

Integrating CAD/CAE Design Technology for Design and Analysis of Bending Tool

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Abstract— World is focusing more towards automation each and every work of human is reduced by machine and computer. Computer aided design and analysis become most important tool in the field of engineering. Integrating computer aided parametric technology and computer aided analysis collaborative technology always eliminates costly try out and error process. In engineering field computer aided design, analysis and manufacturing are utilized in different ways to produce document and design, shaded images animated display ,perform engineering analysis and to perform process planning and NC code generation. In this work some significant aspects of progressive tool are discussed and also integrating CAD/CAE for design and analysis. The work starts from study of component conceptual design process modeling design verification and analysis.

Index Terms—Bending Tool, Cad, Auto Desk Inventor, Process Planning, NC code generation.

I. INTRODUCTION

The present century is known for rapid development in the field of computer in both hardware and software. It has become the most important tool in technological developments. The entry of computer in design and manufacturing has led to the emergence of new areas known as computer aided design and computer aided manufacturing. Traditionally design and manufacturing are two distinct and separate activities. Integration of CAD/CAE/CAM system is born for design analysis and manufacturing of engineering product. Computer aided design is the automation of design process. It is the technology used to integrate the design activities with the help of computer which includes transformation and modification of images of part geometry and analysis of particular part to verify whether the part is capable for that particular environment. In this work computer aided design and analysis technologies are integrating for design and analysis of bending tool for pipe clamp. Solid modeling and FEM analysis carried out in Auto desk inventor software.

II. METHODOLOGY

Methodology is the most important element to be considered to make sure the fluent of the project and get expected result. In other words methodology can be described as a frame work where it contains elements of work based on objectives and scope of the project. A good frame work can get overall view of the project and get the data easily.

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This includes literature survey computer aided design and computer aided analysis.

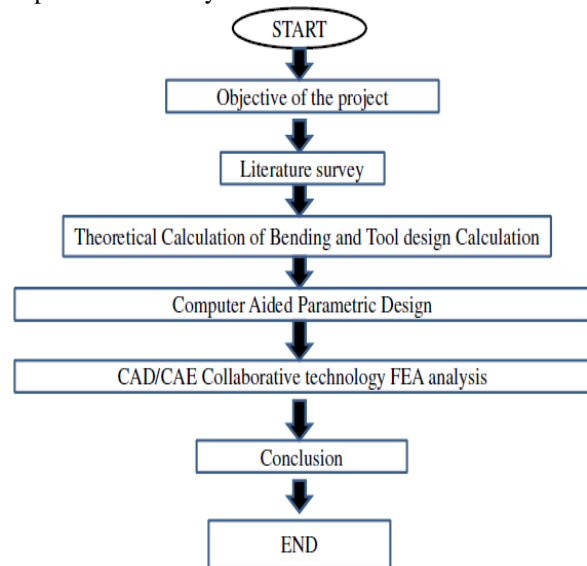


Fig 1: Methodology

III. LITERATURE REVIEW

In engineering practice CAD/CAE/CAM has been utilized in different ways by different people. Some utilize it to produce drawings and document design. Other may employ it as a visual tool by generating shaded images and animated display. A third group may perform engineering analysis of some sort on geometric model such as finite element analysis. A fourth group may use it to perform process planning and generate NC part programs. CAD tools can be defined as the intersection of three sets geometrical modeling, computer graphics and design tools. The abstracted concept of geometric modeling and computer graphics must be applied innovatively to serve the design process .Based on implementation in a design environment CAD tools can be defined as the design tools (analysis codes heuristic procedures ,design practices etc.)being improved by computer hardware and software throughout its various phases to achieve the design goal efficiently and competitively .The level of improvement determines the design capabilities of the various CAD/CAM systems and the effectiveness of the CAD tools they provide. Designer will always require tools that provide them with fast and reliable solutions to design situations that involve iterations and testings of more than one alternative. CAD tools can vary from geometric tools such as manipulations of graphics entities and

interference checking on one extreme to customized applications programs such as developing analysis and optimization routines on the other extreme. In between these two extremes typical tools currently available include tolerance analysis mass property calculations and finite element modeling and analysis.

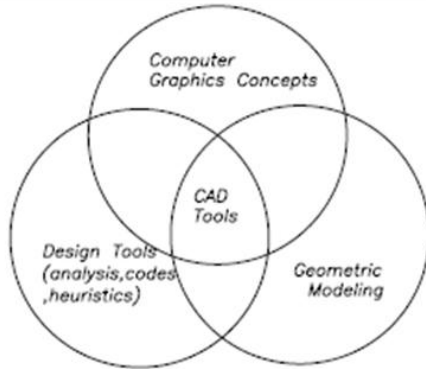


Fig 2: CAD tools based on their constituents

A. Reason for Implementing CAD System

1. To increase the productivity of the designer. This is accomplished by helping the designer to the product and its component subassemblies and parts; and by reducing the time required in synthesizing, analyzing, and documenting the design.
2. To improve the quality of design. A CAD system permits a more thorough engineering analysis and a larger number of design alternatives can be investigated. Design errors are also reduced through the greater accuracy provided by the system.
3. To improve communications. Use of a CAD system provides better engineering drawings, more standardization in the drawings, better documentation of the design, fewer drawing errors and greater legibility.
4. To create a database for manufacturing. In the process of creating the documentation for the product design (geometries and dimensions of the product and its components, material specifications for components, bill of materials, etc.), much of the required database to manufacture the product is also created.

