

Design of Round to L-Section using B-Spline Curve

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Abstract:- In recent days there has been a growing need in the manufacturing industry to supply the needs of the globe. In manufacturing process like cutting, drilling, shaping etc., there is high material wastage and less dimensional accuracy. Moreover complex shapes cannot be obtained easily. Metal forming by extrusion, one of the widely used metals forming process can be a suitable solution to solve these problems. In bulk production extrusion plays a major role in saving the time and makes the process easier and simpler.

In extrusion process, extrusion die plays a major role. The die has a require profile through which the component is extruded. By using stream lines we are able to obtain the profile. But by using stream lines we can't get closeness of the curve, so we are using B-spline curve, a geometrical curve to overcome this problem. The main advantage of this curve is it can be adjusted any point to get the required profile.

In our research, we designed the extrusion die profile using Solid Works and analyzed it with DEFORM-3D software for the extrusion of L-section using B-spline curves. Since L-section has numerous engineering applications and it can be bear high compressive load.

1. INTRODUCION

1.1 EXTRUSION

Extrusion is a process used to create objects of a fixed cross-sectional profile. A material is pushed or drawn through a die of the decided cross-section. The two main advantages of this process over other manufacturing processes are its ability to create very complex cross-sections and work materials that are brittle, because the material only encounters compressive and shear stresses . It also forms finished parts with excellent surface finish.

Extrusion may be continuous (theoretically producing indefinitely long material) or semi-continuous (producing many pieces). The extrusion process can be done with the material hot or cold. Commonly extruded materials include metals, polymers, ceramics, concrete and food stuffs.

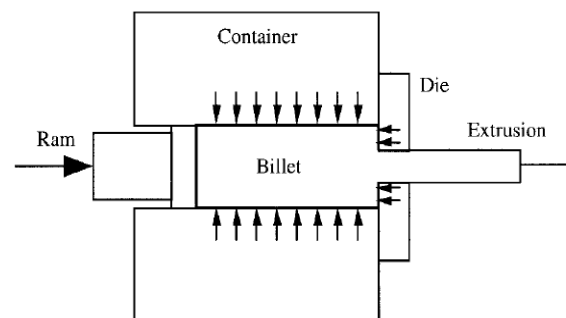


Fig 1.0 Extrusion

1.2 ADVANTAGES OF EXTRUSION

- Uniform cross-sectional area over a long length.
- Low cost of dies making it economical to make small quantities of a shape.
- Good surface finish

1.3 TYPES OF EXTRUSION

- Cold Extrusion.
- Hot Extrusion
- Direct Extrusion
- Indirect Extrusion
- Hydrostatic Extrusion

1.3.1 COLD EXTRUSION.

Cold Extrusion is done at room temperature or near room temperature. The advantages of this over a hot extrusion are the lack of oxidation, higher strength due to cold working, closer tolerances, good surface finish, and fast extrusion speeds if the material is subject to hot shortness. Materials: lead, Tin, Aluminum, Copper, zirconium, Titanium, Molybdenum, Beryllium, Vanadium, Niobium and steel.

Examples: Collapsible tubes, Extinguisher cases, shock absorber cylinders and Gear blanks

1.3.2 HOT EXTRUSION

Warm extrusion is done above room temperature, but below the recrystallization temperature of the material the temperature ranges from 800 to 1800 °F (424 to 975 °C). It is usually used to achieve the proper balance of required forces, ductility and final extrusion properties.

1.3.3 DIRECT EXTRUSION

Direct extrusion is also known as forward extrusion, is the most common extrusion process. It works by placing the billet in a heavy walled container. The billet is push through the die by a ram or screw. There is a reusable dummy block between the ram and the billet to keep them separated. The major disadvantage of this process is that the force required to extrude the billet is greater than the need in the indirect extrusion process because of the frictional forces introduce by the need for the billet to travel the entire length of the container.

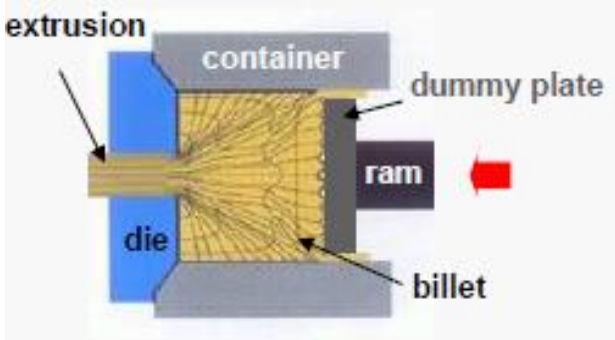


Fig 1.1 Direct Extrusion

1.3.4 INDIRECT EXTRUSION

In indirect extrusion also known as backwards extrusion, the billet and container move together while the die is stationary. The die is held in place by a “stem” which has to be longer than the container length. The maximum length of the extrusion is ultimately dictated by the column strength of the stem. Because the billet moves with the container the frictional forces are eliminated.

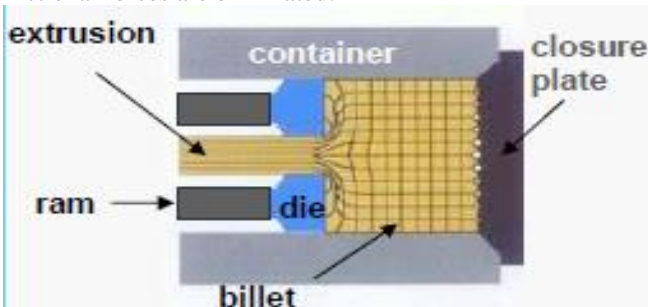


Fig 1.2 Indirect Extrusion

1.3.5 HYDROSTATIC EXTRUSION

In the hydrostatic extrusion process the billet is completely surrounded by a pressurized liquid, except where the billet contacts the die. This process can be done hot, warm,

cold, however the temperature is limited by the stability of the fluid used. The process must be carried out in a sealed cylinder to contain the hydrostatic medium.

