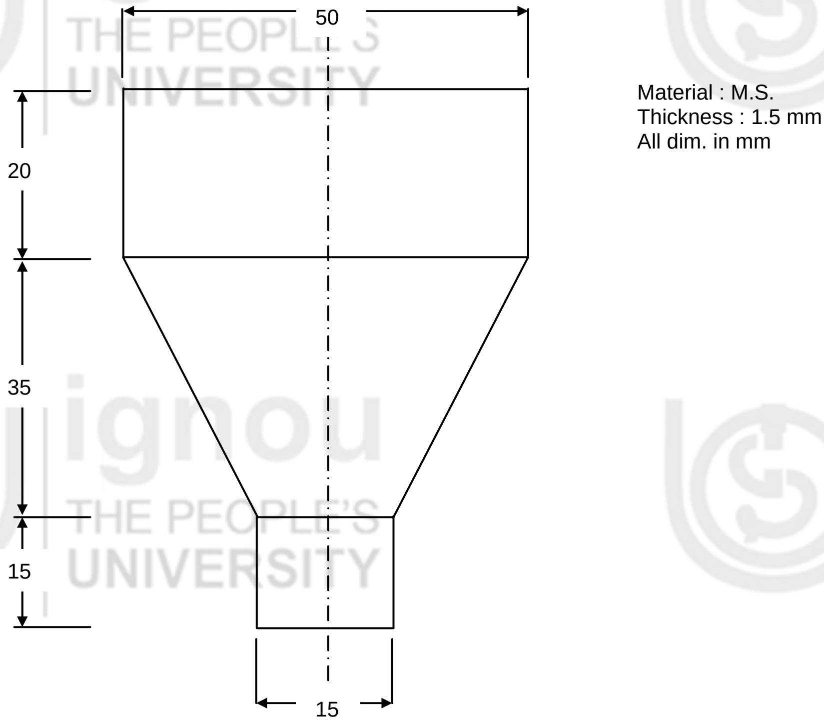


Figure 15.21

15.6 SUMMARY

Sheet metal parts are produced from flat sheets on presses using special metal forming dies. Process planning for sheet metal parts involves complex decision making as the process plan is finally realised in the design of the dies which are capital intensive. Traditionally the process planning and die design are done by human experts having knowledge gathered by years of experience.

To produce consistent and reliable process plans and die designs in shortest possible lead times, Computer Aided Process Planning (CAPP) systems are being developed worldwide. In this unit, CAPP systems for Stamping and Drawing dies have been explained, in detail, in terms of their architecture, functional working and typical case studies.

15.7 ANSWERS TO SAQS

SAQ 1

(a) (ii)

(b) (iii)

(c) (iv)

(d) (iii)

REFERENCES

(1) Herman W. Pollcak, (1978), *Tool Design*, Prentice Hall, USA.

(2) Atul Thakur and S. S. Pande, (2006), *Web Based Feature Modeling and Process Planning System for Sheet Metal Components*, Proc. 22nd All India Mfg. Technology Research Dev. Conf. (AIMTDR), IIT Roorke, 20-22 Dec., pp. 297-302.

(3) L. J. Devin, J. DeVries, T. Strepple, (2000), *Process Planning for Small Batch Manufacturing of Sheet Metal Parts*, Int. Journal of Prod. Research, Taylor and Fransis, UK, V38, n 17, pp. 4273-4283.

(4) Y. K. D. V Prasad and S. Somasundaram, (1992), *CADDS – An Automated Die Design System for Sheet Metal Blanking*, Computers and Control Engineering Journal, Volume 3, Issue 4, pp. 185-191.

(5) K. H. See Toh, H. T. Toh, A. Y. C. Nee, and K. S. Lee (1995), *A Feature Based Flat Pattern Development System for Sheet Metal Parts*, Journal of Materials Processing Technology, Elsevier, Volume 48, pp. 89-95.

(6) J. C. Choli, B. M. Kim and C. Kim, (1999), *An Automated Progressive Process Planning, Die Design and Working System for Blanking, Piercing and Bending of a Sheet Metal Product*, Int. Journal of advanced Mfg. Technology, Volume 15, pp. 485-497.

(7) W. M Sing and K. P. Rao, (1997), *Knowledge Based Process Layout System for Axisymmetrical Deep Drawing using Decision Tables*, Computers Ind. Engg, Pergaman, Volume 32, pp. 299-319.

IMPLEMENTATION OF CAPP

This block consists of four units. In the first unit, i.e. Unit 12 role of process planning in CAD/CAM integration is elaborated. It also discusses different approaches to process planning for machining operations and the non-traditional CAPP applications.

Unit 13 deals with the concepts of variant process planning. Implementation techniques of a variant process planning systems are explained.

Unit 14, i.e. CAPP casting and welding gives basics of CAPP for casting. It also give details of computer aided process planning for welding processes.

In the last unit, i.e. Unit 15 CAPP for forming process has been explained. CAPP forming process include sheet metal, tool design, stamping dies, and drawing dies CAPP.