B. The Design Process

There are six steps in conventional design process. They are

1. Recognition of need
2. Definition of problem
3. Synthesis
4. Analysis and optimization
5. Evaluation
6. Presentation

Recognition of need involves the realization by someone that a problem exists for which some corrective action should be taken. This might be the identification of some defect in a current machine design by an engineer or the perception of a new product marketing opportunity by a salesperson. Definition of the problem involves a thorough specification of the item to be designed. This specification includes physical and functional characteristics, cost, quality, and operating performance. Synthesis and analysis are closely related and highly interactive in the design process. A certain component

or subsystem of the overall system is conceptualized by the designer, subjected to analysis, improved through this analysis procedure, and redesigned. The process is repeated until the design has been optimized within the constraints imposed on the designer. The components and subsystems are synthesized into the final overall system in a similar interactive manner. Evaluation is concerned with measuring the design against the specifications established in the problem definition phase. This evaluation often requires the fabrication and testing of a prototype model to assess operating performance, quality, reliability, and other criteria. The final phase in the design process is the presentation of the design. This includes documentation of the design by means of drawings, material specifications, assembly lists, and so on.

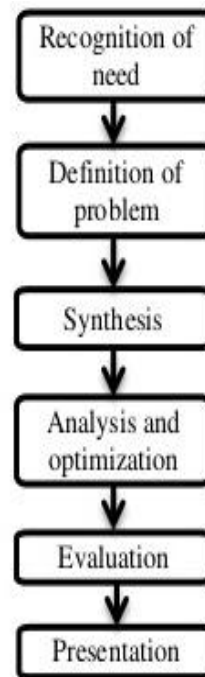


Fig 3: Conventional Design Steps

C. The Application of Computers for Design

There are four main application of computer in design process. 1. Geometric modeling 2. Engineering analysis 3. Design review and evaluation 4. Automated drafting. Geometrical modeling is concerned with developing mathematical description about the model. The mathematical description allows the image of the object to be displayed and manipulated on the graphics terminal. Engineering analysis may involve stress-strain calculations, heat transfer computations etc. The most powerful analysis feature of CAD system is the finite element method. Design review and evaluation is interference checking. This involve the analysis of an assembled structure in which there is a risk that the component of the assembly may occupy same space. Automated drafting includes automatic dimensioning generation of cross hatched areas, scaling of drawing and capability to develop sectional views and enlarged views of particular part details.

Table 1: Chemical Composition

Component	Amount
Aluminum	Balance
Magnesium	0.45-0.9
Silicon	0.2-0.6
Iron	Max 0.35
Copper	0.10
Zinc	Max 0.10
Titanium	Max 0.10
Chromium	0.10
Others	0.05

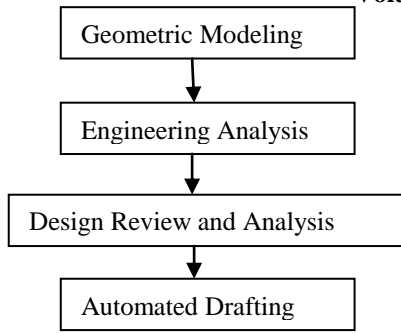


Fig 4: Computer Aided Design Steps

IV. IMPLEMENTATION WORK

➤ Component :Aluminum Pipe Clamp

Component:PipeClamp

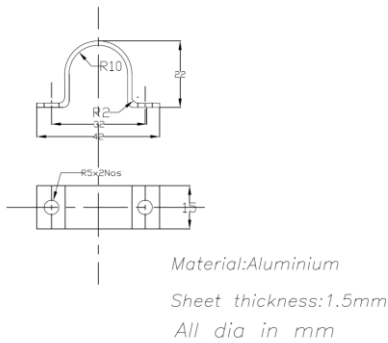


Fig 5: Component Drawing 2D Sketch

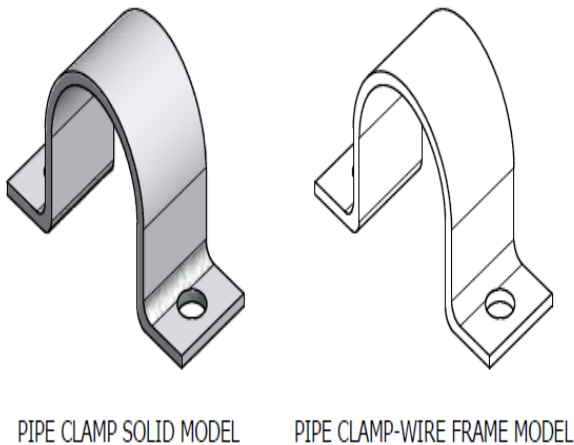


Fig 6: Component Drawing Solid and Wire Frame Model

Aluminum: Properties

Aluminum Alloy 6063

- Shear strength:207Mpa
- Young's Modulus:69.5Gpa
- Yield Strength:240Mpa
- Density:2.70g/cm³
- Melting Point:600 C
- Modulus of rigidity:69.5Gpa

➤ Theoretical Calculation of Bending

Bend Allowance.