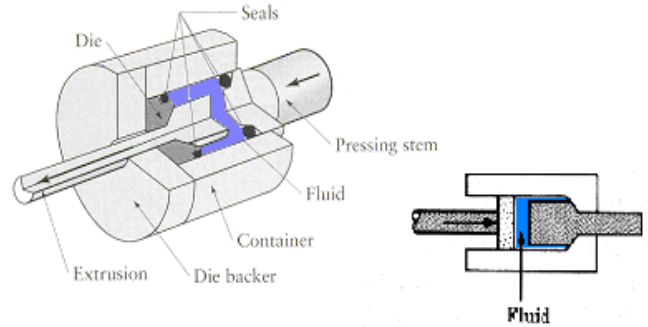


Fig 1.3 Hydrostatic Extrusion

2. PROBLEM IDENTIFICATION

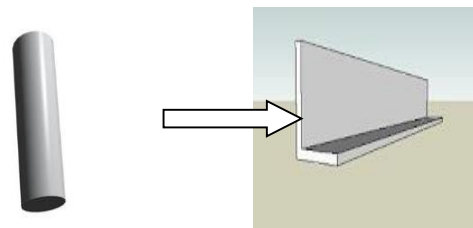


Fig 2.1 Designing of extrusion die for converting circular to L-Section using B-Spline curves

2.1 CONSIDERATION IN DIE DESIGN

- Desired shape of the product
- Material
- Billet size
- Number of die cavities
- Process tool
- Extrusion temperature
- Extrusion pressure
- Die material

For converting circular section to L-section, the profile should be modified using B-spline curves. We have to find what will be the length of the die. We have to compress most of the material over here because it is easy to extruding a square from circle is simple there they are compressing some low amount of material. But here in L-section we are compressing large amount of material so we have to apply high pressure and large amount of stress is created over the surface of die.

3.SCOPE OF THE PROJECT

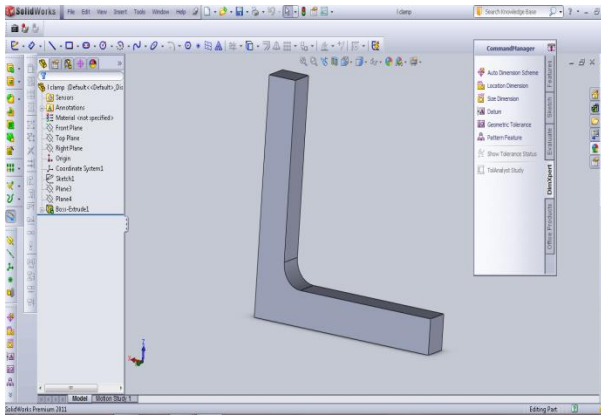


Fig 3.1 L-Section Beam

L Section, giving many benefits. It is very good for giving stiffness (less deformation on loading) and to withstand higher bending moments (as a result of heavy loading) and to with other cross-sectional shapes of same area. Also, it is very easy to manufacture.

- It is very good for giving stiffness (less deformation on loading) and to withstand higher bending moments (as a result of heavy loading) on compression with other cross sectional shapes of same area.
- Also, it is very easy to manufacture.
- L-Angle flange provides more load distribution contact area at key loading points.
- L-Angle flange provides the greatest deck support by increasing deck thickness at impact points
- Spacing between beams is kept to minimum and increase the rigidity of the deck.
- L-Angle has the least twisting action when loaded with shear force.

4. INTRODUCTION TO B-SPLINE CURVES.

4.1 Definition of the B-Spline Curve.

A B-spline curve $P(t)$, is defined by

$$P(t) = \sum_{i=0}^n P_i N_{i,k}(t)$$

Where,

- the $\{P_i : i = 0, 1, \dots, n\}$ are the control points
- k is the order of the polynomial segments of the B-spline curve. Order k means that the curve is made up of piecewise polynomial segments of degree $k - 1$,
- The $N_i, k(t)$ are the “normalized B-spline blending functions”. They are described by the order k and by a non-decreasing sequence of real numbers $\{t_i : i = 0, \dots, n + k\}$ normally called the “knot sequence”. The $N_{i,k}$ functions are described as follows :

$$N_{i,1}(t) = \begin{cases} 1 & t_i \leq t < t_{i+1} \\ 0 & \text{Otherwise} \end{cases}$$

4.2 KNOT VECTORS

A knot vector is a list of parameter values, or knots, that specify the parameter intervals for the individual B´ezier curves that make up a B-spline. For example, if a cubic B-spline is comprised of four B´ezier curves with parameter intervals $[1, 2], [2, 4], [4, 5],$ and $[5, 8]$, the knot vector would be $[t_0, t_1, 1, 2, 4, 5, 8, t_7, t_8]$. Notice that there are two (one less than the degree) extra knots prepended and appended to the knot vector. These knots control the end conditions of the B-spline curve. For historical reasons, knot vectors are traditionally described as requiring n end-condition knots, and in the real world you will always find a meaningless additional knot at the beginning and end of a knot vector.

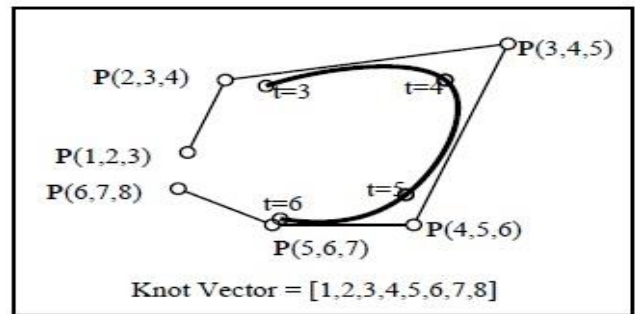


Fig 4.1 knot vector.

