MARMARA UNVERSITY
FACULTY OF ENGINEERING

Design and Analysis of an Extrusion Die Having Rotating Billet

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GRADUATION PROJECT REPORT

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Design and Analysis of an Extrusion Die Having Rotating Billet

by

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ABBREVIATION

- °C: Celsius Degree
- GPa: Giga Pascal
- mm: millimeter
- MPa: Mega Pascal
- RPM: Round per Minute
- STL: Standard Triangle Language

Abstract

The main purpose of this paper is the analyzing the effect of speed and extrusion diameter in extrusion process. For this purpose, a die has designed using Solidworks 2020 program. Then simulation process started. During all the simulation process a rotation value has set to the billet. Which was 100 RPM. Then different shaper designed in order to seeing the effect of the extrusion diameter. Those diameter values are 40 mm, 60mm and 80mm Also during the simulation process speed of the billet changed between 5 mm/s and 15 mm/s with 5 mm/s increment. After the condition determined simulation results collected an analyzed.

Chapter 1: Introduction

The extrusion of metals is widely used in different industries. Variety of different shapes can be extracted using this method. Such as rods, sigma profiles, hollow beams, square profiles etc. Using extrusion techniques complex shapes can be produced with ease. For example, many types of heat sinks produced in this way because of their complex shapes. If extrusion does not exist, these shapes will be nearly impossible to produce. See **Figure 1.1**.

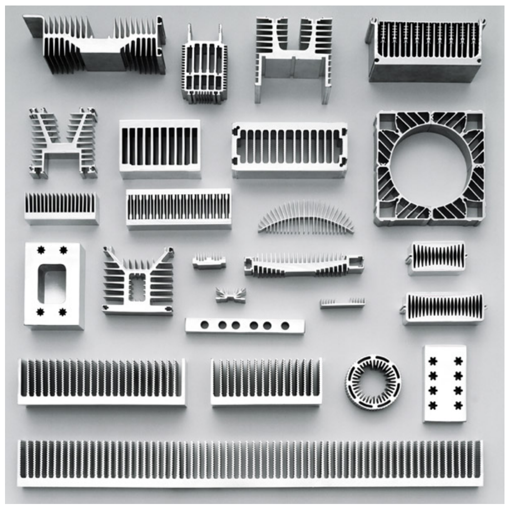


Figure 1.1: Extruded Heat Sink Examples

Also, the extrusion of a basic rod can be done with many extrusion techniques. Extrusion might be completed directly pushing the billet through die cavity. This technique also considered in this paper for comparison. In this type of extrusion, the load on the die elements expected to be higher compared to other methods. The comparison of these techniques will be mentioned in the following sections.

One of the other methods for extrusion is rotating the die element. When these types of extrusion considered a friction generated between die and billet and this friction increased the temperature at the tip of the billed thus extrusion can be completed with less amount of load. This type of extrusion is widely used for extrusion of basic rods. But in this paper, this widely used method will not be considered.

But in this paper instead of rotating the die a different method will be used. In this case the billet will be rotated. This kind of application is not widely used in industries. But like in the rotating the die method also this method generated friction at the tip of the billet. Also, this method can be generated friction of the side walls of the die elements. And the effect of the rotating the billed will be considered as main topic of this paper.

In this paper the extrusion of a basic rod considered. For this purpose, firstly a die has designed. The important thing about designing a die, die must withstand the extreme load that created by the billet. Therefore, the die material selected carefully in order to prevent failure that might be happen in the die section of the system.

After designing the die system analysis has started using **Deform 3D** program. For program entrance, different types of die tip have designed. In order to see the effect of extrusion of different size of rods. Also, along the simulation process the speed of the billet set to be constant. And simulations will be repeated for different speed values. Also, along the simulation process billet will be rotated. In order to see the effect of the rotation on extrusion process. Therefore, the rotation set as constant during all the simulation process. And results will be analyzed and will be compared in the following sections.

Chapter 2 - Material and Method

2.1 – Die Design

2.1.1 – Billet Material Selection

Considering the extrusion process aluminum is dominating the extrusion sector. Therefore, Aluminum selected as an extrusion material for analysis. But there are lots of different aluminum alloy. Considering industries standards 6000 series aluminum is the more suitable for this study. Because 6000 series aluminum widely used in industries, easier to find and has a greater strength compared to lower series of aluminums. Therefore **Aluminum-6063** selected as a material for this study. Mechanical properties of the Al-6063 can be seen in **Table 2.1**.

Table 2.1: Mechanical Properties of Aluminum-6063

Mechanical Properties	Mertic
Ultimate Tensile Strength	241 MPa
Tensile Yield Strength	214 MPa
Modulus of Elasticity	68.9 GPa
Ultimate Bearing Strength	434 MPa
Bearing Yield Strength	276 MPa
Fatigue Strength	68.9 MPa
Poisson's Ratio	0.33
Shear Modulus	25.8 GPa
Shear Strength	152 MPa

2.1.2 Billet Diameter Selection

For die design firstly a billet size selected. This selection made specifically because the billets produced in certain sizes. According to a local billet producer facility billet starts from 120 mm in diameter and up to 6000 mm in length. The diameter values for billets goes up to 202 mm. Considering all the information provided by local billet producer the smallest diameter selected. Thus, this paper considers **120 mm** in diameter billet. Also, this selection matches the general industries standards. The billet can be shown in **Figure 2.1**.

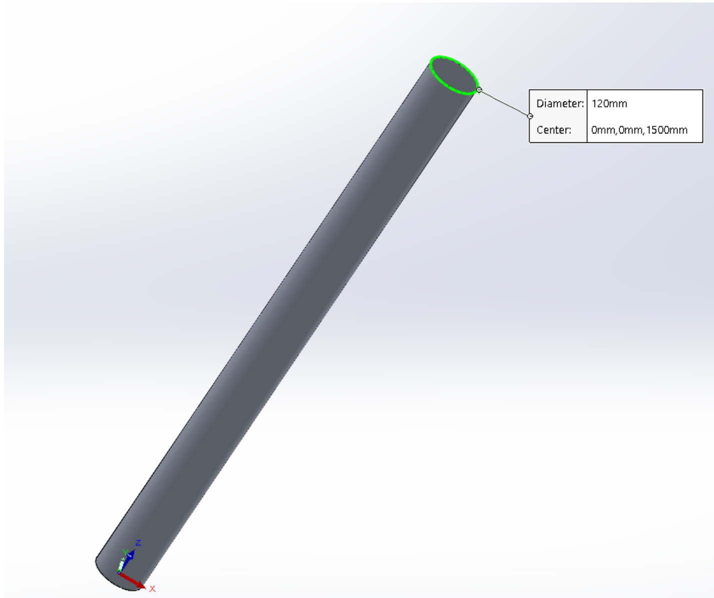


Figure 2.1: Billet Diameter

2.1.3 - Shaper Design

In order to design shaper firstly requirement of the problem has determined. Therefore, first requirement sets as extrude diameter. Then, with the aim of seeing the effect of the diameter changes three basic diameter values selected. First value for diameter selected as 60 mm. Then design process started. In order to finding the optimum shaper design, the shaper design that uses in industries has analyzed. And first concept shaper has designed. See **Figure 2.2.**

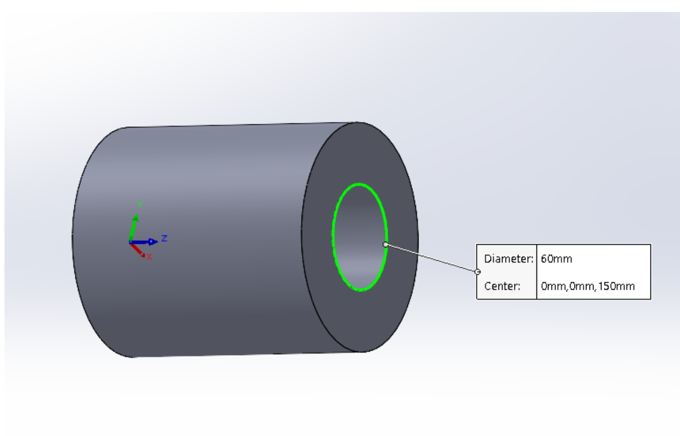


Figure 2.2: Preliminary Shaper Design

After completing first preliminary design other industry standard has considered. And more complicated design has prepared. In this design after a short amount later diameter has growth in order to reduce the stress on the billet. Also, with the aim of reducing the stresses along the placer part center of the shaper has trim down.

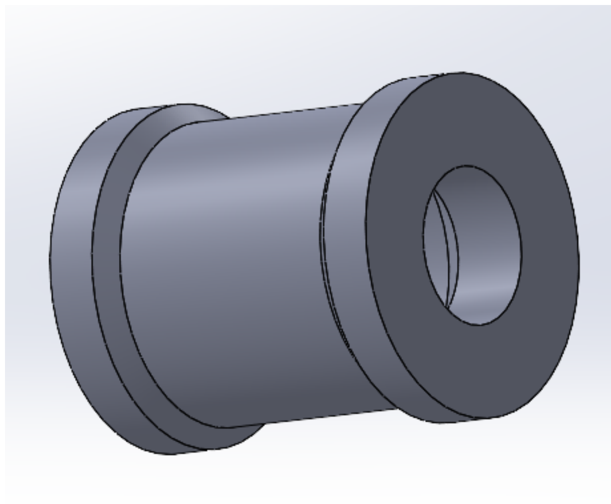


Figure 2.3: Detailed 60 mm Shaper Design

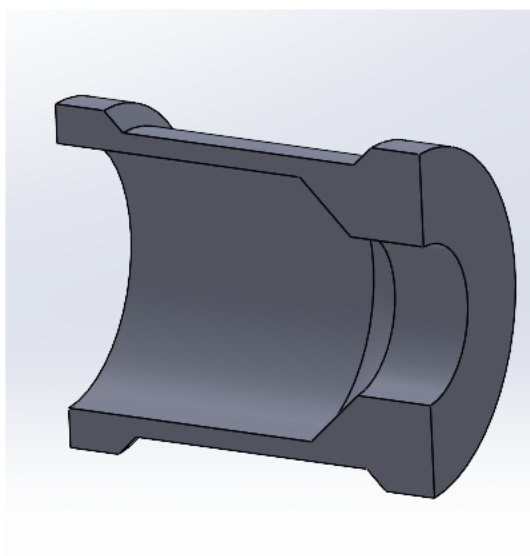


Figure 2.4: Cross-Sectional View of Detailed Shaper

And all the simulations made for this shaper design for convenience. But in real design also more detail added to the shaper design the connection flange added to system in order to connect shaper to placer. The placer design will be discussed in the following sections. Also, 6 counterbore has drilled in order to connect the parts. And as a material selection for shaper stainless steel selected. But in simulation process the shaper treated as rigid matter.

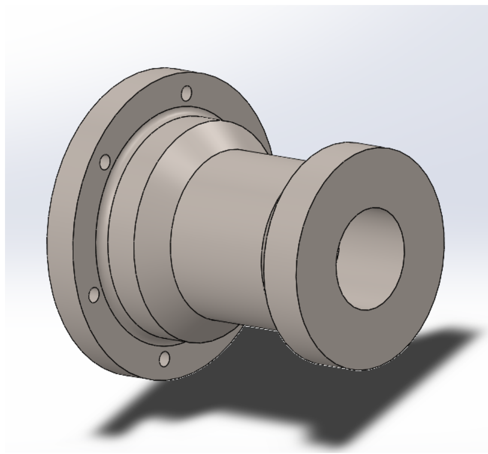


Figure 2.5: Final Shaper Design

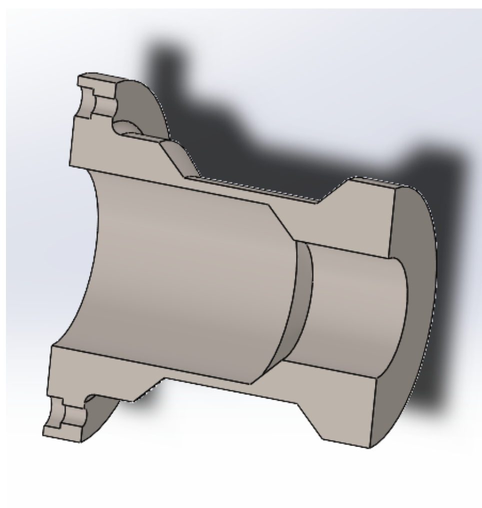


Figure 2.6: Cross-Sectional View od Final Shaper Design

Then in order to seeing effect of different extrusion diameters 2 more different shaper designed. The extrusion diameters are 40 mm and 80 mm.

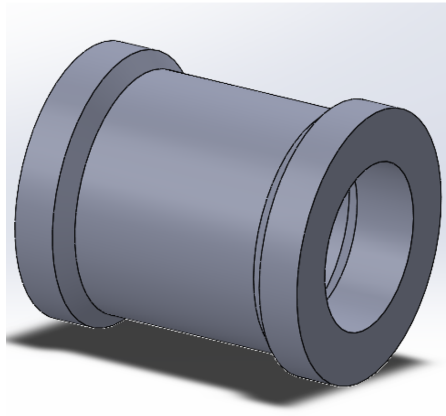


Figure 2.7: 80 mm Shaper Design

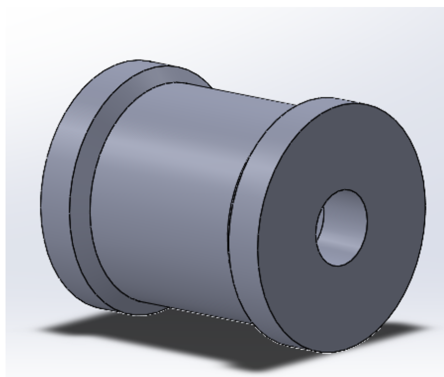


Figure 2.8: 40 mm Shaper Design

2.1.4 – Rotor/Pusher Design

Rotor design mainly design for simulation only. This part considers as a standard equipment. But a design has designed for simulation. This part has 2 jobs mainly. Those are rotating the billet and pushing the billet. For better analysis, different speed values set for rotor/placer. These values are 5 mm/s, 10 mm/s and 15 mm/s. Also, a constant value of rotation has set as 100 RPM.

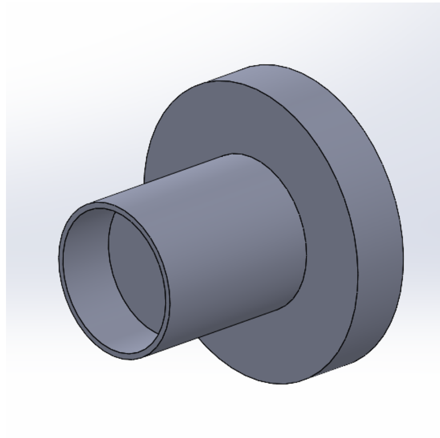


Figure 2.9: Final Rotor Design for Simulation

2.1.5 – Placer Design

As mentioned before if the side movement of the billet does not prevent proper extrusion cannot occur. In order to prevent such expansion a placer designed. Inside diameter sets as 130 mm. This diameter value selected as a greater value then the billet diameter. This selection has made for seeing the effect of little bit of expansion. Also, considering a greater diameter on placer the friction between placer and billet does not occur at first place. Using this kind of selection enables to seeing multiple variation in 1 simulation system.