The required length of flat work piece to make a bend.

$$\text{Length of strip} = A + 2(B + D + C)$$

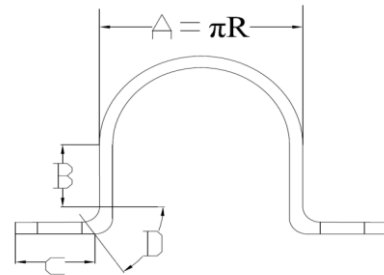


Fig 7: Bend Allowance

$$A = \pi R$$

$$D = \frac{2 \pi \theta}{360} (R + kt)$$

Where R=Internal Radius of Bend
θ=Bend angle
t=Sheet thickness
k=Constant (1/3 when R>2t)
A=3.14x10=31.4mm

$$D = \frac{2 \pi \theta}{360} (R + kt)$$

Bend angle θ=90degree

Internal Radius of Bend R=2mm

Constant k=1/3

Sheet metal thickness t=2mm

$$D = \frac{2 \times 3.14 \times 90}{360} (2 + (0.33 \times 2))$$

$$= 3.925 \text{mm}$$

$$B = 8.55 \text{mm}$$

$$C = 7.151 \text{mm}$$

$$\begin{aligned} \text{Total length of flat strip} &= A + 2(B + D + C) \\ &= 31.4 + 2(3.925 + 8.55 + 7.151) \\ &= 70.625 \end{aligned}$$

Considering trimming allowance total length of flat strip=73mm

➤ Various Stages of Operations

Three stage progressive bending tool

Stage 1: Piercing Operation

Stage 2: Cut off Operation

Stage 3: Bending Operation

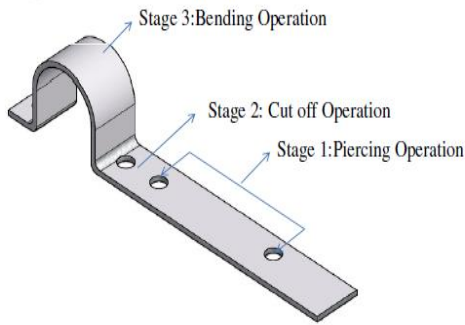


Fig 8: Various Stages of Operations

➤ Design Calculations

Stage 1: Piercing Operation

Cutting force = $L \times S \times T_{max}$

L=Length of periphery to be cut in mm

S=Stock thickness in mm

T_{max} =shear strength of material N/mm^2

Length of periphery to be cut = $\pi D = 3.14 \times 5 = 15.7mm$

$T_{max} = 207Mpa$

Stock thickness = 1.5mm

Cutting force = $L \times S \times T_{max}$

$$= 15.7 \times 1.5 \times 207$$

$$= 4874.85N$$

Stripping Force = 25% cutting force

$$= 4874.85 \times 0.25 = 1218.7N$$

Cutting clearance

$$C = 0.0032t\sqrt{ts} \text{ mm/side}$$

t=sheet thickness = 1.5mm

$t_s = 207Mpa$

$$C = 0.0032 \times 1.5 \times \sqrt{207} = 0.0690 \text{ mm per side}$$

Piercing Punch size = Hole size = 5mm

Piercing Die size = (Hole size + Total clearance)

$$= 5 + (2 \times 0.0690)$$

$$= 5.138mm$$

Stage 2: Cut off Operation

Cutting Force = $L \times S \times T_{max}$

$$= 15 \times 1.5 \times 207$$

$$= 4657.5N$$

Clearance = 0.0690mm

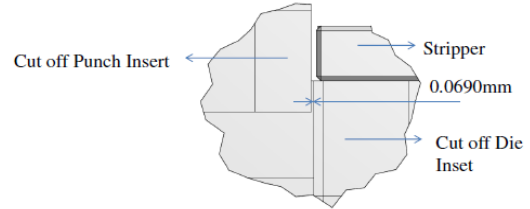
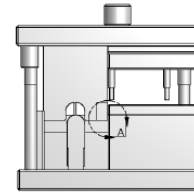