4.3 MULTIPLE KNOTS

If a knot vector contains two identical non-end-condition knots $t_i = t_{i+1}$, the B-spline can be thought of as containing a zero-length B´ezier curve over $[t_i, t_{i+1}]$. Figure 8 shows what happens when two knots are moved together. The B´ezier curve over the degenerate interval $[5, 5]$ has polar values $P(5, 5, 5), P(5, 5, 5), P(5, 5, 5), P(5, 5, 5)$, which is merely the single point $P(5, 5, 5)$.

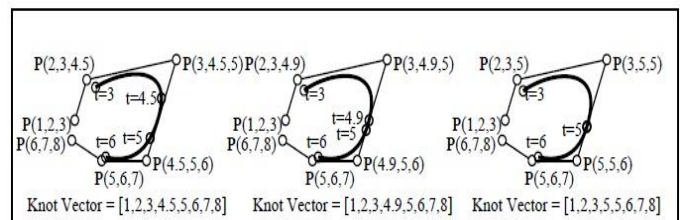


Fig. 4.2 Multiple knots

4.4 PROPERTIES OF B-SPLINE SURFACES

- The highest order in each parametric direction is limited to the number of defining polygon vertices in that direction
- The continuity of the surface in each parametric direction is $k-2, l-2$ respectively
- The surface is invariant to an affine transformation
- The variation diminishing property of B-spline surface is not well known
- The influence of any polygon net vertex is limited to $k/2, l/2$ spans in the respective parametric direction.

- If the number of polygon net vertices is equal to the order of basis in that direction and if there are no interior knot values, then the B-spline surface reduces to a Bezier surface.
- The flexibility of B-spline curves and surfaces is increased by raising the order of the basis function and hence the defining polygon/grid segments.
- The nature of the knot vector is preserved (uniform, open) even after insertion of new knot value

4.5 ADVANTAGES OF USING B-SPLINE CURVES

- B-spline curve require more information (i.e., the degree of the curve and a knot vector) and a more complex theory than Bezier curves.
- But it has more advantages to offset this short coming
- First, a B-spline curve can be a Bezier curve.
- Second, B-spline curve satisfies all important properties that a Bezier curve has.
- Third, B-spline curve provide more control flexibility than Bezier curve can do.

5. DESIGNING OF DIE FOR L-SECTION IN SOLID WORKS SOFTWARE

5.1 DESIGN OF EXTRUSION DIE USING B-SPLINE CURVES.

Here we are using B-Spline curves for designing the extrusion die to convert a round billet to an L-Section beam. The design process is as follows.

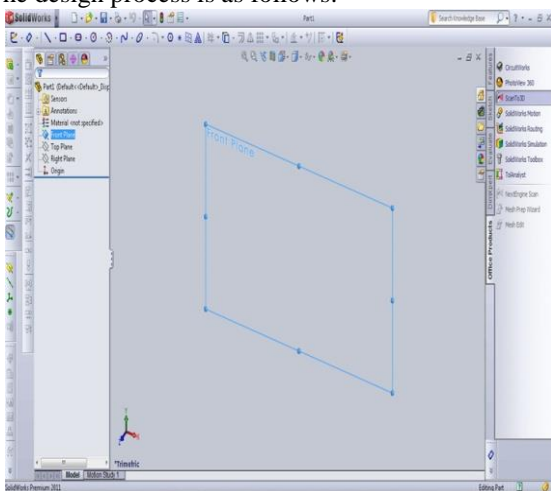


Fig 5.1 The Solid Works interface.

Initially the L section is drawn in the front plane with the basic dimensions

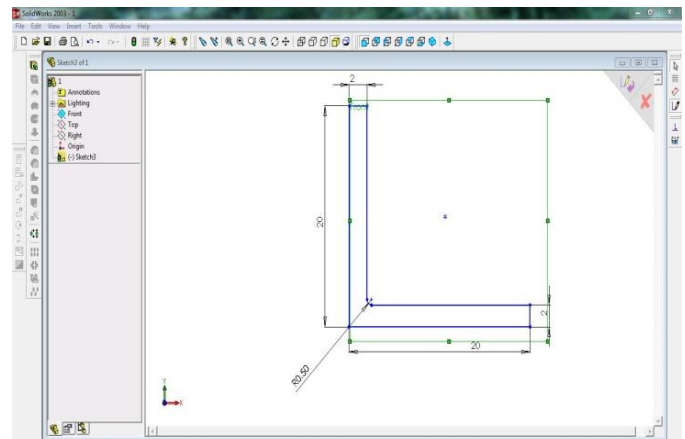


Fig 5.2 L-Section in front plane.

Create one offset plane at a distance of 10 mm from the front plane and draw a circle of diameter 30 mm. select 3D sketch from tool bar and join the circle with the L section using 5 splines

If we join the two sections without guide curves, it will be a streamlined die. To apply our concept in this die we should connect the two sections with the B-Spline curves. We took the guide curves from each corners of the L-Section and connected to the circular section. Totally we take 5 Guide curves to join the two sections.

The following fig shows the process of creating the B-Spline curves for connecting two sections.