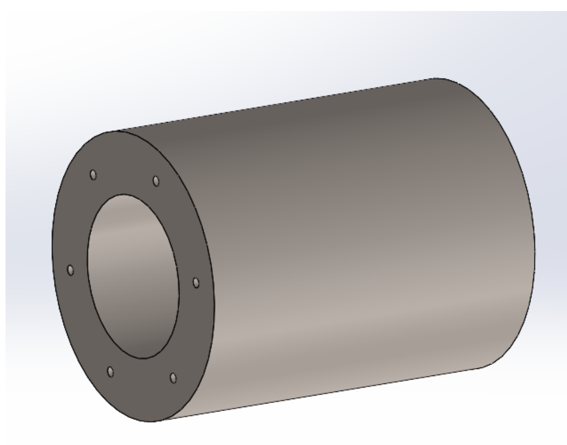


Figure 2.10: Final Placer Design

2.1.6 Billet Length

Also, the length of the aluminum billet has selected with care as a 200 mm in size. This selection made for maximum extrusion amount. In early stages of the design process different sizes consider. But when the billet size increased couple different problem has occurred. Firstly a 1500 mm billet consider. When the pressure applies on 1500 mm billet after a short time billet started to bend instead of extrusion. In that case this approach abandoned. Of course, this kind of problem can be solved with different type of design and different type of process. For example, if the billet pre heated before the process this bending effect will be significantly decreased. Also, other optimum solutions can be derived for this type of problem.

Then the size of the billet decreased to 600 mm and simulation performed again. But in this case connection type between billet and rotor changed.

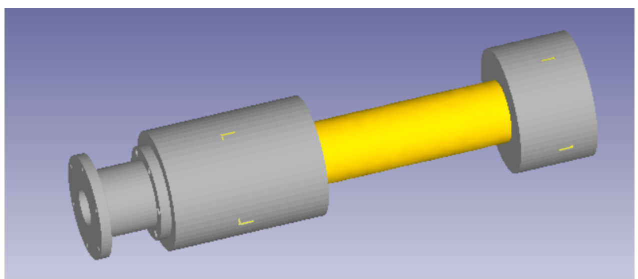


Figure 2.11: 600 mm billet design,

After changing the connection type and billet length simulation started and result collected. In this case bending doesn't occur. But instead of bending the effect of compression seen tip of the billet.

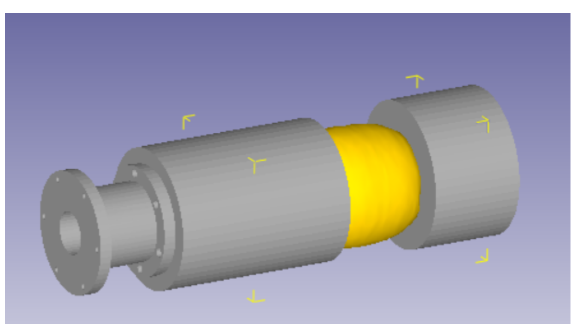


Figure 2.12: Effect of Compression on the 600 mm billet

And all the billet behaviors analyzed, and perfect billet length selected as 250 mm for extrusion process. The main reason of this selection is to be keeping the extrusion process inside the boundary conditions to prevent deformation that causes by compression force. When this type of deformation does not prevent extrusion process does not performed properly. All the metals that need to extrude moves sidewards of the billet and therefore extrusion cannot occur.

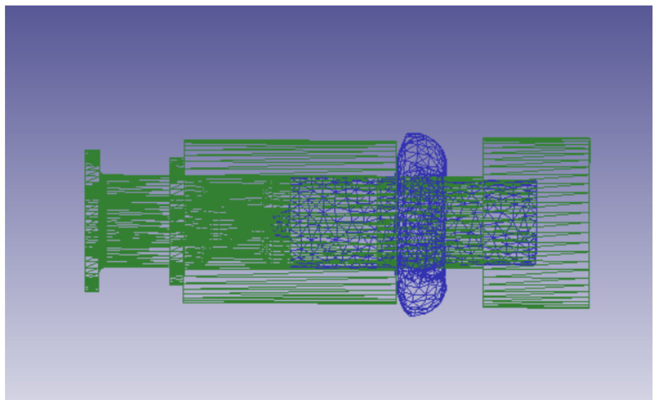


Figure 2.13: 250 mm Billet Simulation that Shows the Flaws of the System

After considering the flaws of the 250 mm billet system. Final diameter selected as 200 mm. This selection made for the corresponding the design requirements. When a longer billet required design can be changed slightly in order to correspond the billet size.

Therefore, considering all the information that given above suitable billet length selected as 200 mm.

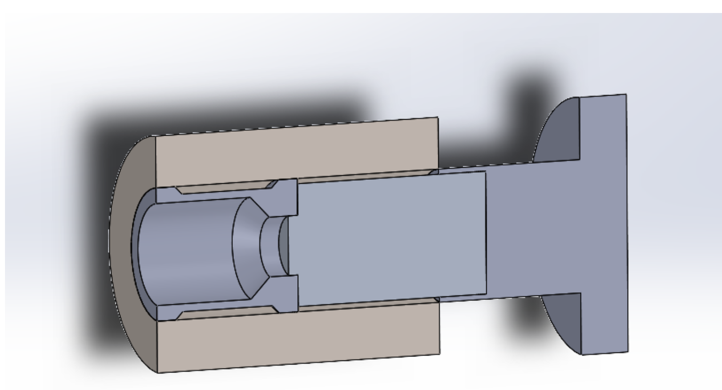


Figure 2.14: 200 mm Billet System

2.1.7 Holder Design

The design of the shaper and placer required to holder in order to prevent movement of the shaper. For that reason, a placer has design and integrated to the system. 3D view of the holder can be seen in following figures.

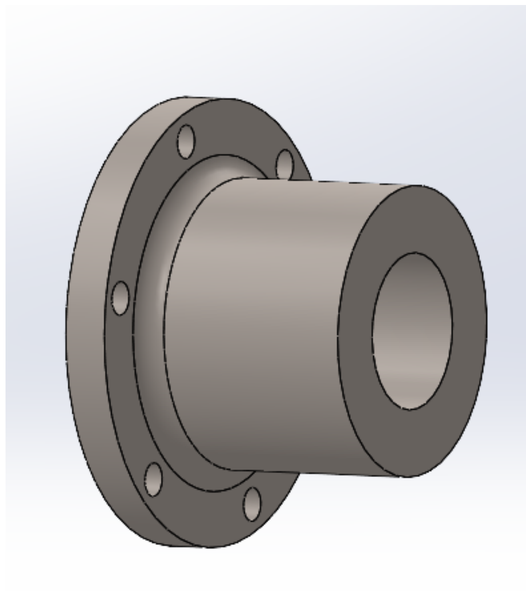


Figure 2.15: Final Placer Design

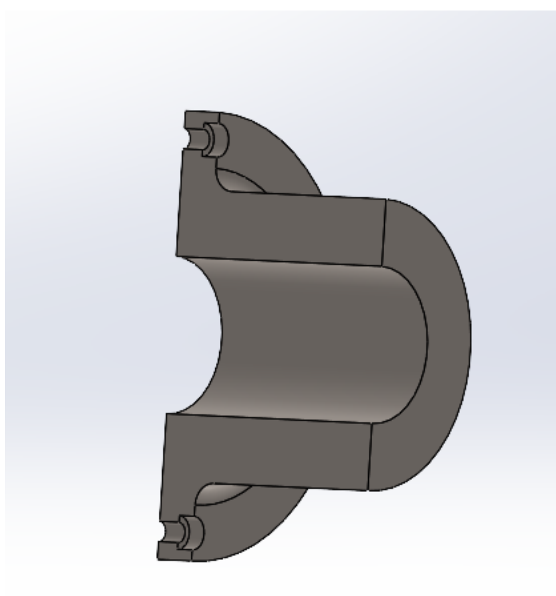


Figure 2.16: Cross-Section View of Placer

2.2 – Die Assembly

After all the individual elements designed assembly process started. Firstly, Placer and shaper connected to each other using 6 M8x40 hexagonal socket head bolt. Then holder added to system in design part the connection points between die and the main system does not consider so holder added to system in order to prevent unwanted failures in the system. Then billet connected to rotor and placed into the placer. After all the steps that mentioned before completed. Simulation process will be ready to start. Full assembly of the system can be seen in **Figure 2.17** and **Figure 2.18.**

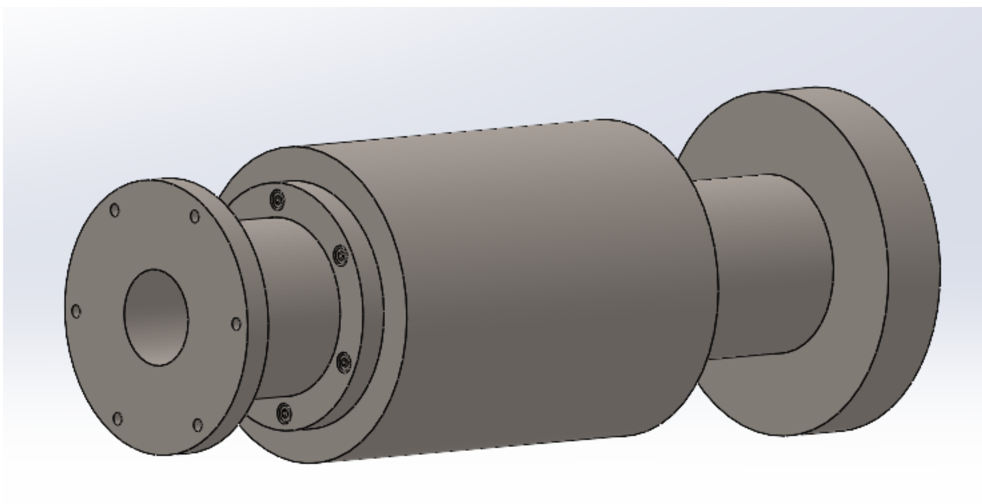


Figure 2.17: Final Assembly of the Die

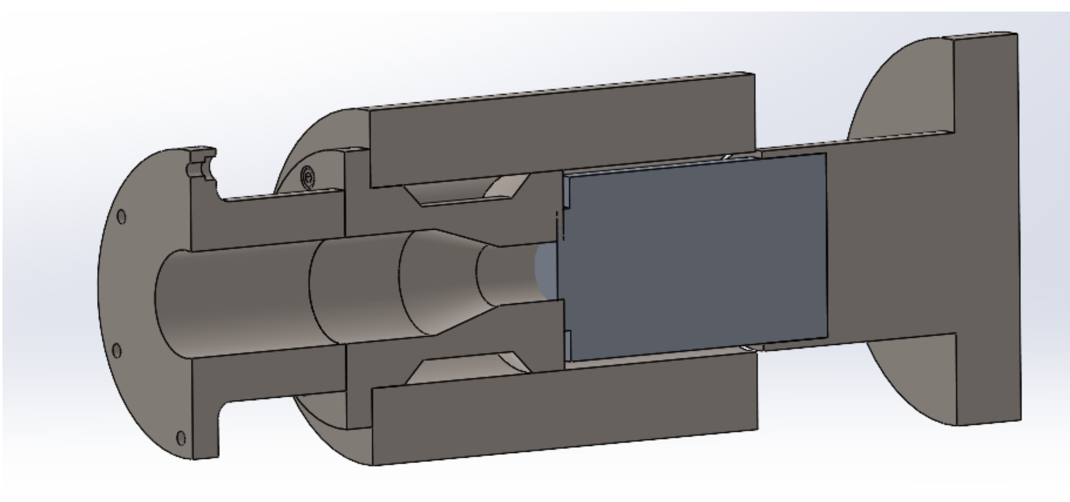


Figure 2.18: Cross-Sectional View of the Final assembly of the Die

2.3 – Simulation Process

2.3.1 – Part Types

In order to simulate the effect of the extrusion DEFORM 2D/3D program have been used. After designing all the necessary parts and completing assembly process the design has been saved in STL format. Because deform program only takes input from this format. The main reason of this file format STL format uses triangles to save the data. Therefore, the format can be helpful when using mesh prosses. For design process and saving STL process Solidworks 2020 program was used. And all the detail technical drawing can be found in the appendix section.

2.3.2 – Material Selection

After design process simulation process has started. Firstly, billet material and initial temperature set. As mentioned before, Aluminum-6063 material selected as a billet material and initial temperature sets as 200 °C. The reason of preheating is for easing the extrusion process. Also, preheating the billet one of the most widely use method for extrusion process. See the following Figure!

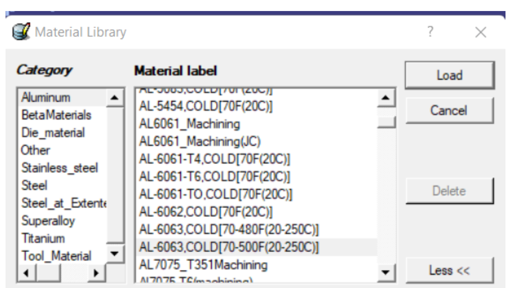


Figure 2.19: Material Selection Page

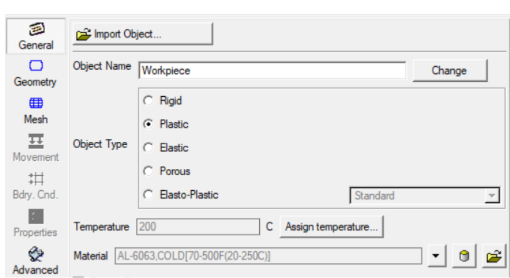


Figure 2.20: Inlet Temperature Selection Page

2.3.3 – Mash Settings

Then billet called in STL format and mash generated. For mash generation 32000 nodes have been used. The reason behind the 32000 nodes selection is working on a quire basic part. Therefore, increasing the node amount also increases the precision of the solution but at the same time significantly increases the simulation time for this reason 32000 node was used. If the extrusion output will be quite difficult to make increasing the node amount will be the best solution. So, considering all the information selection of node number determined as 32000.