Fig 9: Cut off Clearance

Stage 3: Bending Operation

Bending Force = $klft^3/w$

Where k=Die opening factor=0.67

l=contact length of work = 15mm

f=Yield strength of material = 240N/mm²

t=Sheet thickness = 5mm

w=Width of die opening = 22mm

$$\text{Bending force} = (0.67 \times 15 \times 240 \times 1.5^3) / 22 = 370N$$

Pad force = 25% of Bending force

$$= 0.25 \times 370 = 92.5N$$

Total force = Bending force + Pad force

$$= 370 + 92.5 = 463N$$

Press Selection

Total force = Bending force + Pad force + Cut off force + Piercing force

$$= 340 + 92.5 + 4657.5 + (2 \times 4874.85)$$

$$= 14839.7N$$

Considering 70% Press efficiency

Press capacity = $14839.7 / 0.7 = 21199.57N$

$$= 21Tons$$

➤ Computer Aided Design

Parametric design Process

Software: AutoDesk Inventor

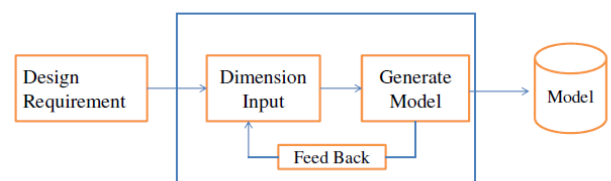


Fig 10: Computer Aided Design

Conceptual Design Steps

Bottom half

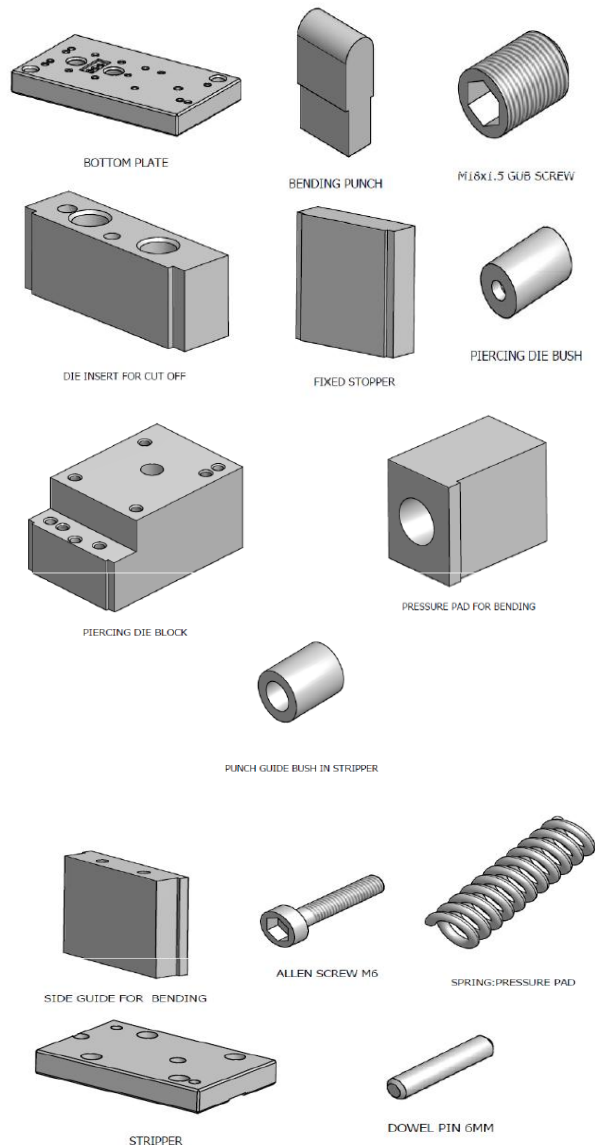
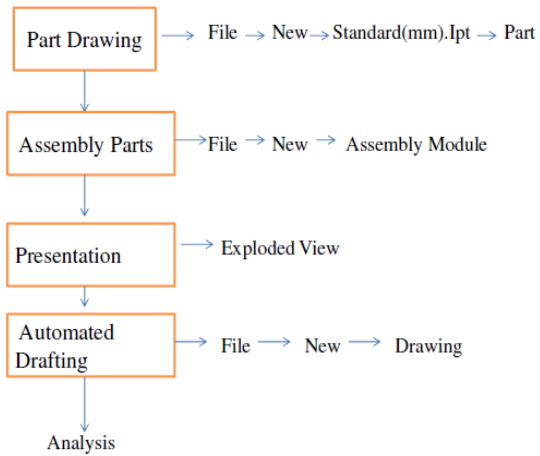


Fig 11: Conceptual Design Steps

➤ Design of Part Drawing

Top half

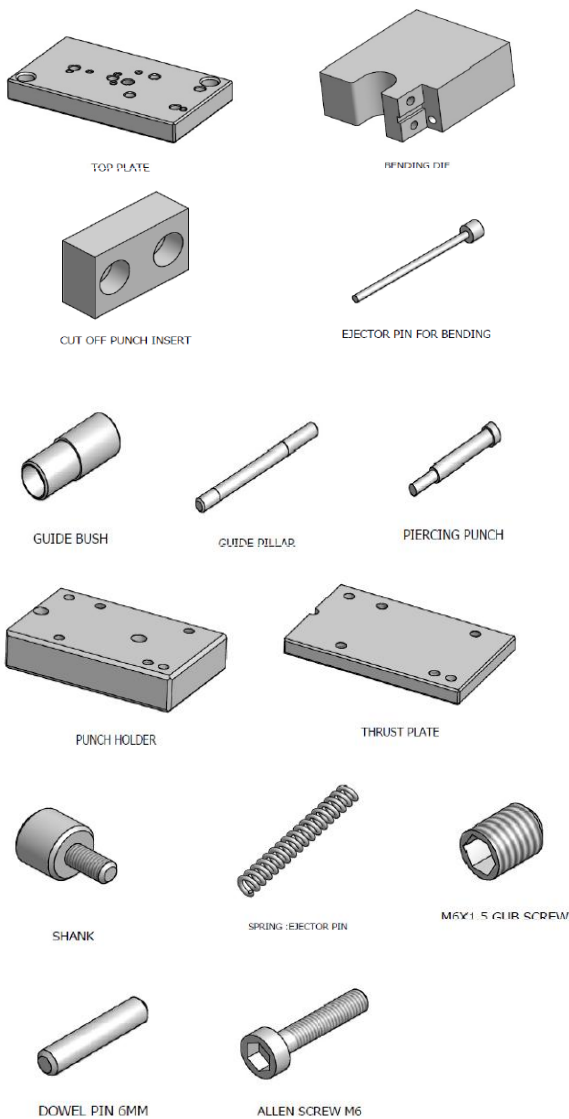


Fig 12: Bending Tool Parts

➤ Bill of Material

Table 2: Bill of Material

Sl No	Description	Qty	Material	Size	Remark
1	Piercing Die Block	1	MS	65x70x107	
2	Cut off Die Insert	1	D3	20x20x70	58-60HRC
3	Side Guide for Bending	2	W1	17.5x65x77	40-42HRC
4	Pressure Pad	2	W1	28x35x44	35-40HRC
5	Fixed Stopper	1	W1	20x70x70	35-40HRC
6	Bending Punch	1	S1	20x35x67	40-42HRC
7	Stripper Plate	1	MS	12x70x106.5	
8	Punch Holder	1	MS	20x70x106.5	
9	Thrust Plate	1	C14	8x70x106.5	Case Hardened
10	Bending Die	1	S1	35x73x89	40-42HRC
11	Piercing Punch	2	D3/HSS	Φ9x57	58-60HRC
12	Ejector Pin	1	EN8	Φ10x46	35-40HRC
13	Top Plate	1	MS	24x120x210	
14	Bottom Plate	1	MS	24x120x210	
15	Guide Bush	2	C14	Φ20x50	Case Hardened
16	Guide Pillar	2	C14	Φ14x17	Case Hardened
17	Piercing Die Bush	2	D3	Φ13x20	58-60HRC
18	Punch Guide Bush in Stripper	2	EN8	Φ8.50x12	58-60HRC
19	Cut off Punch Insert	1	D3	14x22x35	58-60HRC