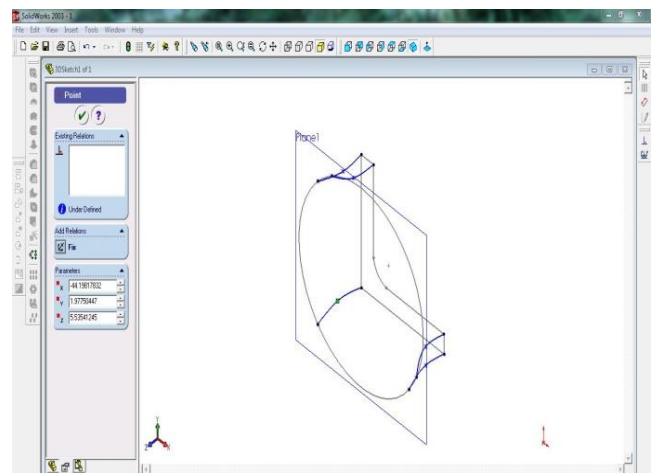


fig 5.3 complete diagram which is connected by 5-spline curves.

Now the sketching part is over. Then by using "LOFTED SURFACE" command the sketch is converted into the part. When using the "LOFTED SURFACE" command the two sections are selected in the 'profile' area and the guide curves are selected in the 'guide area'.

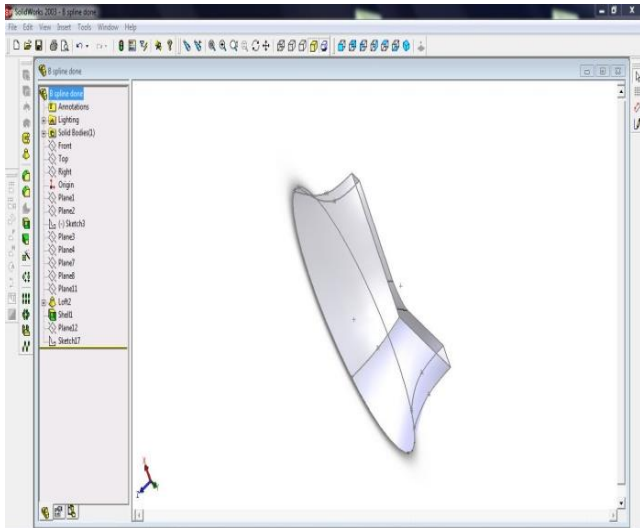


Fig 5.4 Using LOFTED SURFACE command

Thus a die with a sheet metal thickness is produced. We can add the thickness up to the required level by using “THICKEN” option.

INSERT → BOSS/BASE → THICKEN

Thus the die profile is created. But practically it is not possible to extend an Object without using guide ways. So we should create an guide path for the work piece to enter into the die profile. It is created by using “EXTRUDED BOSS/BASE” command by leaving the hollow space in the centre to permit the work piece.

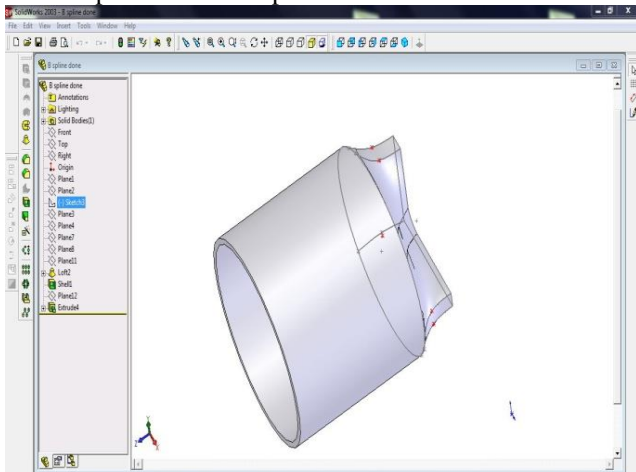
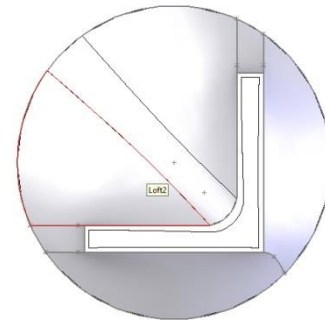
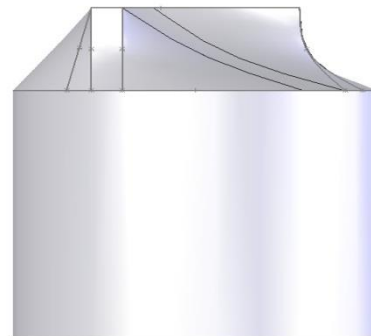


Fig 5.5 Final die using B spline curves.

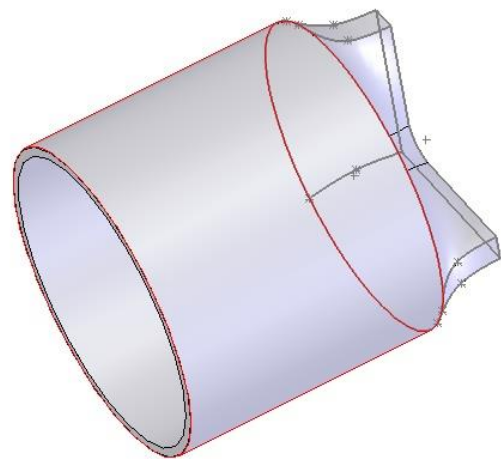
Thus the die is well prepared using B spline curves and it is shown in the following figures



Front view.



Top view.



Isometric view.

Fig 5.6 Die using B spline curves

5.2 DESIGNING OF EXTRUSION DIE USING NORMAL STREAMLINED CURVES

Streamlined dies are the commonly used dies in the market. To compare our newly designed die using B-spline curves we need to design the streamlined die for the same section and same dimensions.

The same procedure as like above is followed for this process. But instead of creating spline curves for the guide curves we use straight lines. Remaining all the commands are same.