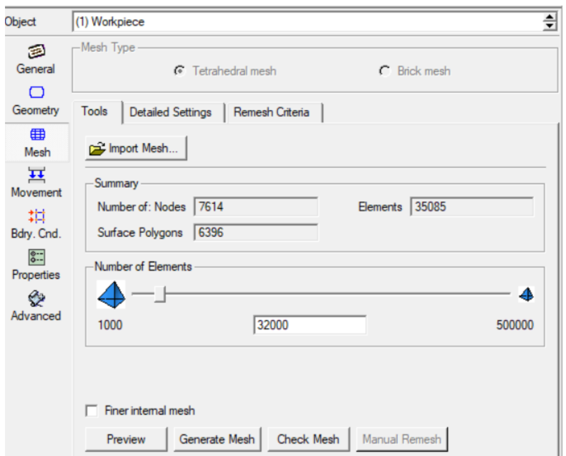


Figure 2.21: Mash Settings

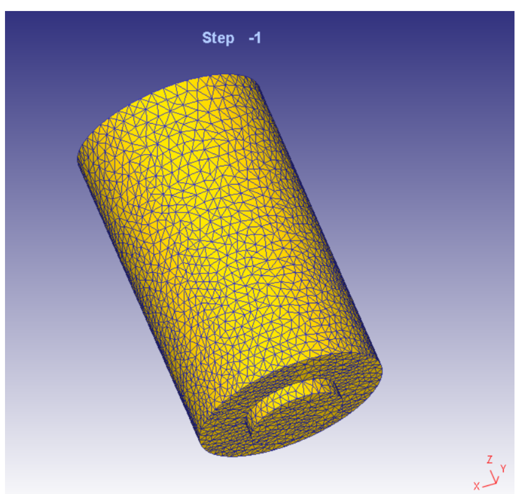


Figure 2.22: Mashed Billet

2.3.4 Billet Movement

In order to generate friction between shaper and the billet, billet has to rotate. Therefore, a rotation value of 100 RPM has set for billet. Also, the center of the billet has selected as a center of rotation. Then in order to generate extrusion a force needed to apply on the billet. For force value, a speed value has set instead of force. So firstly a 10 mm/s speed has set along the -z axis for billet. Then simulation repeated for 5 mm/s and 15 mm/s values. In order to seeing the effect of the speed on extrusion process. Also, the speed values apply for 40 mm and 80 mm extrude diameter.

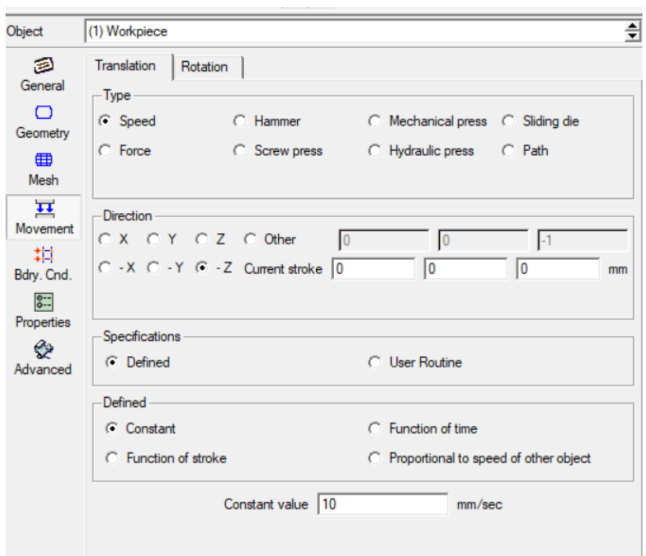


Figure 2.23: Speed Value Entry

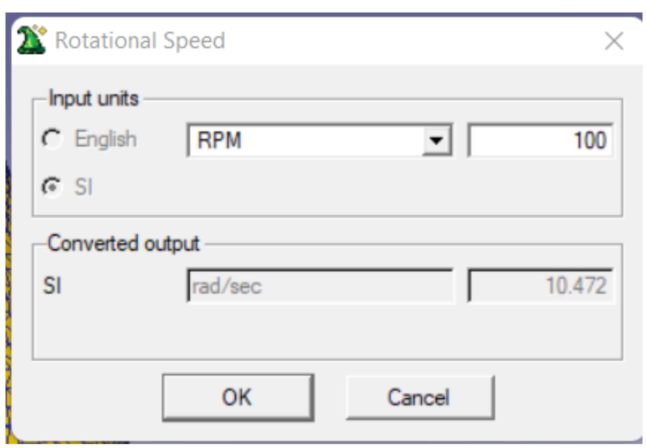


Figure 2.24: Rotation Value Entry

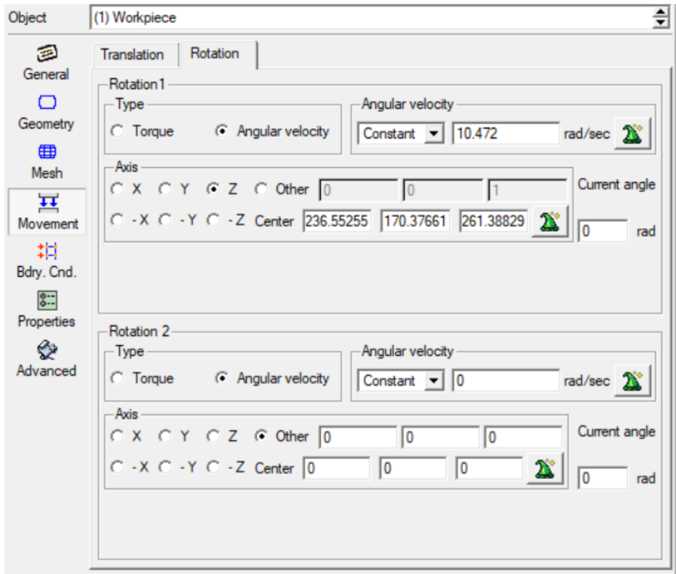


Figure 2.25: Center of Rotation Selection

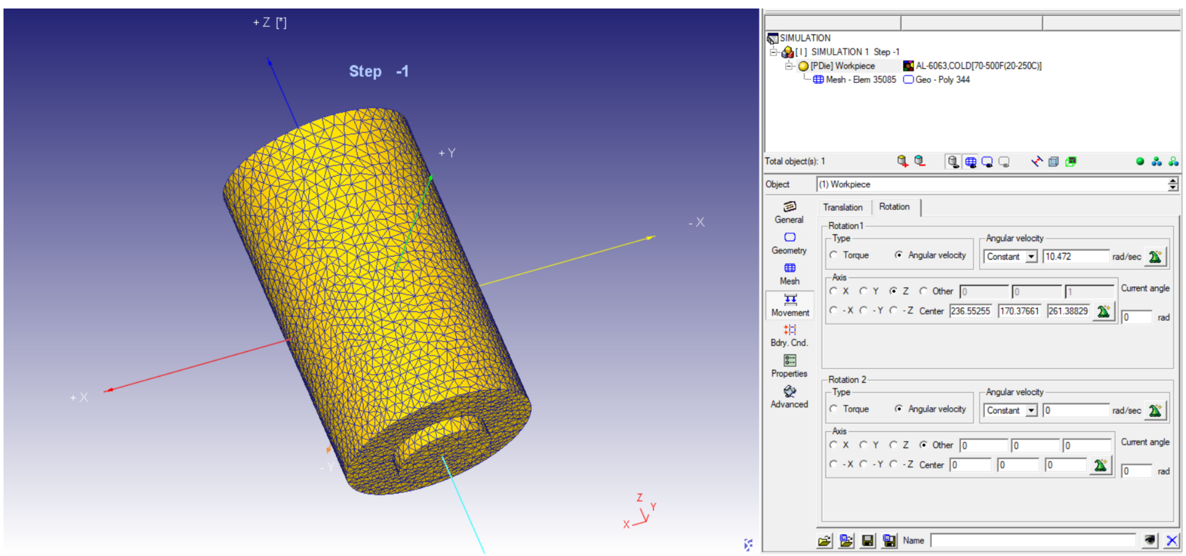


Figure 2.26: Billet's Axis and Movement Values

2.3.5 Calling Rotor

After billet movement determined rotor has called. And rotor has accepted as a rigid body and no preheating and material set for rotor. Also, no mash generated for rotor because of the acceptation of rigid body. Then movement values have set for rotor speed value has set as 10 mm/s along the -z axis. Also 100 RPM rotation value set for rotor in order to prevent unnecessary friction between billet and rotor.

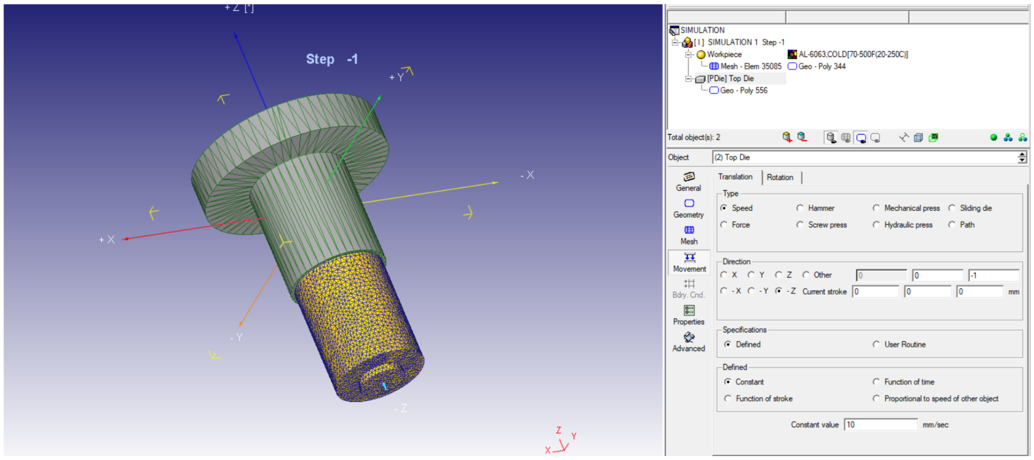


Figure 2.27: Movement Value Settings for Rotor

2.3.6 – Calling Shaper and Placer

Those 2 parts are called. Those parts have accepted as a rigid body and no preheating and material set for those parts. Also, no movement has set for these parts.

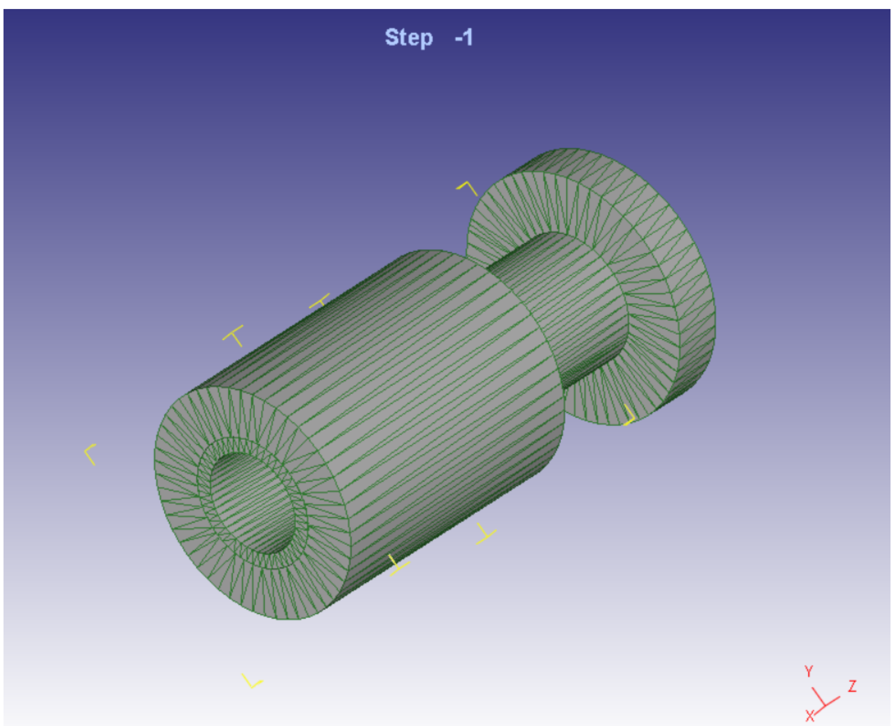


Figure 2.28: Final Simulation Design

2.3.7 - Contact Areas

In order to solve the problem contact point needed to determine. For this purpose, a contact between billet and shaper, billet and placer, billet and rotor has set. Also, sheer value has set to 0.4 for aluminum billet. Then tolerance values between the parts have set as 0.162 and this apply all the parts.

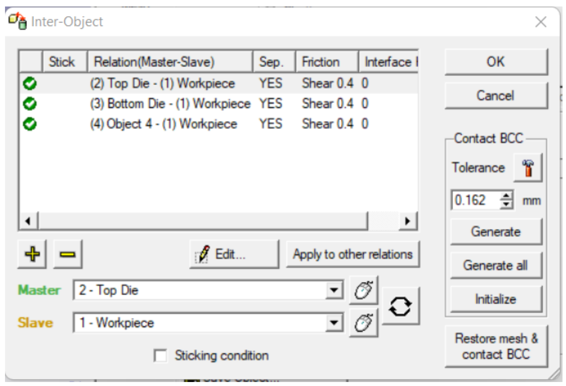


Figure 2.29: Contact Points and Tolerance Settings

2.3.8 – Simulation Settings

Then in order to start the simulation process simulation steps has set initially program designed to have 150 steps. And every 0.1 second is the time between the steps. And program duration has selected as 15 second. Of course, this selection is made for 10 mm/s speed value. When the step value changed program duration and step number will change in order to correspond the die design All the simulation settings can be seen in following figures.

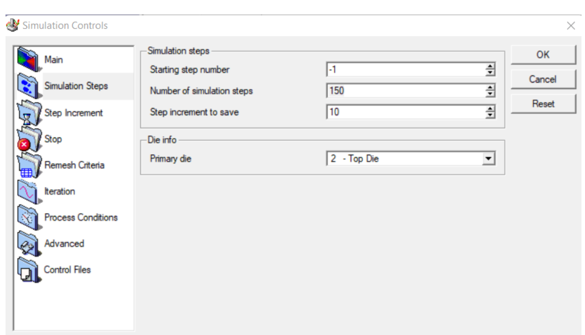


Figure 2.30: Simulation Step Settings

2.3.9 – Generating Database

After all the steps that mentioned before, first database checked then data base generated.

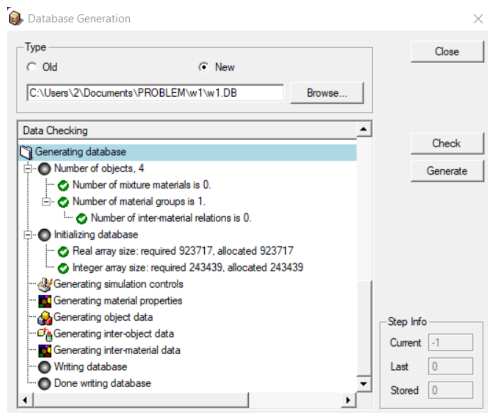


Figure 2.31: Database Generation

And all the process that mentioned before repeated for different values. But during the simulation process rotation value doesn't change. All the simulation variables can be seen in **Table 2.2**.