➤ Assembly

Bottom Half Bending Tool

Top Half Bending Tool

Assembly of parts are done in assembly module of Auto desk Inventor.

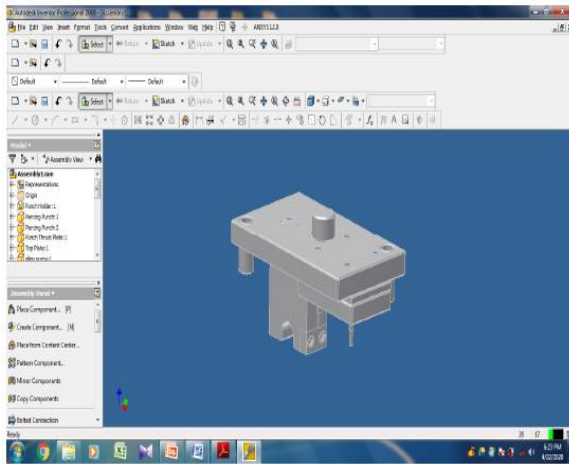


Fig 13: Assembly Module

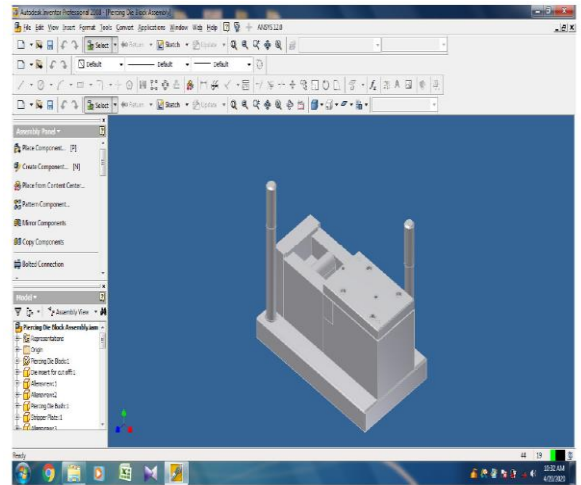


Fig 16: Assembly Module

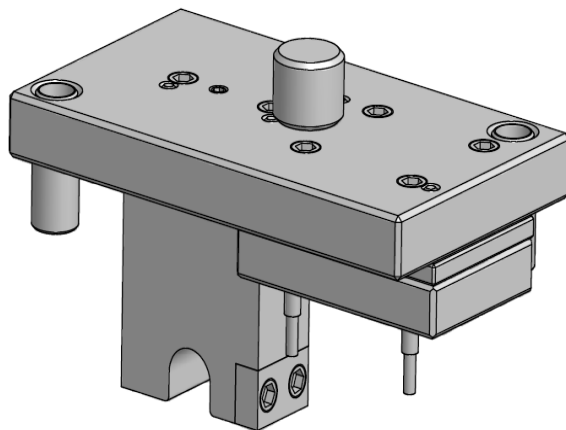


Fig 14: Solid Model Bending Tool Top Half

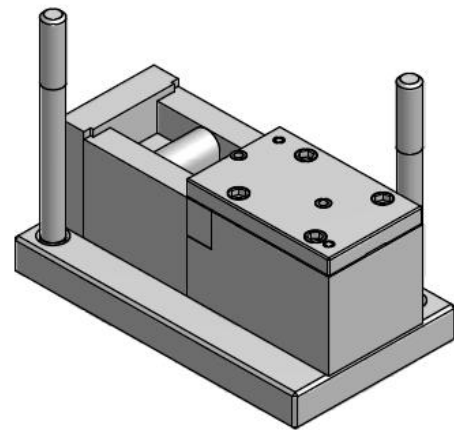


Fig 17: Solid Model Bending Tool Bottom Half

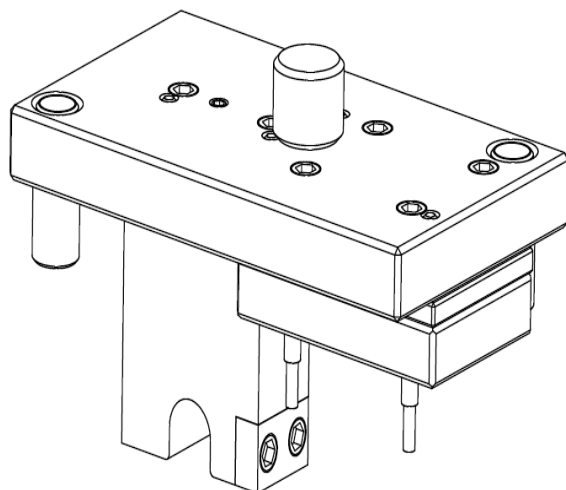


Fig 15: Wire Frame Model Bending Tool Top Half

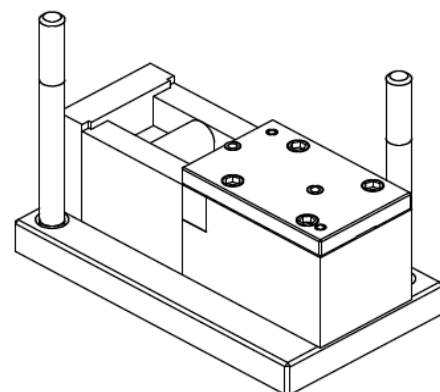


Fig 18: Wire Frame Model Bending Tool Bottom Half

Exploded View

Exploded view is created in the Presentation module of Auto Desk Inventor.