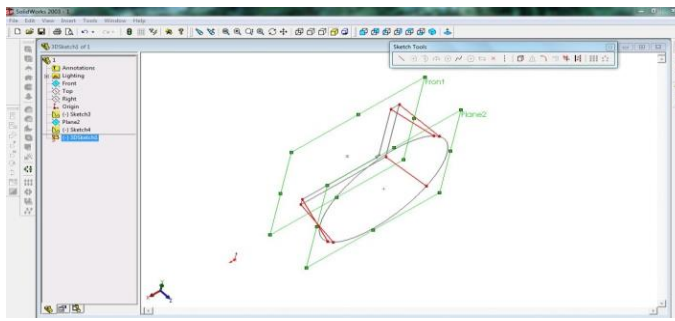
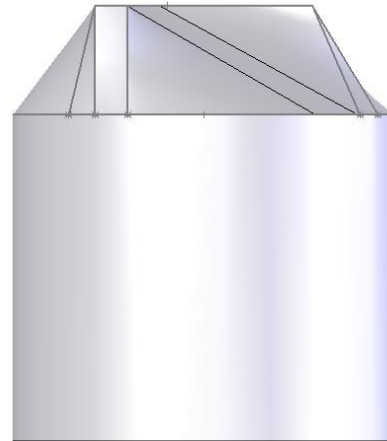
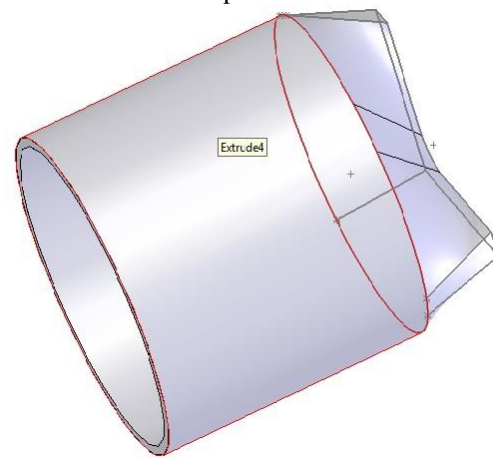


Fig 5.7 complete diagram which is connected by straight lines.



Top view



Isometric view

Fig 5.10 Die using Straight line curves

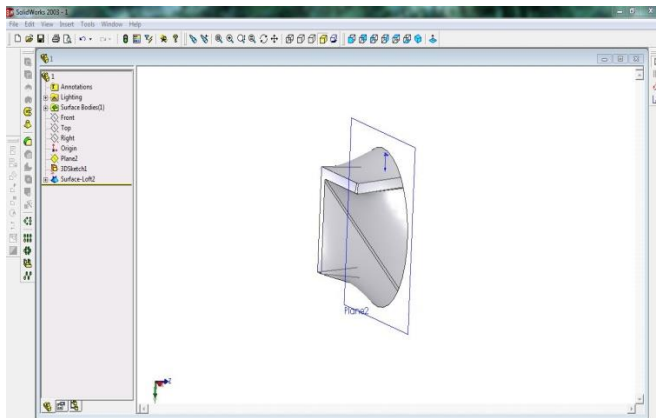


Fig 5.8 Use of streamlined guide curves

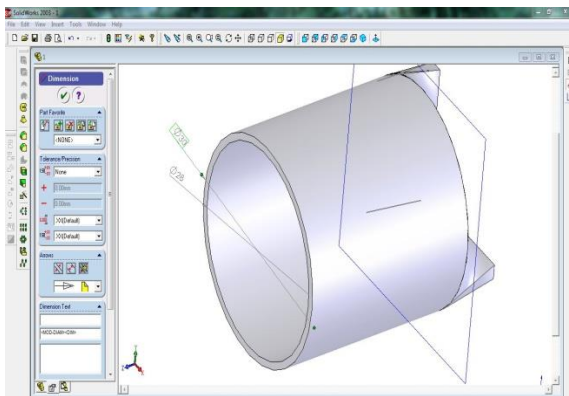


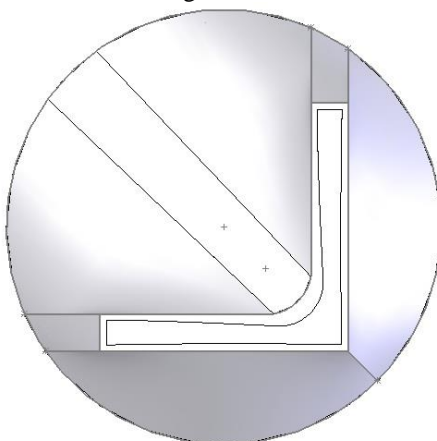
Fig 5.9 Final die using streamlined curves.

5.3 DESIGNING OF TOP DIE (RAM)

Top die is nothing but the ram, Which is used to push the work piece through the die or to give load to the work piece for extrusion. It is a cylindrical object with circular cross section.

Designing of top die (ram) is a simple process which requires sketching the circle using “Circle” command and the solid cylinder is made Using “EXTRUDED BASE”.