Table 2.2: Simulation Variables

Extrude Diameter	Billet Speed
40 mm	5 mm/s
40 mm	10 mm/s
40 mm	15 mm/s
60 mm	5 mm/s
60 mm	10 mm/s
60 mm	15 mm/s
80 mm	5 mm/s
80 mm	10 mm/s
80mm	15 mm/s

Then all the previous steps have applied for values that mentioned in Table 2.2. The results can be sown in the following sections.

Chapter 3 - Results and Discussion

3.1 – 60 mm Diameter and 5 mm/s Speed

Firstly, as mentioned before a 60 mm shaper has called. And system assembled. Then all the steps that are mentioned in section 2.3 are applied on the system. Then, 200 mm billet has called, and 32000 mash nodes has generated, and movement value has set for billet. Those movement values are rotation and translation. For rotation 100 RPM angular speed has set along z axis. And for translation 5 mm/s has set along -z axis. Then connection nodes selected, and tolerance values has set as 0.162. Then simulation duration determined for 30 seconds. The reason behind the selection of 30 second is the rotor has to move 150 mm to complete extrusion process. Therefore 30 second input for duration was the right. Then Simulation database generated, and simulation started.

When simulation started process whole process monitored using simulation graphics that provided by Deform 2D/3D program the simulation graphics can be shown below. Also, main reason of monitoring all the process is checking any possible mistake.

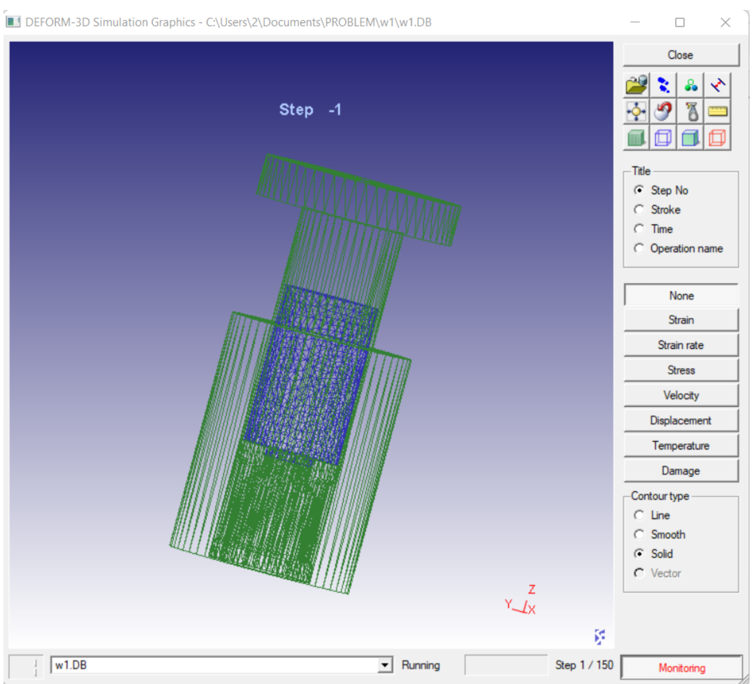


Figure 3.1: Simulation Graphics

After program completed post processor has opened in order to checking all the necessary information. And load prediction, angular velocity, rotated angle, Surface area graphics generated using Deform 2D/3D program. Also speed value was monitored for different point on the billet. Also strain point, stress points, billet displacement and billet velocity have been saved at the middle of the program and at the end of the program.

3.1.1 – Visual Result of the Extrusion

As can be seen in the figure during the simulation process extrusion continued. After 30 seconds later simulation completed. And result visually checked. And no anomaly founded. Extrusion completed properly. The main problem with the extrusion is the when the extrusion process moves the tip of the billet moves outwards. The reason this unwanted error will be analyzed in the following section. See Figure 3.2 in order to see final visual result.

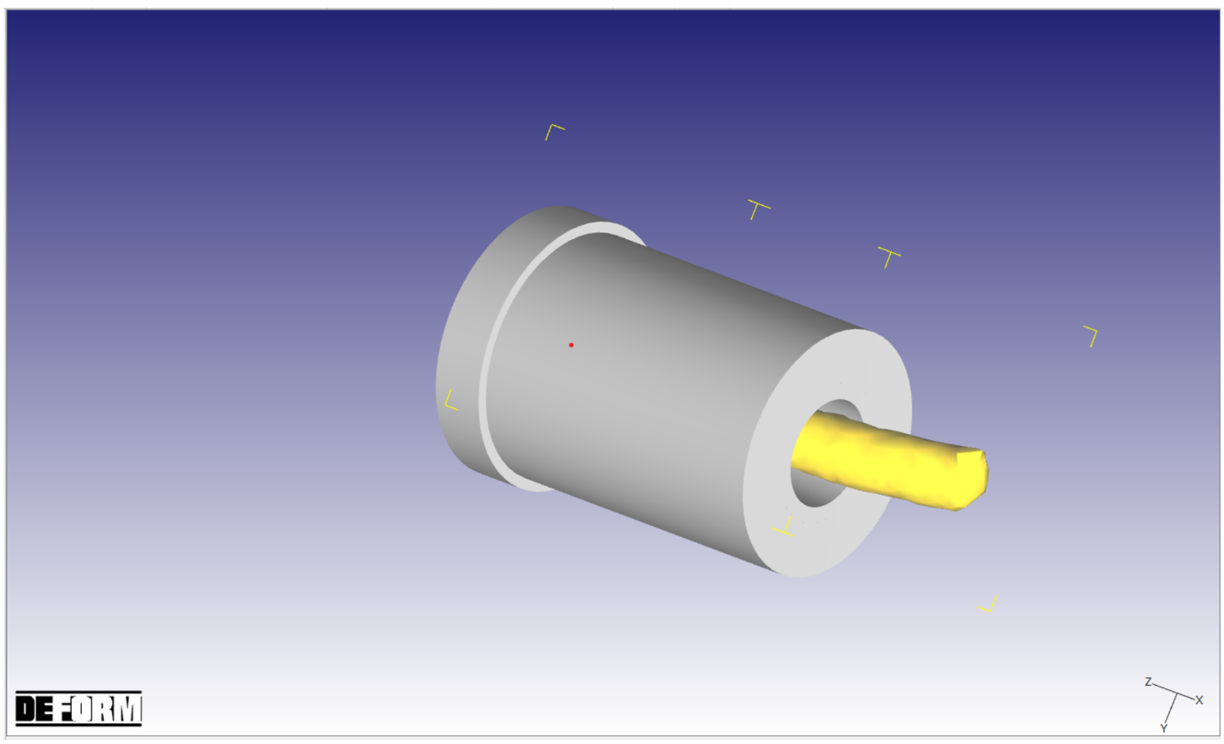


Figure 3.2: Result of the Simulation

3.1.2 - Angular velocity

As can be seen in the graph, during the simulation process the angular velocity of the billet has constant value of 100 RPM which is equal to 10.471 rad/s. The main reason behind the constant angular velocity during all the simulation process is to be seeing the effect of speed and extrude diameter during the constant angular velocity condition. See the **Figure 3.3**.

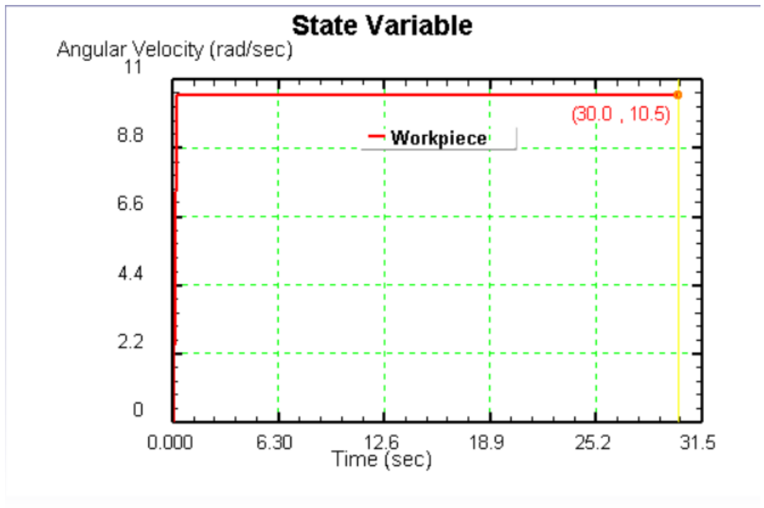


Figure 3.3: Time vs Angular Velocity for Billet

The previous graph only shows the angular velocity of the billet. The angular velocity of rotor didn't mention in the graph.

3.1.3 – Load Prediction

For load prediction 3 part of the die considered. Those parts are rotor, placer and shaper. The load on the billet has not consider. The graph of the load prediction can be seen in the **Figure 3.4.** As can be seen in the figure the loads on the element increased immediately after the program started. Then after this point the loads on the parts have been increased up to $5.43x10^6\ N$ then extrusion continues the load on the parts decreased slightly as can be seen in the figure. After 30 second later which is the last second of the extrusion the loads on the parts have decreased $3.44x10^6\ N$ for same element that the highest load measured which is rotor. So, in 30 second load on the rotor has decreased 38%. Also, at the 5 second time the load on the shaper has measured as $4.61x10^6\ N$ as highest load on the shaper. Again in 30 second the load on the shaper has decreased but not as much as in the rotor. In shaper's case the load decreased to $3.54x10^6$ N so in this case there was 24% decrease in the load. And for placer there was no load at first place after the cavity filled the load on the placer has increased up to $7.84x10^5$ N.Then as the simulation process continues the load on the placer decreased up to $1.24x10^5$ N. This also expected because when the simulation continues the pressure on the placer will be decreased and upper points of the shaper will not have load. The reason behind the first drop at second 5 is the simulation error.

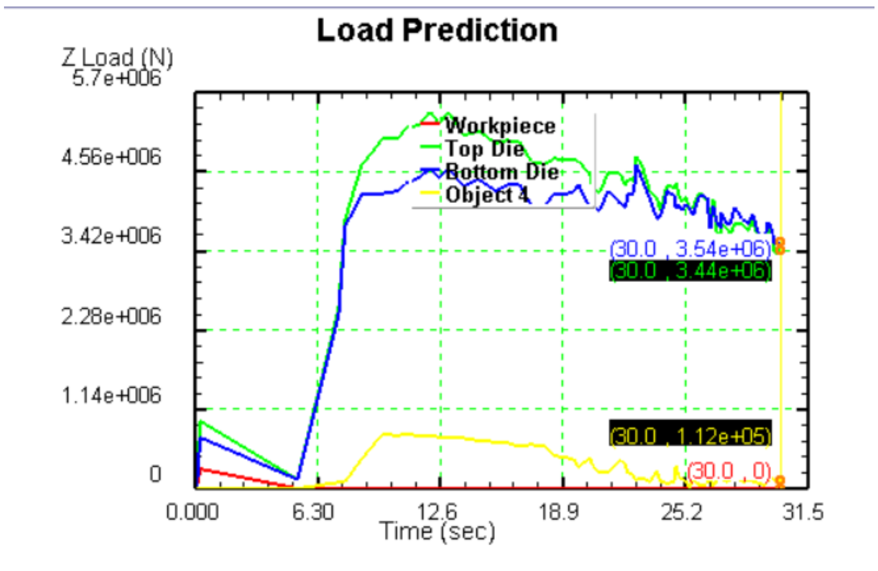


Figure 3.4: Load Prediction of the Parts

3.1.4 – Velocity

The velocity of the billet has set as a 10 mm/s but at the tip of the billet the velocity value expected to be higher. And for this purpose, a node selected from tip of the billet and velocity analysis has started. After 30 second later final speed of the tip of billet calculated as 10.504 mm/s along z axis. Which is quite expected. And speed values at every axis can be seen in the following figure.

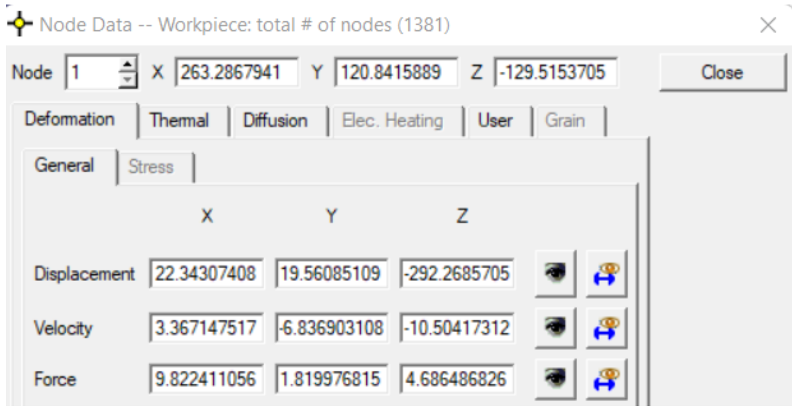


Figure 3.5: Velocity and Displacement values at the Tip of the Billet

And the effect of velocity can be seen in the following figure.

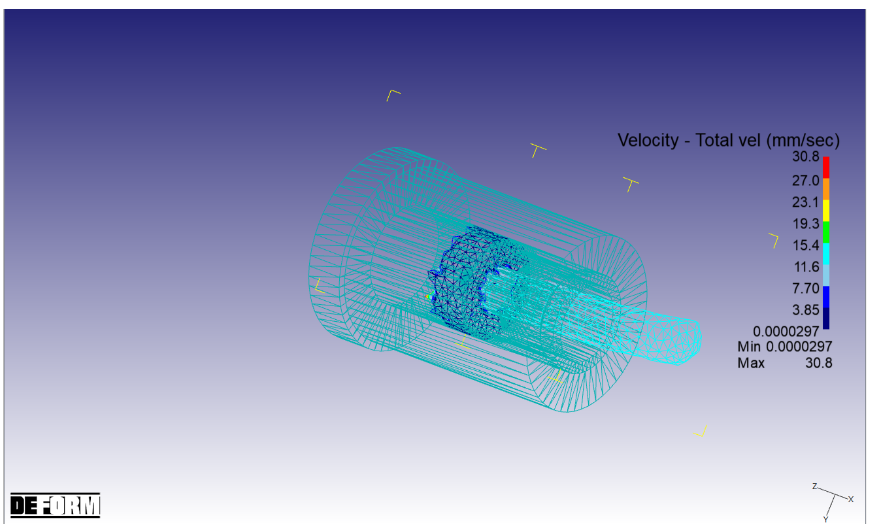


Figure 3.6: Velocity Values

3.1.5 – Displacement

Also, the displacement at the tip of the billet can be shown in the **figure 3.5.** At the tip of the billet displacement amount moves to 304 mm.