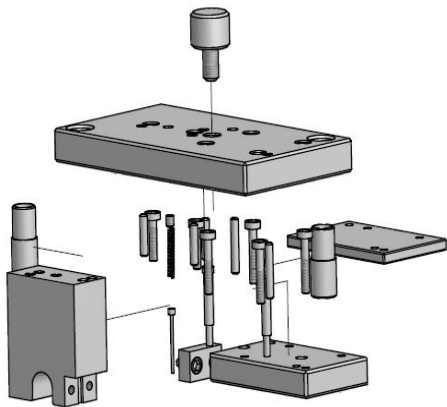


Fig 19: Exploded View Top Half

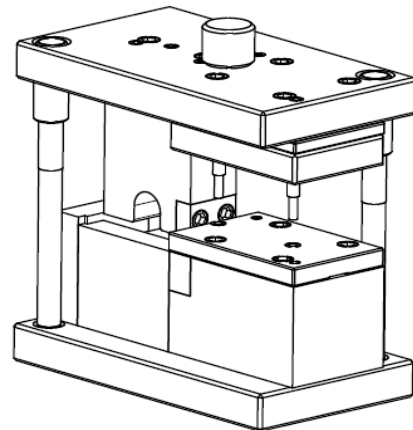


Fig 22: Bending Tool Wire Frame Model

➤ Automated Drafting

This feature includes automatic dimensioning, generation of cross hatched areas, scaling of the drawing and capability to develop sectional views and enlarged views of particular part detail. Drawing module in Autodesk inventor is used for automated drafting.

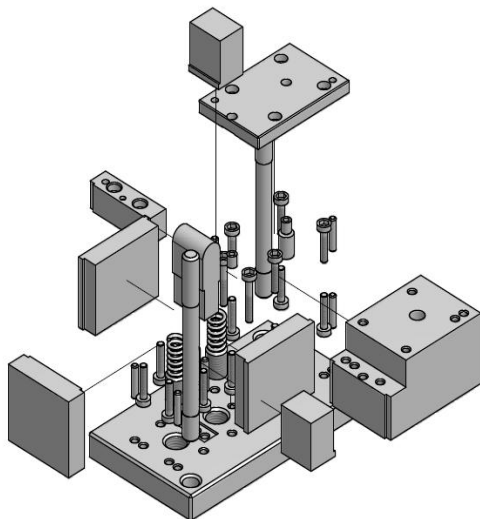


Fig 20: Exploded View Bottom Half

Completely Assembly

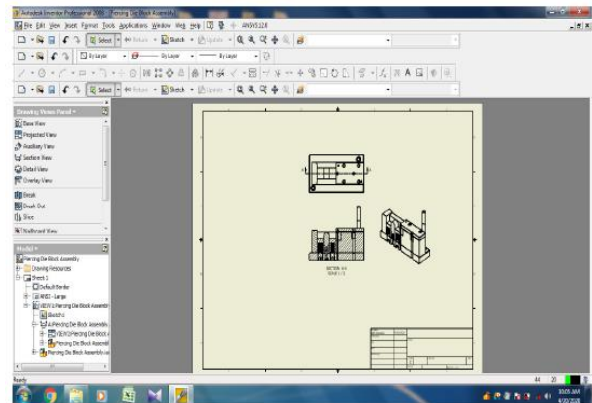


Fig 23: Drawing Module

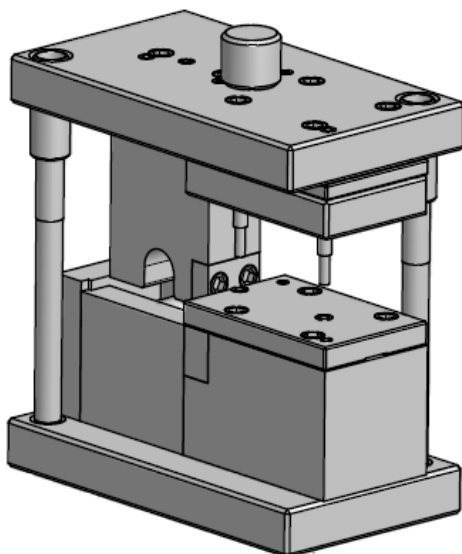
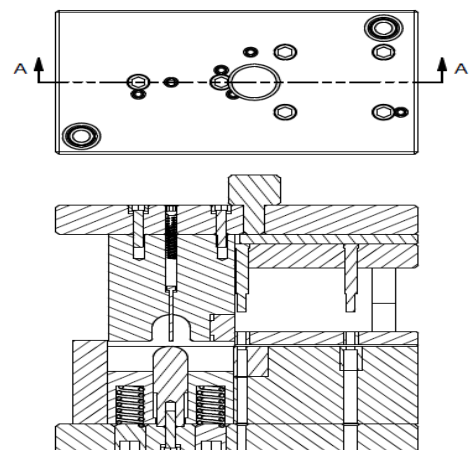