Thus the die is well prepared using Straight line curves and it is shown in the following



Front view

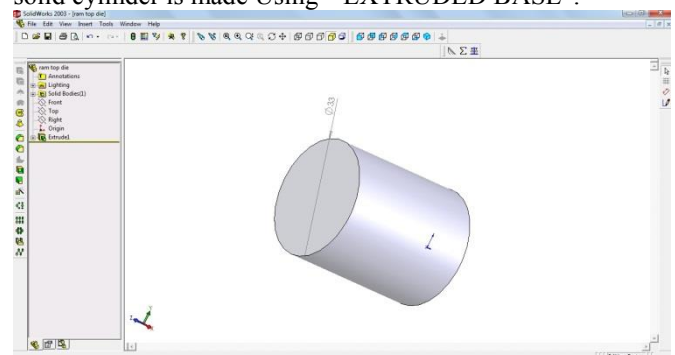


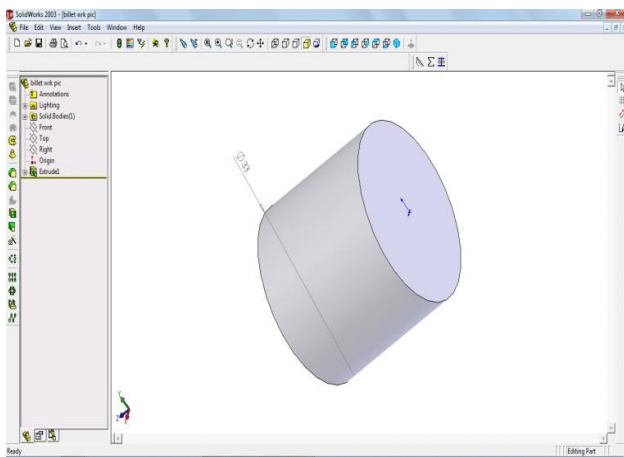
Fig 5.11 Designing of Top die

5.4 DESIGNING OF WORKPIECE (BILLET)

Work piece is nothing but a billet. Here the work piece has a cylindrical cross Section of diameter 30mm with some tolerance.

Designing of work piece is same as the top die by using solid works, In this project we are going to convert a circular billet to L-Section.

Work piece is heated up to recrystallisation temperature and then it is passed into the die profile and required L-section is extruded.



5.12 Designing of Work piece

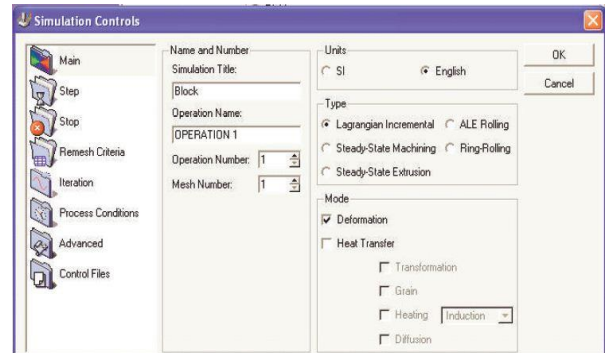


Fig 6.2 Simulation Controls

2. Loading Object Data

This process comprises of importing the needed objects i.e., ‘Work piece, Bottom die, Top die’ into the working area.

Initially the work piece have to be imported and it is meshed in to several small objects.

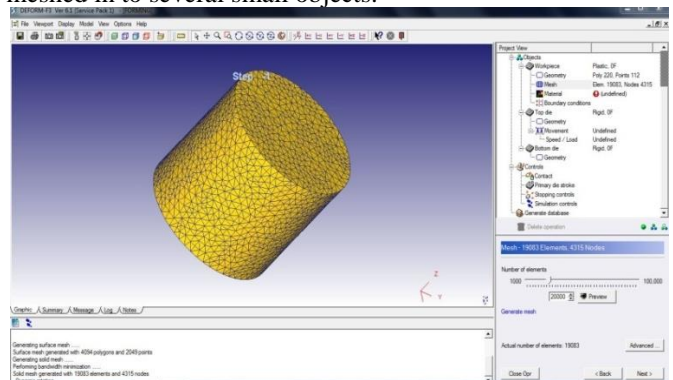


Fig 6.3 Meshed Work piece.

6. ANALYSIS USING DEFORM 3D SOFTWARE

6.1 ANALYSIS OF EXTRUSION PROCESS THROUGH DIEDESIGNED USING B-SPLINE CURVES.

Then the main screen opens. The interface screen is shown below :

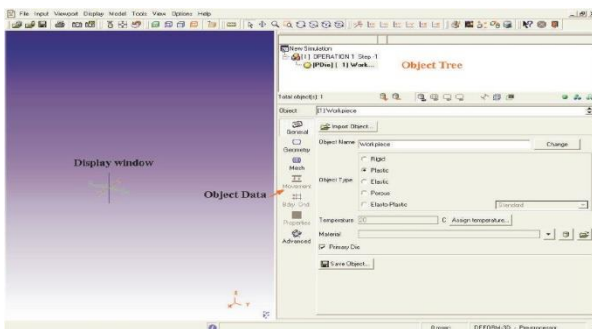


Fig 6.1 Main Screen

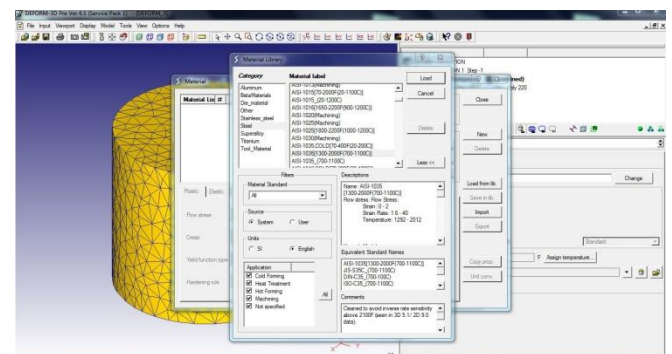


Fig 6.4 Specifying Work piece Properties

The various steps have to be followed is as follows:

1. Simulation Control Settings

In this step the units, Type of problem, Number of steps to be simulated and Top die displacements are fed here.

Then the top and bottom die is inserted and they are aligned properly in the manner so that their axis should lie in straight line.