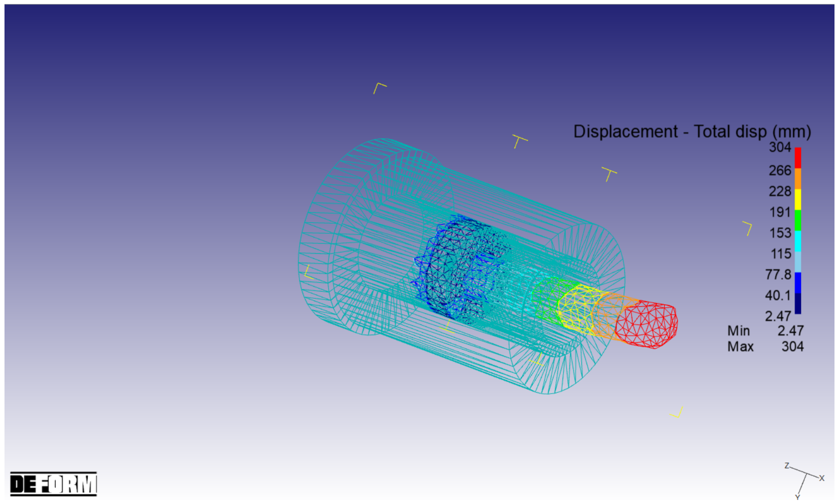


Figure 3.7: Displacement of the Billet

Also Strain, stress diagram and energy graph will be given in the appendix section.

3.2 – 60 mm Diameter and 10 mm/s Speed

In order to convenience all the process that mentioned in section 3.1 applied to this part. The main differences between are the program duration. In this case program duration has set as 15 second. And also speed value has changed to 10 mm/s. Other steps that mentioned that mentioned in section 3.1 apply on this step.

After all the changed made simulation process started using Deform 2D/3D program. And all the results saved.

3.2.1 – Visual Result of the Extrusion

As can be seen in the figure during the simulation process extrusion continued. After 15 seconds later simulation completed. And result visually checked. And no anomaly founded. Extrusion completed properly. The main problem with the extrusion is the when the extrusion process moves the tip of the billet moves outwards. The reason this unwanted error will be analyzed in the following section. See Figure 3.8 in order to see final visual result.

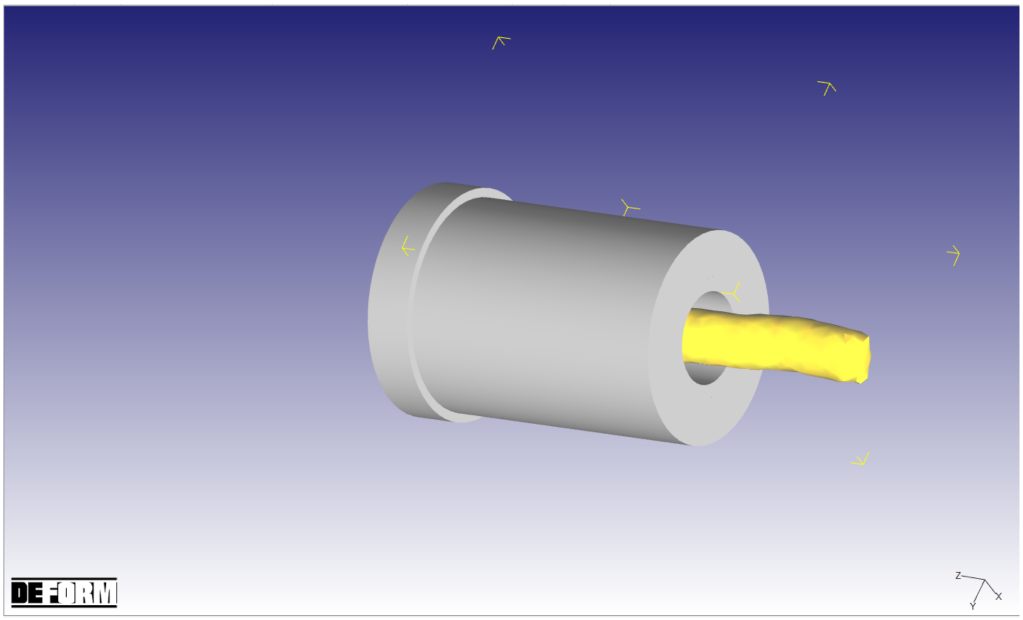


Figure 3.8: Result of the Simulation

3.2.2 - Angular velocity

As can be seen in the graph, during the simulation process the angular velocity of the billet has constant value of 100 RPM which is equal to 10.471 rad/s. The main reason behind the constant angular velocity during all the simulation process is to be seeing the effect of speed and extrude diameter during the constant angular velocity condition. See the **Figure 3.9**

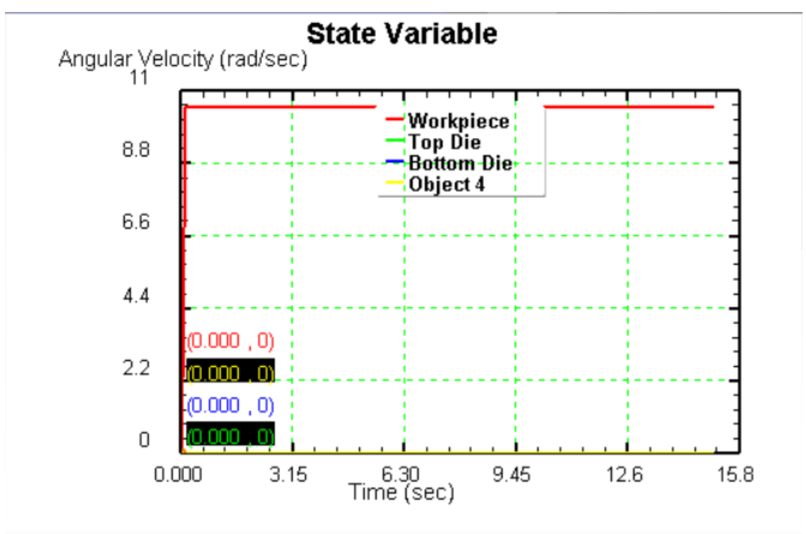


Figure 3.9: Angular Velocity

3.2.3 – Load Prediction

For load prediction 3 part of the die considered. Those parts are rotor, placer and shaper. The load on the billet has not consider. The graph of the load prediction can be seen in the **Figure 3.10**. As can be seen in the figure the loads on the element increased immediately after the program started. Then after this point the loads on the parts have been increased up to $5.76x10^6\ N$ then extrusion continues the load on the parts decreased slightly as can be seen in the figure. After 15 second later which is the last second of the extrusion the loads on the parts have decreased $3.28x10^6\ N$ for same element that the highest load measured which is rotor. So, in 15 second load on the rotor has decreased 43%. Also, the load on the shaper has measured as $4.94x10^6\ N$ as highest load on the shaper. Again in 30 second the load on the shaper has decreased but not as much as in the rotor. In shaper's case the load decreased to $3.37x10^6\ N$ so in this case there was 32% decrease in the load. And for placer there was no load at first place after the cavity filled the load on the placer has increased up to $9.14x10^5\ N$.Then as the simulation process continues the load on the placer decreased up to $0.552x10^5\ N$. This also expected because when the simulation continues the pressure on the placer will be decreased and upper points of the shaper will not have load.

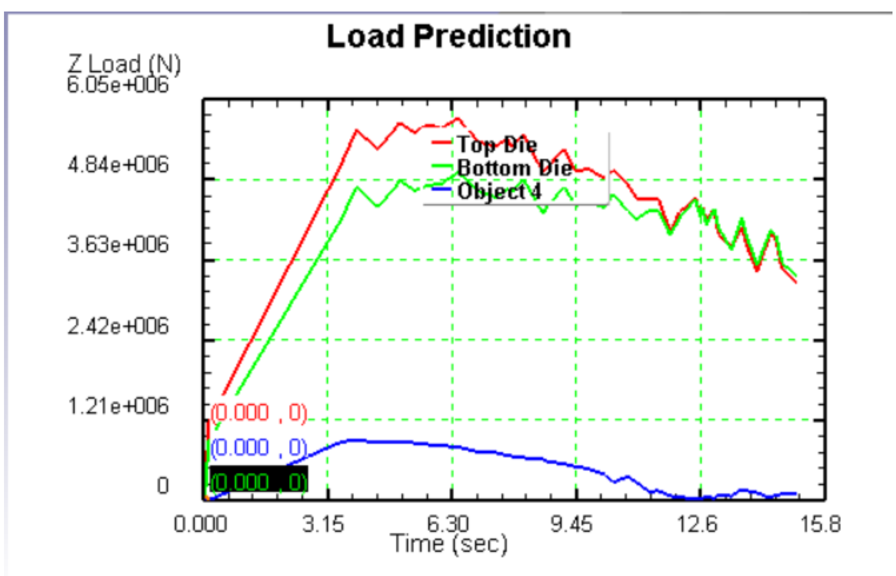


Figure 3.10: Load Prediction Graph

3.2.4 – Velocity

The velocity of the billet has set as a 10 mm/s but at the tip of the billet the velocity value expected to be higher. And for this purpose, a node selected from tip of the billet and velocity analysis has started. After 15 second later final speed of the tip of billet calculated as 22.4 mm/s along z axis. Which is quite expected. And speed values at every axis can be seen in the following figure.

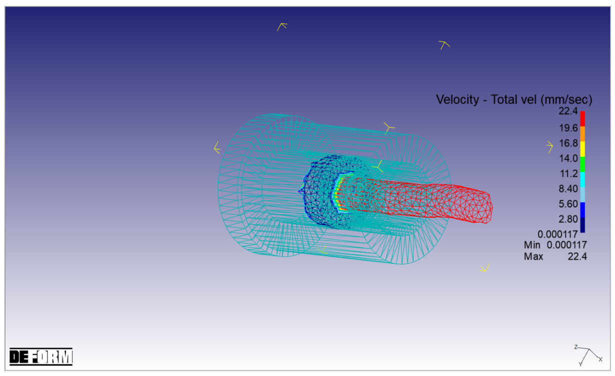


Figure 3.11: Velocity of the billet

3.2.5 – Displacement

Also, the displacement at the tip of the billet can be shown in the **figure 3.12.** At the tip of the billet displacement amount moves to 328 mm.

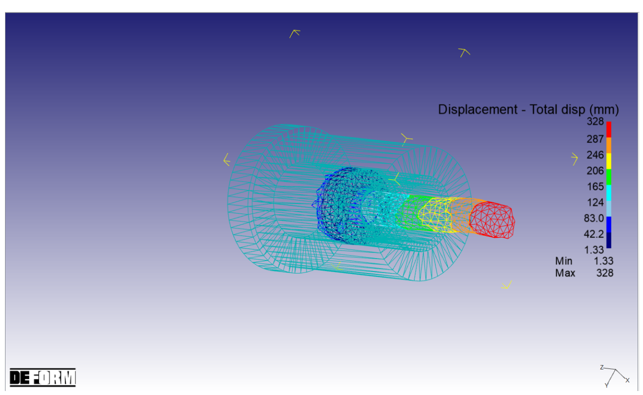


Figure 3.12: Displacement of the billet

Also Strain, stress diagram and energy graph will be given in the appendix section.

3.3– 60 mm Diameter and 15 mm/s Speed

In order to convenience all the process that mentioned in section 3.1 applied to this part. The main differences between are the program duration. In this case program duration has set as 10 second. And also speed value has changed to 15 mm/s. Other steps that mentioned that mentioned in section 3.1 apply on this step.

After all the changed made simulation process started using Deform 2D/3D program. And all the results saved.

3.3.1 – Visual Result of the Extrusion

As can be seen in the figure during the simulation process extrusion continued. After 10 seconds later simulation completed. And result visually checked. And no anomaly founded. Extrusion completed properly. The main problem with the extrusion is the when the extrusion process moves the tip of the billet moves outwards. The reason this unwanted error will be analyzed in the following section. See Figure 3.13 in order to see final visual result.

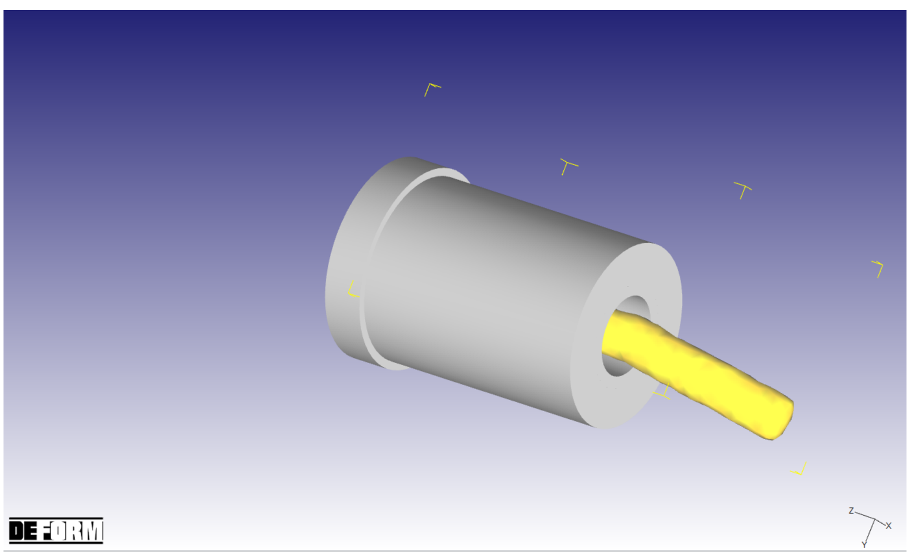


Figure 3.13: The Result of Simulation

3.3.2 - Angular velocity

As can be seen in the graph, during the simulation process the angular velocity of the billet has constant value of 100 RPM which is equal to 10.471 rad/s. The main reason behind the constant angular velocity during all the simulation process is to be seeing the effect of speed and extrude diameter during the constant angular velocity condition. See the **Figure 3.14.**

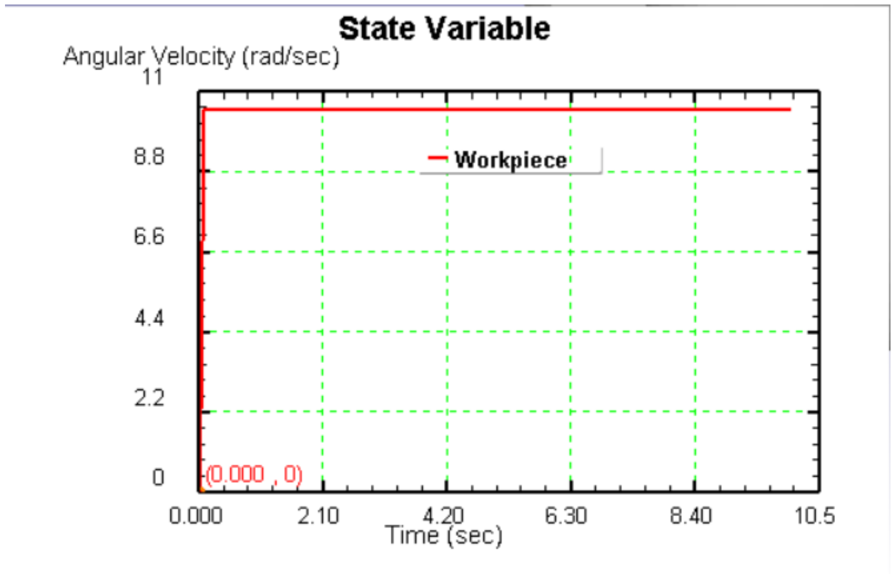


Figure 3.14: Angular Velocity Values for Billet

3.3.3 – Load Prediction

For load prediction 3 part of the die considered. Those parts are rotor, placer and shaper. The load on the billet has not consider. The graph of the load prediction can be seen in the **Figure 3.15**. As can be seen in the figure the loads on the element increased immediately after the program started. Then after this point the loads on the parts have been increased up to $5.93x10^6\ N$ then extrusion continues the load on the parts decreased slightly as can be seen in the figure. After 10 second later which is the last second of the extrusion the loads on the parts have decreased $3.47x10^6\ N$ for same element that the highest load measured which is rotor. So, in 24 second load on the rotor has decreased 42%. Also, the load on the shaper has measured as $5.14x10^6\ N$ as highest load on the shaper. Again in 30 second the load on the shaper has decreased but not as much as in the rotor. In shaper's case the load decreased to $3.60x10^6\ N$ so in this case there was 30% decrease in the load. And for placer there was no load at first place after the cavity filled the load on the placer has increased up to $1x10^6\ N$.Then as the simulation process continues the load on the placer decreased up to

$0.369x10^5$ N. This also expected because when the simulation continues the pressure on the placer will be decreased and upper points of the shaper will not have load.