Fig 21: Bending Tool Solid Model

Half sectional view



SECTION A-A
SCALE 1 / 2

Fig 24: Half Sectional View

Projected View

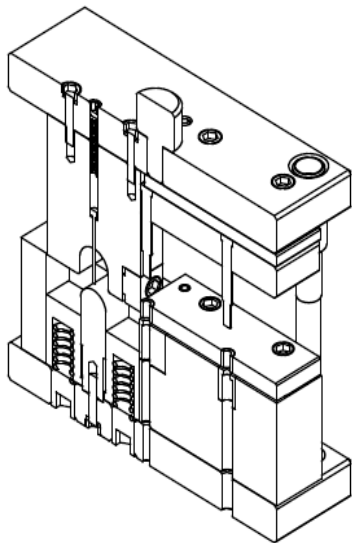
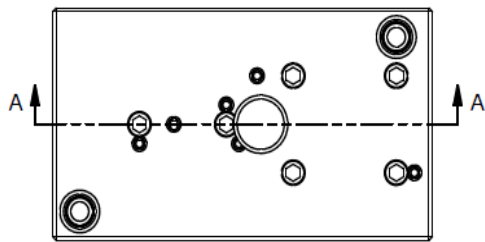
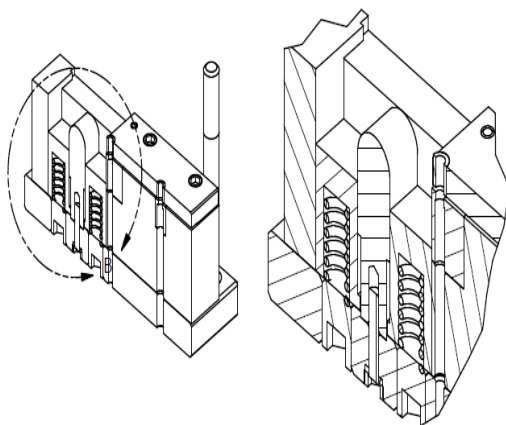


Fig 25: Half Sectional View Projected

Detail View



DETAIL B
SCALE 1 : 1

Fig 26: Detail View

➤ *Component Ejection Method*

Two methods are used to eject pipe clamp out of bending tool .Spring actuated pressure pad which lift the component from punch and also there is chance that due to spring back component will stick in side die surface ,spring operated ejector pin will pull out the component out of die surface.

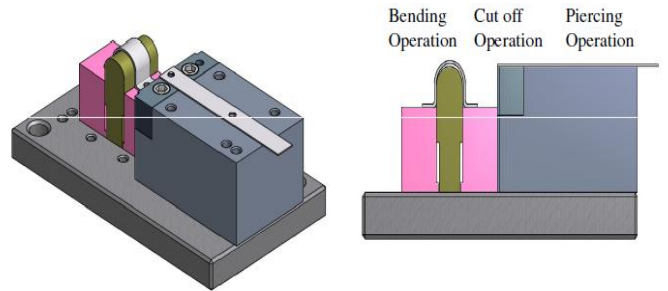


Fig 27: Operations in Bending Tool

Spring actuated pressure pad.

Helical spring lift the pressure pad when the top half of bending tool moving upward direction.

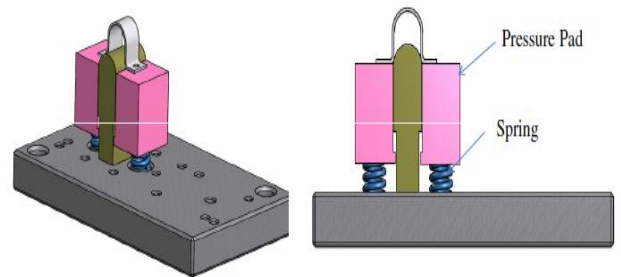


Fig 28: Spring actuated pressure pad

Ejector pin

Spring operated ejector pin push the component form die surface in order to overcome spring back.

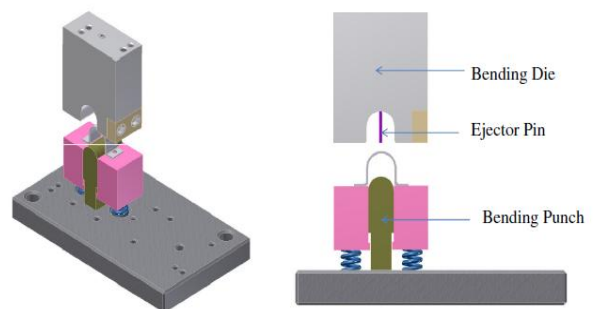


Fig 29: Components Ejection by Pressure Pad and Ejector Pin

➤ *CAD/CAE Integration System*

The block diagram below shows the integration of CAD /CAE system.

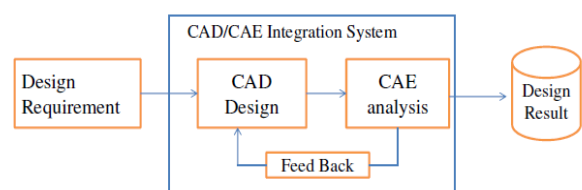
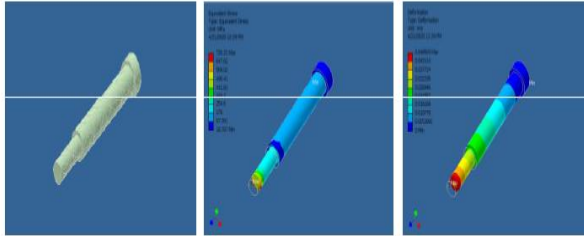


Fig 30: CAD/CAE Integration System

Most powerful analysis feature of CAD system is the finite element method.