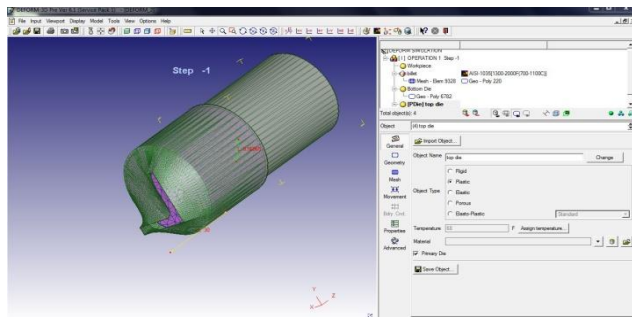


Fig .6.4 Object Positioning

And then the material properties for both the dies are specified

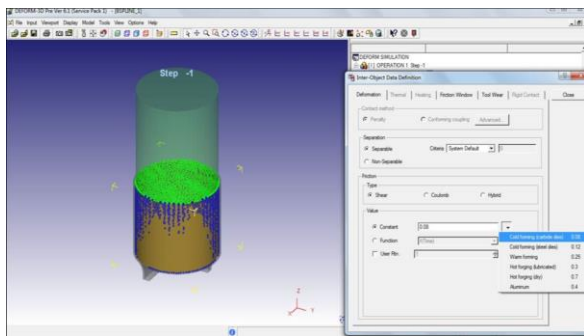


Fig 6.4 specifying die properties

Then the relevant steps are given to the Top Die to push the Work piece through the Bottom Die with the appropriate increment steps.

The next step is to run the **SIMULATION**. Here the deformation is being carried out step by step.

The next step is **DEFORM POST PROCESSOR**. In post processor, the exact results of both the B-spline and Streamline dies are obtained.

7. RESULTS.

7.1 EXTRUSION DIE USING B-SPLINE CURVES.

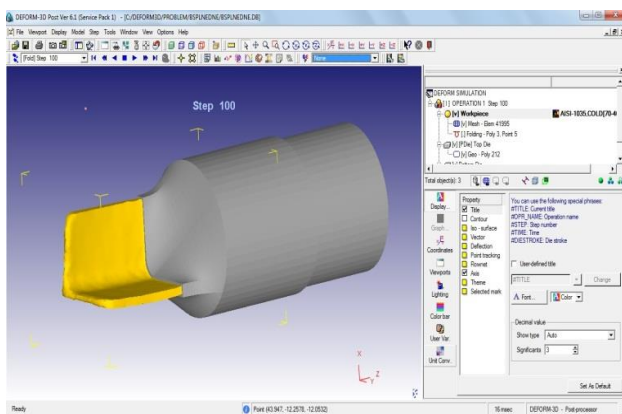


Fig 7.1 Output of L-section (B-Spline Die)

Velocity in B-spline die.

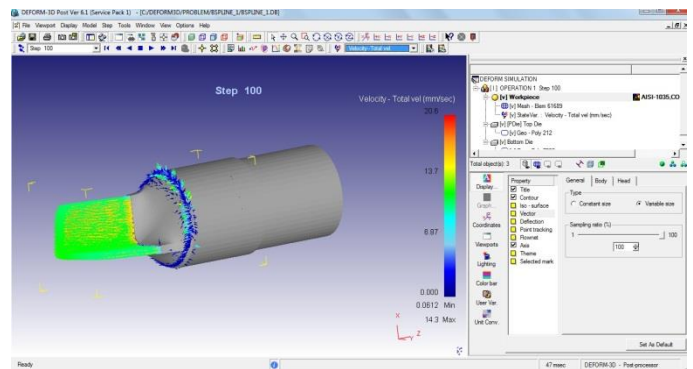


Fig. 7.2 velocity in b-spline dies.

Stress in B-Spline Die

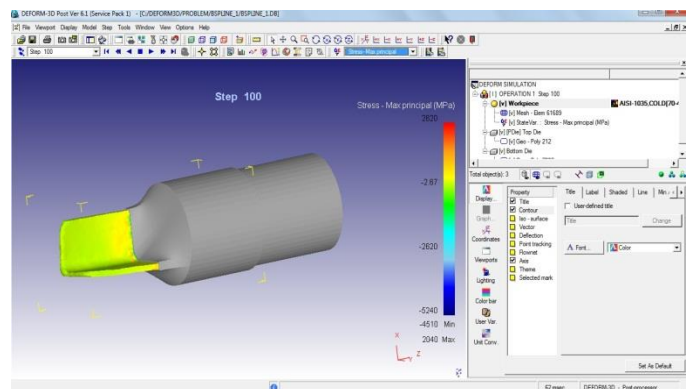


Fig 7.3 Stress in B-spline

Load Prediction in B-spline Die

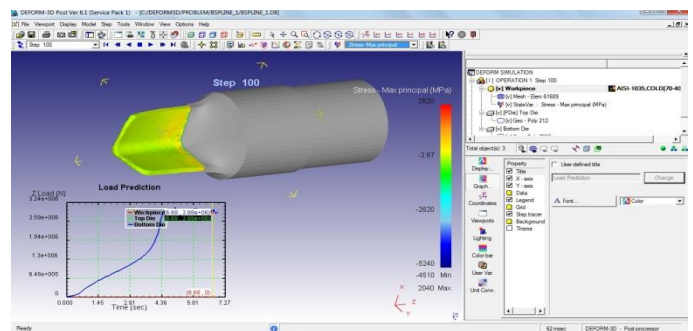


Fig 7.2 Load Prediction in B-Spline Die

Damage in b-spline die.

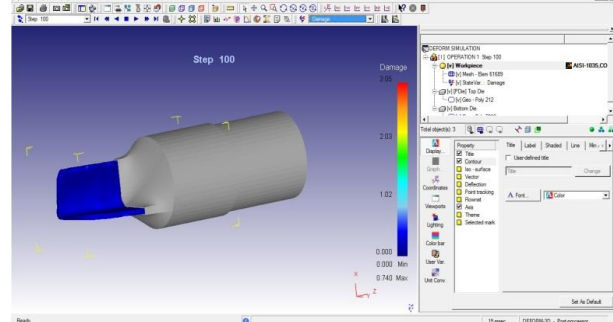


Fig 7.3 Damage in b-spline die.