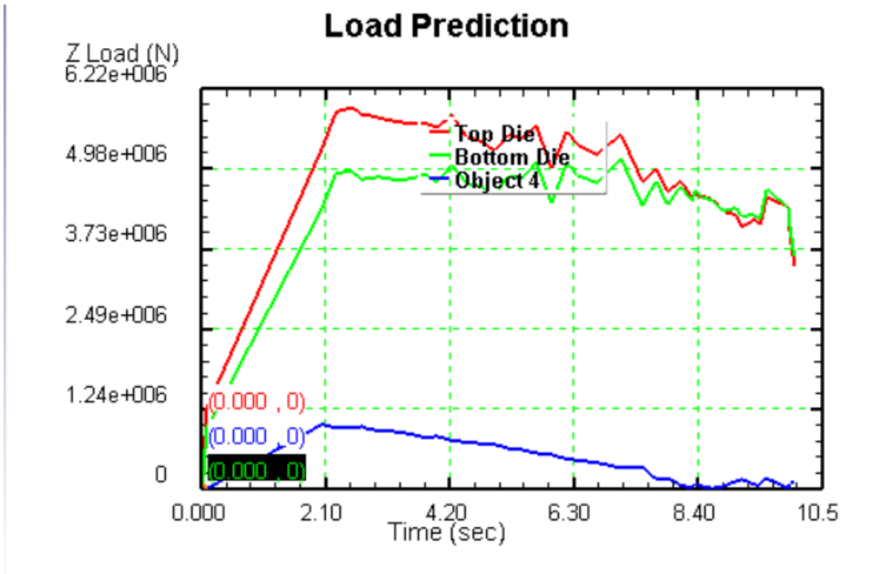


Figure 3.15: Load Prediction for Die Elements

3.3.4 – Velocity

The velocity of the billet has set as a 15 mm/s but at the tip of the billet the velocity value expected to be higher. And for this purpose, a node selected from tip of the billet and velocity analysis has started. After 10 second later final speed of the tip of billet calculated as 45.7 mm/s along z axis. Which is quite expected. And speed values at every axis can be seen in the following figure.

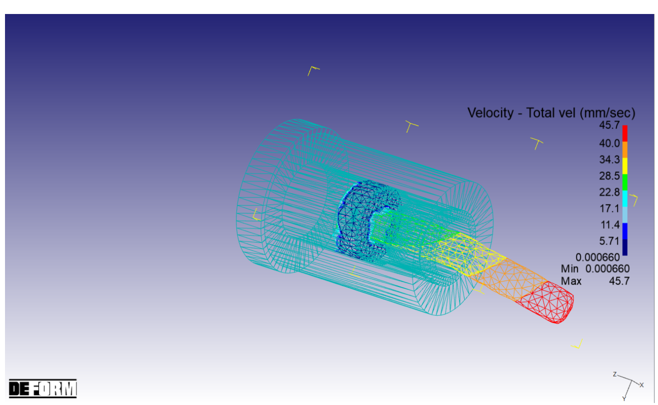


Figure 0.16: Velocity of the Billet

3.3.5 – Displacement

Also, the displacement at the tip of the billet can be shown in the **figure 3.17.** At the tip of the billet displacement amount moves to 373 mm.

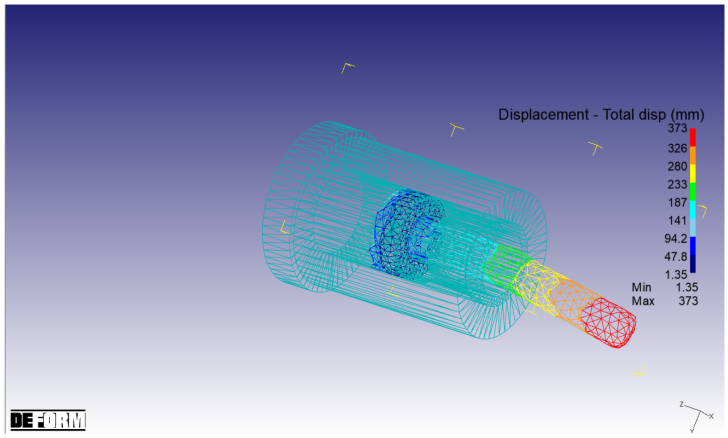


Figure 3.17: Displacement of the Billet

Also Strain, stress diagram and energy graph will be given in the appendix section.

3.4 – 80 mm Diameter and 5 mm/s Speed

Firstly, as mentioned before, a 80 mm shaper has called. And system assembled. Then all the steps that are mentioned in section 2.3 are applied on the system. Then, 200 mm billet has called, and 32000 mash nodes has generated, and movement value has set for billet. Those movement values are rotation and translation. For rotation 100 RPM angular speed has set along z axis. And for translation 5 mm/s has set along -z axis. Then connection nodes selected, and tolerance values has set as 0.162. Then simulation duration determined for 30 seconds. The reason behind the selection of 30 second is the rotor has to move 150 mm to complete extrusion process. Therefore 30 second input for duration was the right. Then Simulation database generated, and simulation started.

When simulation started process whole process monitored using simulation graphics that provided by Deform 2D/3D program the simulation graphics can be shown below. Also, main reason of monitoring all the process is checking any possible mistake.

After program completed post processor has opened in order to checking all the necessary information. And load prediction, angular velocity, rotated angle, Surface area graphics generated using Deform 2D/3D program. Also speed value was monitored for different point on the billet. Also strain point, stress points, billet displacement and billet velocity have been saved at the middle of the program and at the end of the program.

3.4.1 – Visual Result of the Extrusion

As can be seen in the figure during the simulation process extrusion continued. After 30 seconds later simulation completed. And result visually checked. And no anomaly founded. Extrusion completed properly. The main problem with the extrusion is the when the extrusion process moves the tip of the billet moves outwards. The reason this unwanted error will be analyzed in the following section. See Figure 3.18 in order to see final visual result.

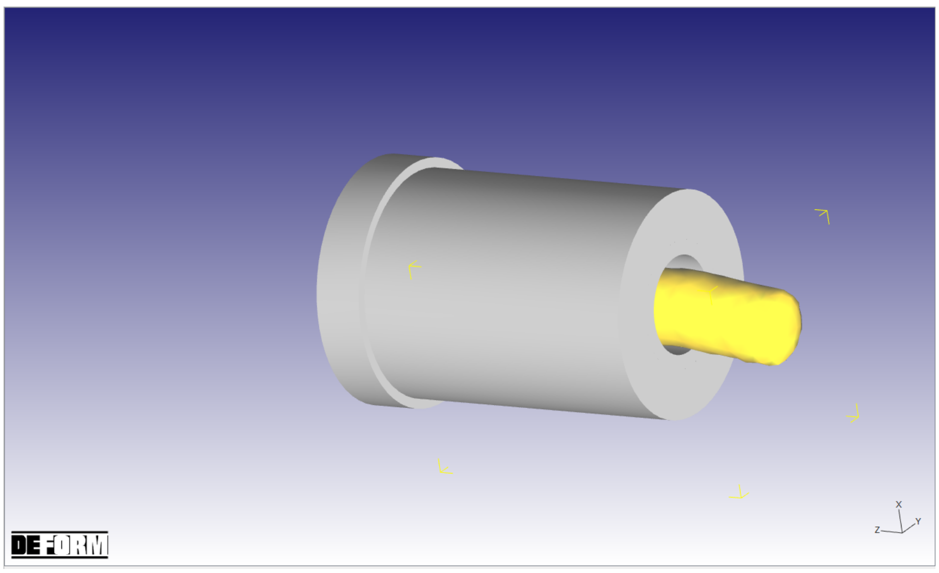


Figure 3.18: Result of the Simulation

3.4.2 - Angular velocity

As can be seen in the graph, during the simulation process the angular velocity of the billet has constant value of 100 RPM which is equal to 10.471 rad/s. The main reason behind the constant angular velocity during all the simulation process is to be seeing the effect of speed and extrude diameter during the constant angular velocity condition. See the **Figure 3.19.**

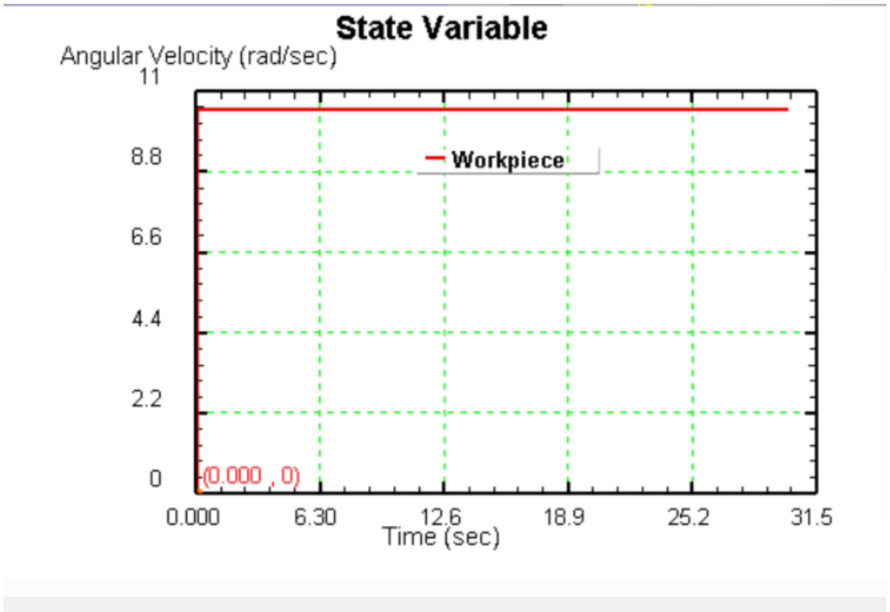


Figure 3.19: Angular Velocity Value

3.4.3 – Load Prediction

For load prediction 3 part of the die considered. Those parts are rotor, placer and shaper. The load on the billet has not consider. The graph of the load prediction can be seen in the **Figure 3.20**. As can be seen in the figure the loads on the element increased immediately after the program started. Then after this point the loads on the parts have been increased up to $4.23x10^6\ N$ then extrusion continues the load on the parts decreased slightly as can be seen in the figure. After 10 second later which is the last second of the extrusion the loads on the parts have decreased $2.51x10^6\ N$ for same element that the highest load measured which is rotor. So, in 24 second load on the rotor has decreased 41%. Also, the load on the shaper has measured as $3.42x10^6\ N$ as highest load on the shaper. Again in 30 second the load on the shaper has decreased but not as much as in the rotor. In shaper's case the load decreased to $2.55x10^6\ N$ so in this case there was 26% decrease in the load. And for placer there was no load at first place after the cavity filled the load on the placer has increased up to $0.837x10^6\ N$.Then as the simulation process continues the load on the placer decreased up to $5.51x10^3\ N$. This also expected because when the simulation continues the pressure on the placer will be decreased and upper points of the shaper will not have load.

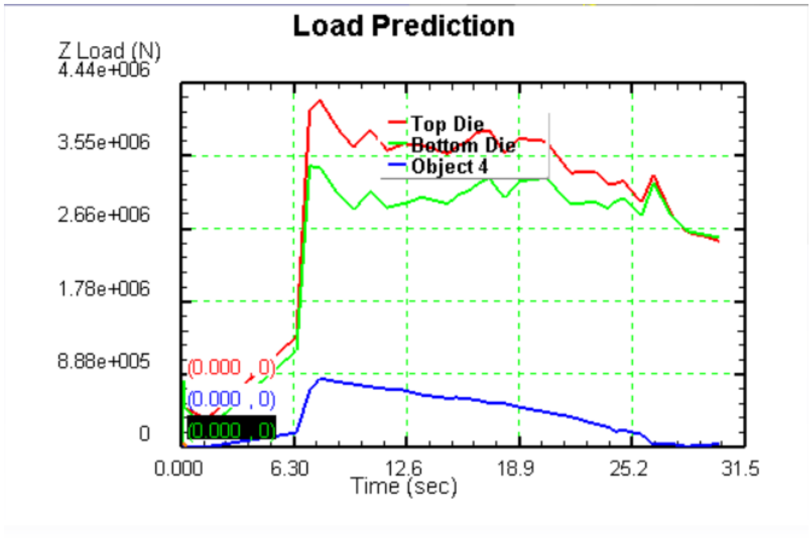


Figure 3.20: Load Prediction of the Billet

3.4.4 – Velocity

The velocity of the billet has set as a 5 mm/s but at the tip of the billet the velocity value expected to be higher. And for this purpose, a node selected from tip of the billet and velocity analysis has started. After 30 second later final speed of the tip of billet calculated as 8.74 mm/s along z axis. Which is quite expected. And speed values at every axis can be seen in the following figure.