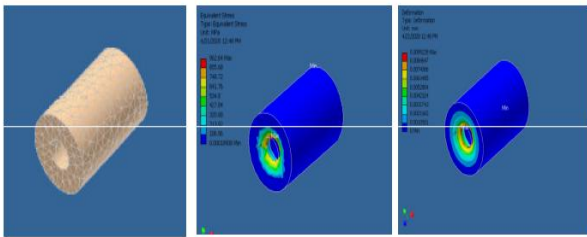
Structural analysis of piercing punch



Mesh model Equivalent stress Deformation

Fig 31: Structural analysis of piercing punch

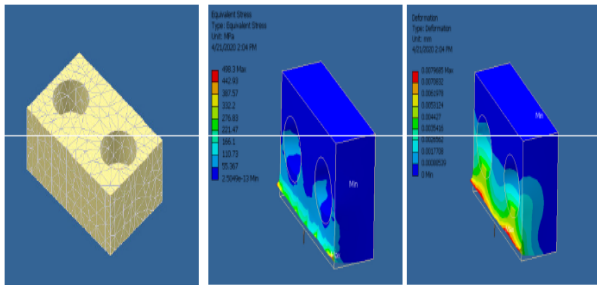
Structural analysis of piercing die bush



Mesh model Equivalent stress Deformation

Fig 32: Structural Analysis of Piercing Die bush

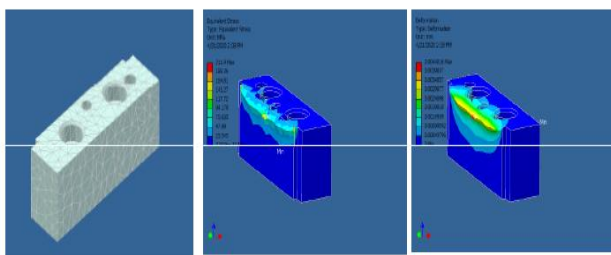
Structural analysis of cut off punch insert



Mesh model Equivalent stress Deformation

Fig 33: Structural Analysis of punch Insert

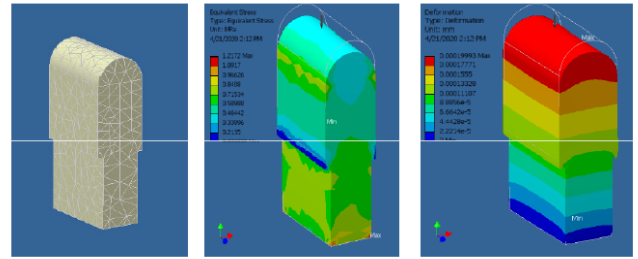
Structural analysis of cut off die insert



Mesh model Equivalent stress Deformation

Fig 34: Structural Analysis of Cut off die Insert

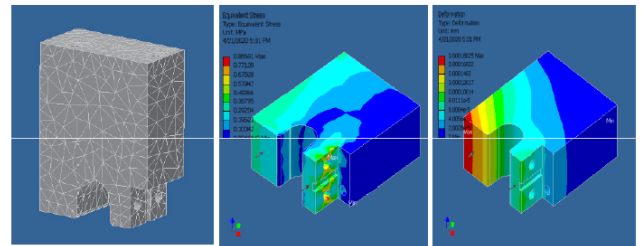
Structural analysis of drawing punch



Mesh model Equivalent stress Deformation

Fig 35: Structural Analysis of Drawing Punch

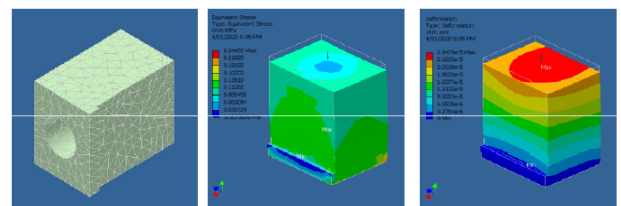
Structural analysis of drawing die



Mesh model Equivalent stress Deformation

Fig 36: Structural Analysis of Drawing Die

Structural analysis of pressure pad



Mesh model Equivalent stress Deformation

Fig 37: Structural Analysis of Pressure Pad

Consolidated Analysis Report

	Equivalent stress	Deformation
Piercing Punch	726.22Mpa	0.04850mm
Piercing Die Bush	962.64Mpa	0.0095228mm
Cut off Punch Insert	498.3Mpa	0.0079685mm
Cut off Die Insert	211.9Mpa	0.0044846mm
Drawing Punch	1.2172Mpa	0.00019993mm
Drawing Die	0.86691Mpa	0.0001825mm
Pressure Pad	0.24465Mpa	2.9479e-5mm

V.CONCLUSION

By implementation of computer in design accuracy of design is improved and design process time is reduced drastically than by traditional method. Many design problems which are complicated to eliminate by traditional methods are eliminated by using CAD system.

Static structural analysis where carried main parts of bending tool. Equivalent stress and deformation are effectively analyzed.

VI.FUTURE WORK

CAE plays very significant role in the decision making of various parameter of sheet metal forming processes and it helps to designer during product design as well as tool design stage to decide optimum and accurate process parameter. CAE software such as hyper form, FEA used for formability analysis and prediction of any defects during forming operation.

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