7.2 EXTRUSION DIE USING STRAIGHT LINE CURVES.

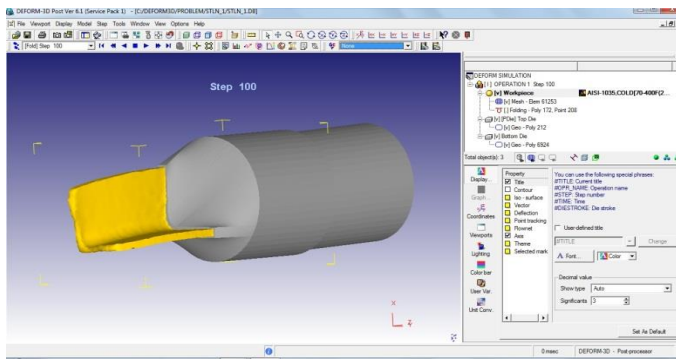


Fig 7.4 Output of L-section (Streamline)

Velocity in Streamline Die.

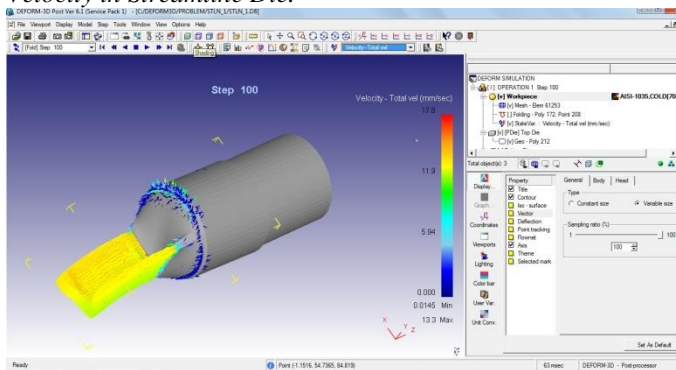


Fig 7.5 velocity in Streamline Die.

Stress in Streamline Die.

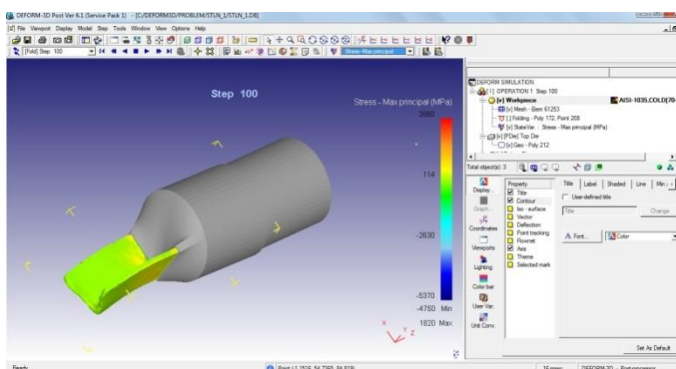


Fig 7.6 Stress in Streamlined Die.

Load Prediction in Streamline Die

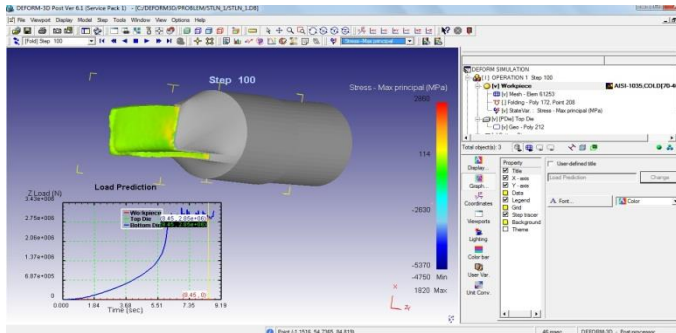


Fig 7.7 Load Prediction in streamline Die

Damage in Streamline Die.

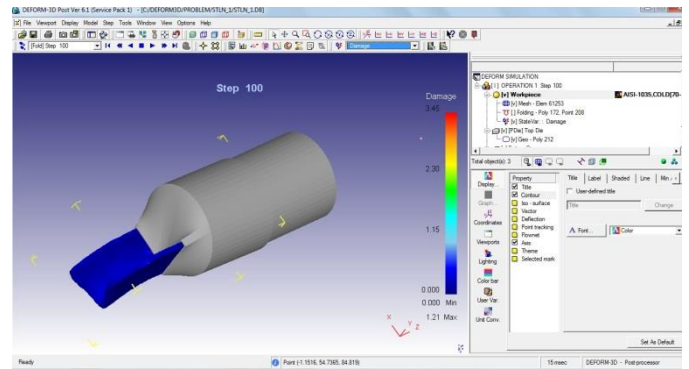


Fig 7.8 Damage in Streamlined Die.

8.7. CONCLUSION.

The purpose of our project is to design the extrusion die for converting circular billet to L-section by using B-Spline curves. The designing part is done using SolidWorks software and the analysis part is done using Deform 3D software.

The analysis part is done for both the dies, i.e., B-spline die and Streamline die, and the results are compared. When we compare the results, the following statistics are found.

- The velocity of ram movement is increased up to (2.8mm/sec) in B-spline die than in Streamline die.
- Stress in the workpiece is low when compared to other dies up to 240 Mpa
- Load required for the extrusion process has been reduced upto 230 KN
- Damage in the workpiece extruded through the B-spline die is less (3.05) than the Streamlined Die (3.45)

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