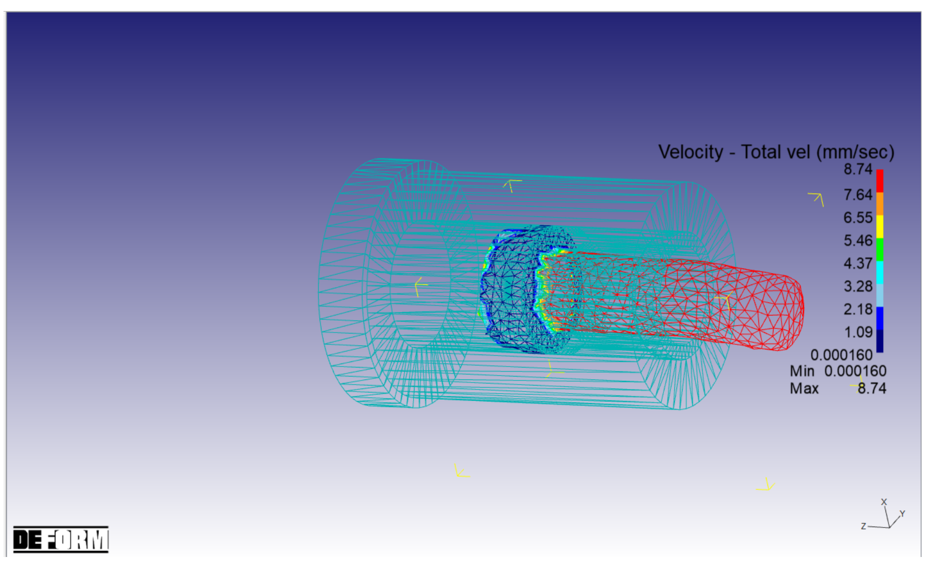


Figure 3.21: Velocity values of the Billet

3.4.5 – Displacement

Also, the displacement at the tip of the billet can be shown in the **figure 3.22.** At the tip of the billet displacement amount moves to 269 mm.

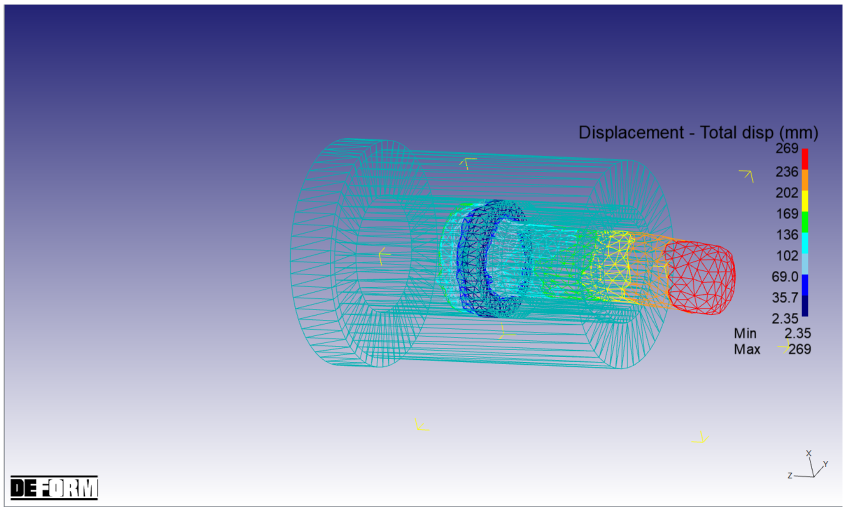


Figure 3.22: Displacement values of the Billet

Also Strain, stress diagram and energy graph will be given in the appendix section.

3.5 – 80 mm Diameter and 10 mm/s Speed

In order to convenience all the process that mentioned in section 3.1 applied to this part. The main differences between are the program duration. In this case program duration has set as 15 second. And also speed value has changed to 10 mm/s. Other steps that mentioned that mentioned in section 3.1 apply on this step.

After all the changed made simulation process started using Deform 2D/3D program. And all the results saved.

3.5.1 – Visual Result of the Extrusion

As can be seen in the figure during the simulation process extrusion continued. After 15 seconds later simulation completed. And result visually checked. And no anomaly founded. Extrusion completed properly. The main problem with the extrusion is the when the extrusion process moves the tip of the billet moves outwards. The reason this unwanted error will be analyzed in the following section. See Figure 3.8 in order to see final visual result.

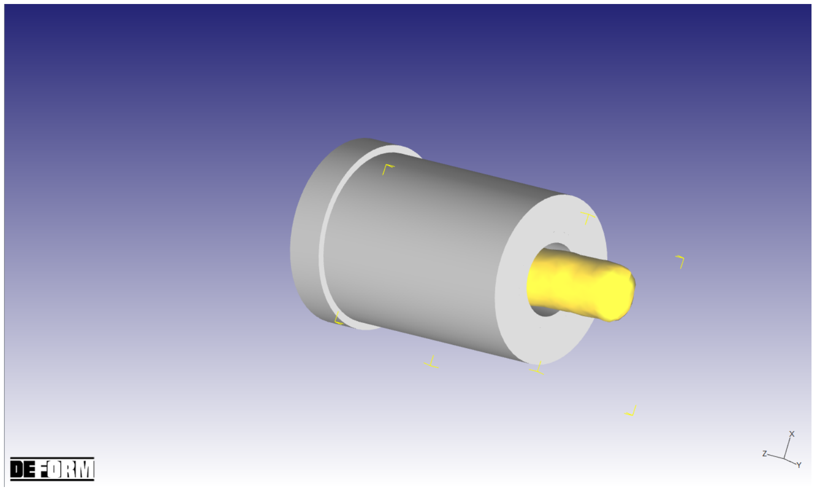


Figure 3.23: Result of the Simulation

3.5.2 - Angular velocity

As can be seen in the graph, during the simulation process the angular velocity of the billet has constant value of 100 RPM which is equal to 10.471 rad/s. The main reason behind the constant angular velocity during all the simulation process is to be seeing the effect of speed and extrude diameter during the constant angular velocity condition. See the **Figure 3.24.**

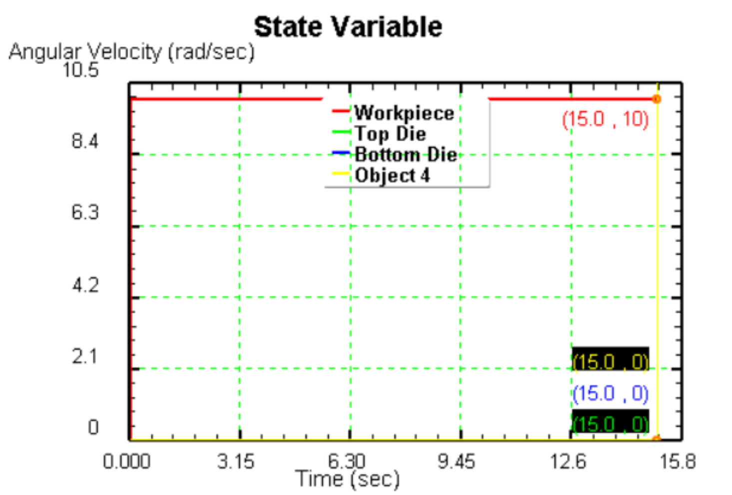


Figure 3.24: Angular velocity values of the billet

3.5.3 – Load Prediction

For load prediction 3 part of the die considered. Those parts are rotor, placer and shaper. The load on the billet has not consider. The graph of the load prediction can be seen in the **Figure**

3.25. As can be seen in the figure the loads on the element increased immediately after the program started. Then after this point the loads on the parts have been increased up to $4.32x10^6$ N then extrusion continues the load on the parts decreased slightly as can be seen in the figure. After 10 second later which is the last second of the extrusion the loads on the parts have decreased $3.01x10^6$ N for same element that the highest load measured which is rotor. So, in 10 second load on the rotor has decreased 31%. Also, the load on the shaper has measured as $3.45x10^6$ N as highest load on the shaper. Again in 10 second the load on the shaper has decreased but not as much as in the rotor. In shaper's case the load decreased to $3.03x10^6$ N so in this case there was 13% decrease in the load. And for placer there was no load at first place after the cavity filled the load on the placer has increased up to $0.975x10^6$ N.Then as the simulation process continues the load on the placer decreased up to $0.213x10^5$ N. This also expected because when the simulation continues the pressure on the placer will be decreased and upper points of the shaper will not have load.

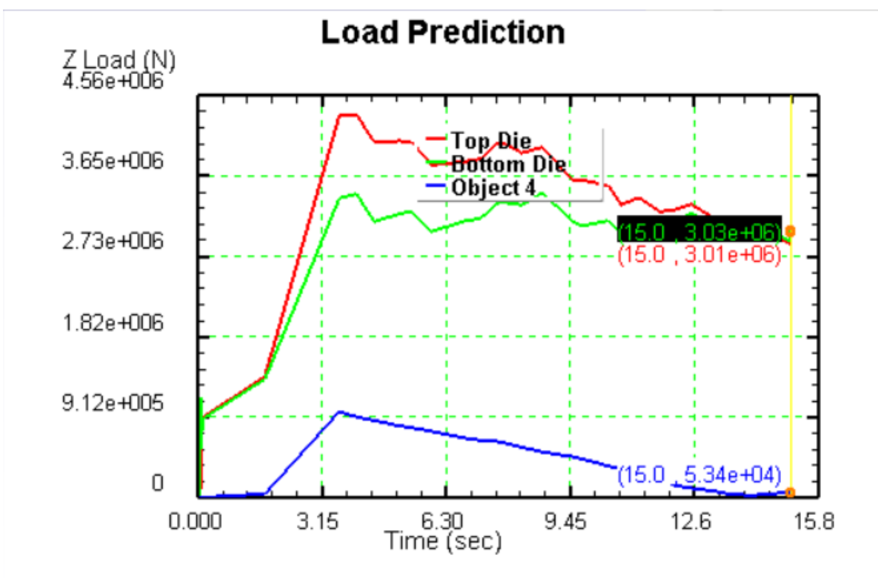


Figure 3.25: Load Prediction of the billet

3.5.4 – Velocity

The velocity of the billet has set as a 10 mm/s but at the tip of the billet the velocity value expected to be higher. And for this purpose, a node selected from tip of the billet and velocity analysis has started. After 15 second later final speed of the tip of billet calculated as 23.3 mm/s along z axis. Which is quite expected. And speed values at every axis can be seen in the following figure.

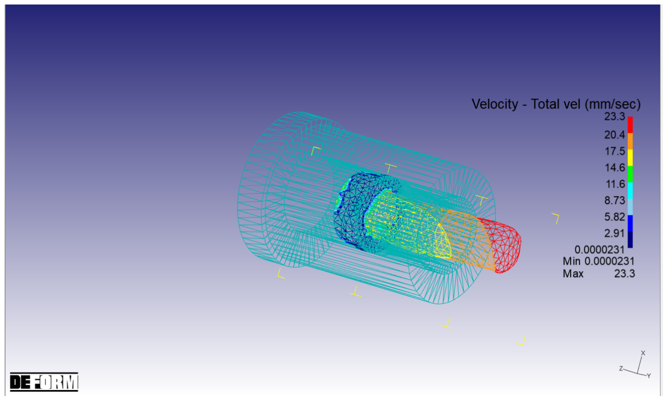


Figure 3.26: Velocity Values of the Billet

3.5.5 – Displacement

Also, the displacement at the tip of the billet can be shown in the **figure 3.27.** At the tip of the billet displacement amount moves to 273 mm.

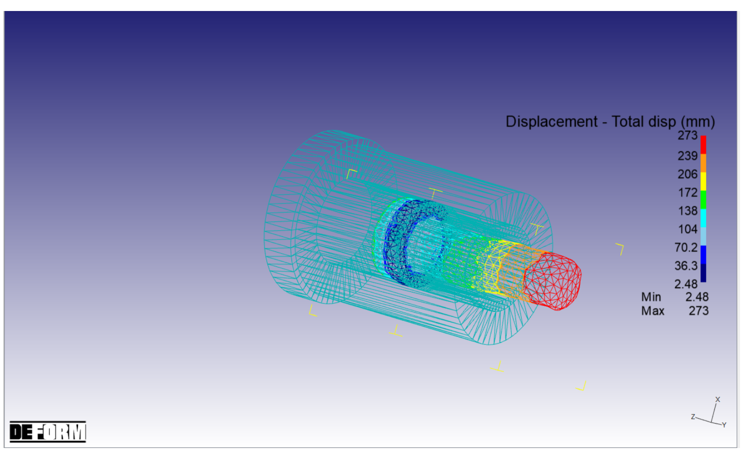


Figure 3.27: Displacement Values of the Billet

Also Strain, stress diagram and energy graph will be given in the appendix section.

3.6 – 80 mm Diameter and 15 mm/s Speed

In order to convenience all the process that mentioned in section 3.1 applied to this part. The main differences between are the program duration. In this case program duration has set as

10 second. And also speed value has changed to 15 mm/s. Other steps that mentioned that mentioned in section 3.1 apply on this step.

After all the changed made simulation process started using Deform 2D/3D program. And all the results saved.

3.6.1 – Visual Result of the Extrusion

As can be seen in the figure during the simulation process extrusion continued. After 30 seconds later simulation completed. And result visually checked. And no anomaly founded. Extrusion completed properly. The main problem with the extrusion is the when the extrusion process moves the tip of the billet moves outwards. The reason this unwanted error will be analyzed in the following section. See Figure 3.28 in order to see final visual result.

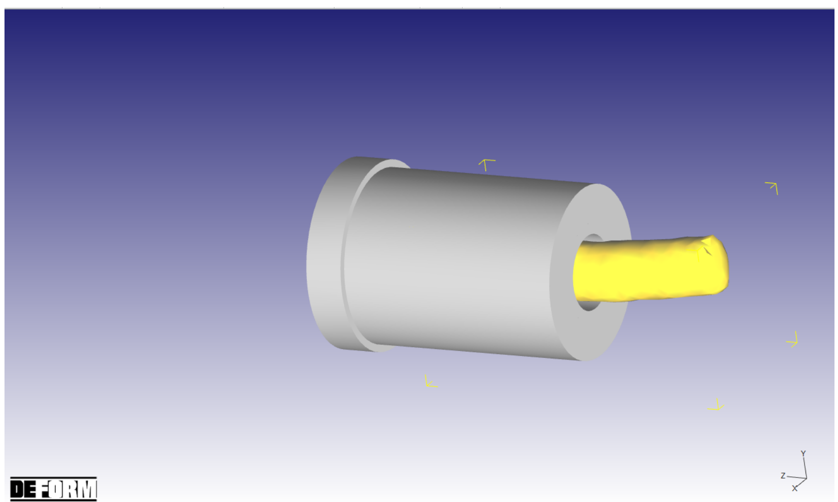


Figure 3.28: Result of the Simulation

3.6.2 - Angular velocity

As can be seen in the graph, during the simulation process the angular velocity of the billet has constant value of 100 RPM which is equal to 10.471 rad/s. The main reason behind the constant angular velocity during all the simulation process is to be seeing the effect of speed and extrude diameter during the constant angular velocity condition. See the **Figure 3.29.**

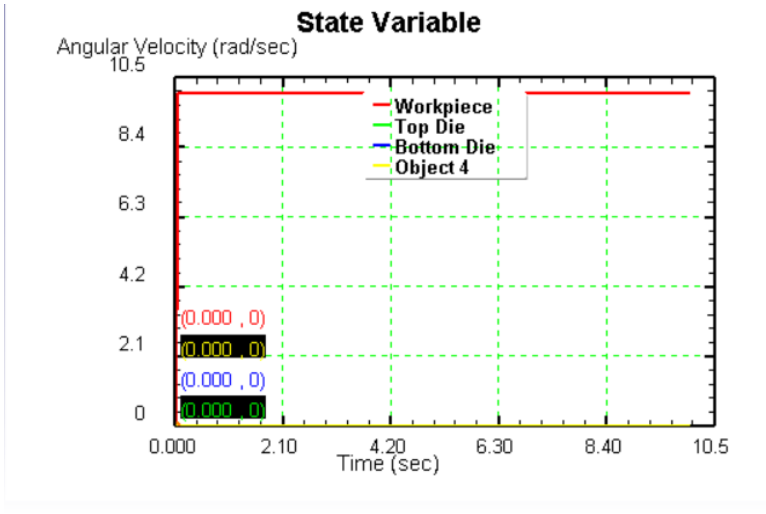


Figure 3.29: Angular Velocity of the Billet

3.6.3 – Load Prediction

For load prediction 3 part of the die considered. Those parts are rotor, placer and shaper. The load on the billet has not consider. The graph of the load prediction can be seen in the **Figure 3.30.** As can be seen in the figure the loads on the element increased immediately after the program started. Then after this point the loads on the parts have been increased up to $4.57x10^6\ N$ then extrusion continues the load on the parts decreased slightly as can be seen in the figure. After 10 second later which is the last second of the extrusion the loads on the parts have decreased $3.47x10^6\ N$ for same element that the highest load measured which is rotor. So, in 10 second load on the rotor has decreased 26%. Also, the load on the shaper has measured as $3.67x10^6\ N$ as highest load on the shaper. Again in 10 second the load on the shaper has decreased but not as much as in the rotor. In shaper's case the load decreased to $3.56x10^6\ N$ so in this case there was 3% decrease in the load. And for placer there was no load at first place after the cavity filled the load on the placer has increased up to $0.971x10^6\ N$.Then as the simulation process continues the load on the placer decreased up to $1.07x10^3\ N$. This also expected because when the simulation continues the pressure on the placer will be decreased and upper points of the shaper will not have load.

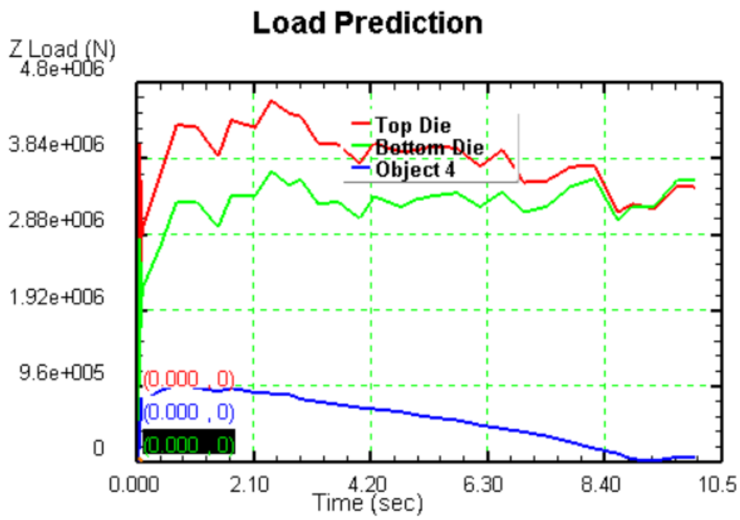


Figure 3.30: Load Prediction of The Die

3.6.4 – Velocity

The velocity of the billet has set as a 15 mm/s but at the tip of the billet the velocity value expected to be higher. And for this purpose, a node selected from tip of the billet and velocity analysis has started. After 10 second later final speed of the tip of billet calculated as 29.4 mm/s along z axis. Which is quite expected. And speed values at every axis can be seen in the following figure.

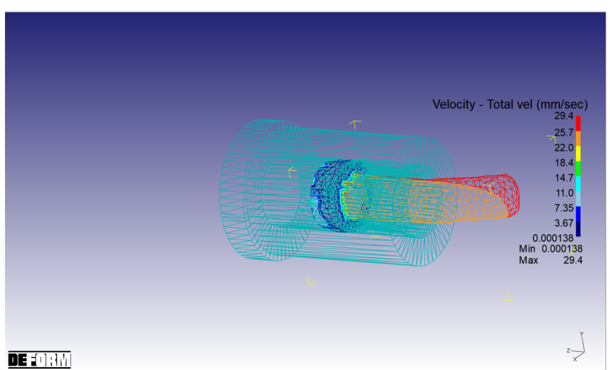


Figure 3.31: Velocity Values of the Billet

3.6.5 – Displacement

Also, the displacement at the tip of the billet can be shown in the **figure 3.32.** At the tip of the billet displacement amount moves to 336 mm.

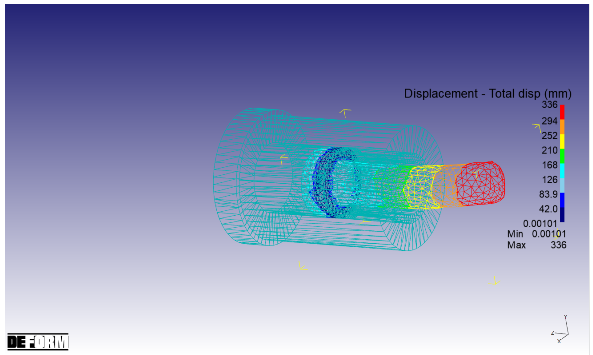


Figure 3.32: Displacement Values for Billet

Also Strain, stress diagram and energy graph will be given in the appendix section.

3.7 – 40 mm Diameter and 5 mm/s Speed

Firstly, as mentioned before, a 40 mm shaper has called. And system assembled. Then all the steps that are mentioned in section 2.3 are applied on the system. Then, 200 mm billet has called, and 32000 mash nodes has generated, and movement value has set for billet. Those movement values are rotation and translation. For rotation 100 RPM angular speed has set along z axis. And for translation 5 mm/s has set along -z axis. Then connection nodes selected, and tolerance values has set as 0.162. Then simulation duration determined for 30 seconds. The reason behind the selection of 30 second is the rotor has to move 150 mm to complete extrusion process. Therefore 30 second input for duration was the right. Then Simulation database generated, and simulation started.

When simulation started process whole process monitored using simulation graphics that provided by Deform 2D/3D program the simulation graphics can be shown below. Also, main reason of monitoring all the process is checking any possible mistake.

After program completed post processor has opened in order to checking all the necessary information. And load prediction, angular velocity, rotated angle, Surface area graphics generated using Deform 2D/3D program. Also speed value was monitored for different point on the billet. Also strain point, stress points, billet displacement and billet velocity have been saved at the middle of the program and at the end of the program.

3.7.1 – Visual Result of the Extrusion

As can be seen in the figure during the simulation process extrusion continued. After 30 seconds later simulation completed. And result visually checked. And no anomaly founded. Extrusion completed properly. The main problem with the extrusion is the when the extrusion process moves the tip of the billet moves outwards. The reason this unwanted error will be analyzed in the following section. See Figure 3.33 in order to see final visual result.

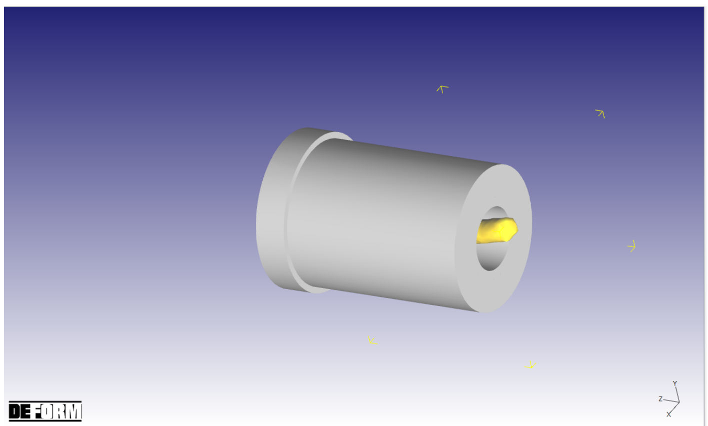


Figure 3.33: Result of the simulation

3.7.2 - Angular velocity

As can be seen in the graph, during the simulation process the angular velocity of the billet has constant value of 100 RPM which is equal to 10.471 rad/s. The main reason behind the constant angular velocity during all the simulation process is to be seeing the effect of speed and extrude diameter during the constant angular velocity condition. See the **Figure 3.34.**

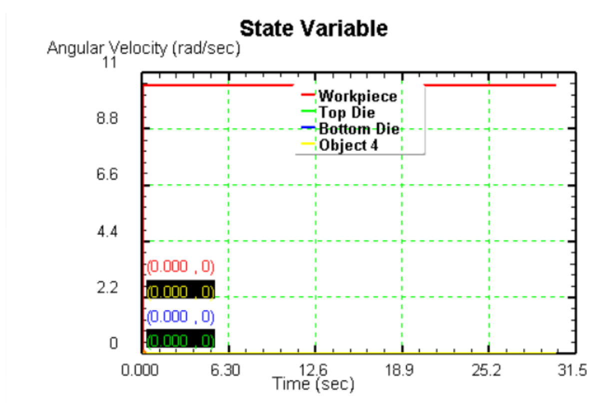


Figure 3.34: Angular velocity of the Billet

3.7.3 – Load Prediction

For load prediction 3 part of the die considered. Those parts are rotor, placer and shaper. The load on the billet has not consider. The graph of the load prediction can be seen in the **Figure 3.35**. As can be seen in the figure the loads on the element increased immediately after the program started. Then after this point the loads on the parts have been increased up to $5.95x10^6\ N$ then extrusion continues the load on the parts decreased slightly as can be seen in the figure. After 30 second later which is the last second of the extrusion the loads on the parts have decreased $4.17x10^6\ N$ for same element that the highest load measured which is rotor. So, in 30 second load on the rotor has decreased 30%. Also, the load on the shaper has measured as $5.39x10^6\ N$ as highest load on the shaper. Again in 30 second the load on the shaper has decreased but not as much as in the rotor. In shaper's case the load decreased to $4.56x10^6\ N$ so in this case there was 16% decrease in the load. And for placer there was no load at first place after the cavity filled the load on the placer has increased up to $0.667x10^6\ N$.Then as the simulation process continues the load on the placer decreased up to $2.19x10^4\ N$. This also expected because when the simulation continues the pressure on the placer will be decreased and upper points of the shaper will not have load.

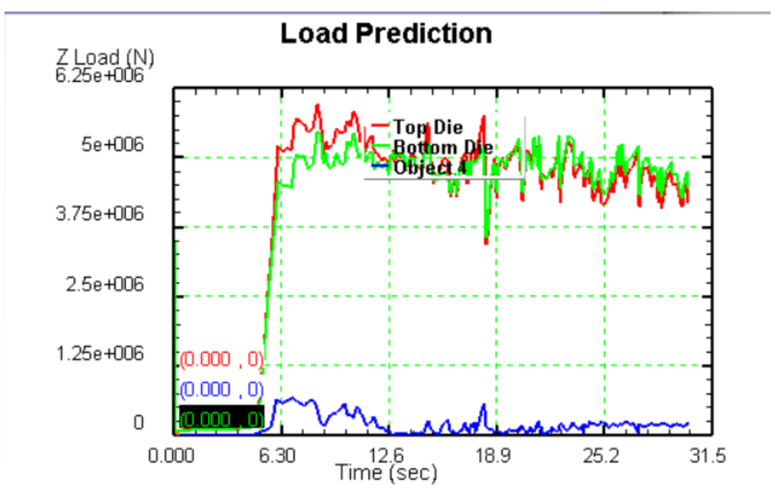


Figure 3.35: Load Prediction of the Die

3.7.4 – Velocity

The velocity of the billet has set as a 5 mm/s but at the tip of the billet the velocity value expected to be higher. And for this purpose, a node selected from tip of the billet and velocity analysis has started. After 30 second later final speed of the tip of billet calculated as 16.84 mm/s along z axis. Which is quite expected. And speed values at every axis can be seen in the following figure.

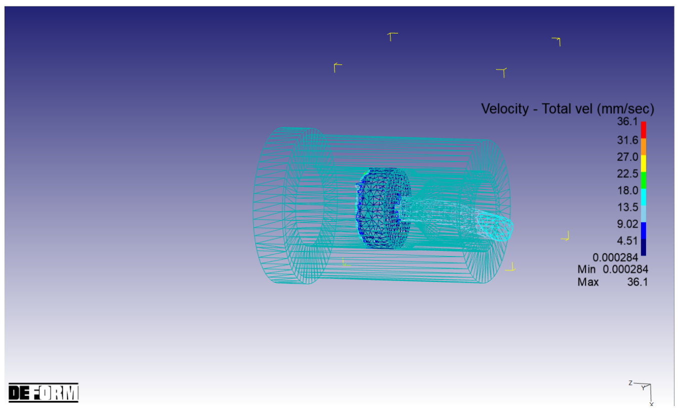


Figure 3.36: velocity value of the billet

3.7.5 – Displacement

Also, the displacement at the tip of the billet can be shown in the **figure 3.37.** At the tip of the billet displacement amount moves to 213 mm.

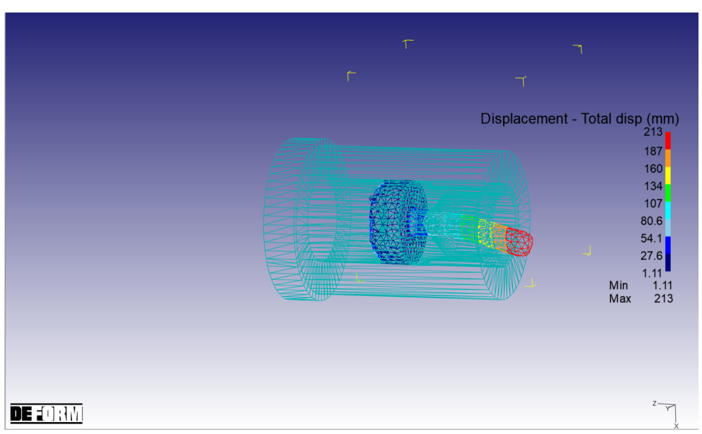


Figure 3.37: Displacement Values of the Billet

Also Strain, stress diagram and energy graph will be given in the appendix section.

3.8 – 40 mm Diameter and 10 mm/s Speed

In order to convenience all the process that mentioned in section 3.1 applied to this part. The main differences between are the program duration. In this case program duration has set as 15 second. And also speed value has changed to 10 mm/s. Other steps that mentioned that mentioned in section 3.1 apply on this step.

After all the changed made simulation process started using Deform 2D/3D program. And all the results saved.

3.8.1 – Visual Result of the Extrusion

As can be seen in the figure during the simulation process extrusion continued. After 15 seconds later simulation completed. And result visually checked. And no anomaly founded. Extrusion completed properly. The main problem with the extrusion is the when the extrusion process moves the tip of the billet moves outwards. The reason this unwanted error will be analyzed in the following section. See Figure 3.38 in order to see final visual result.

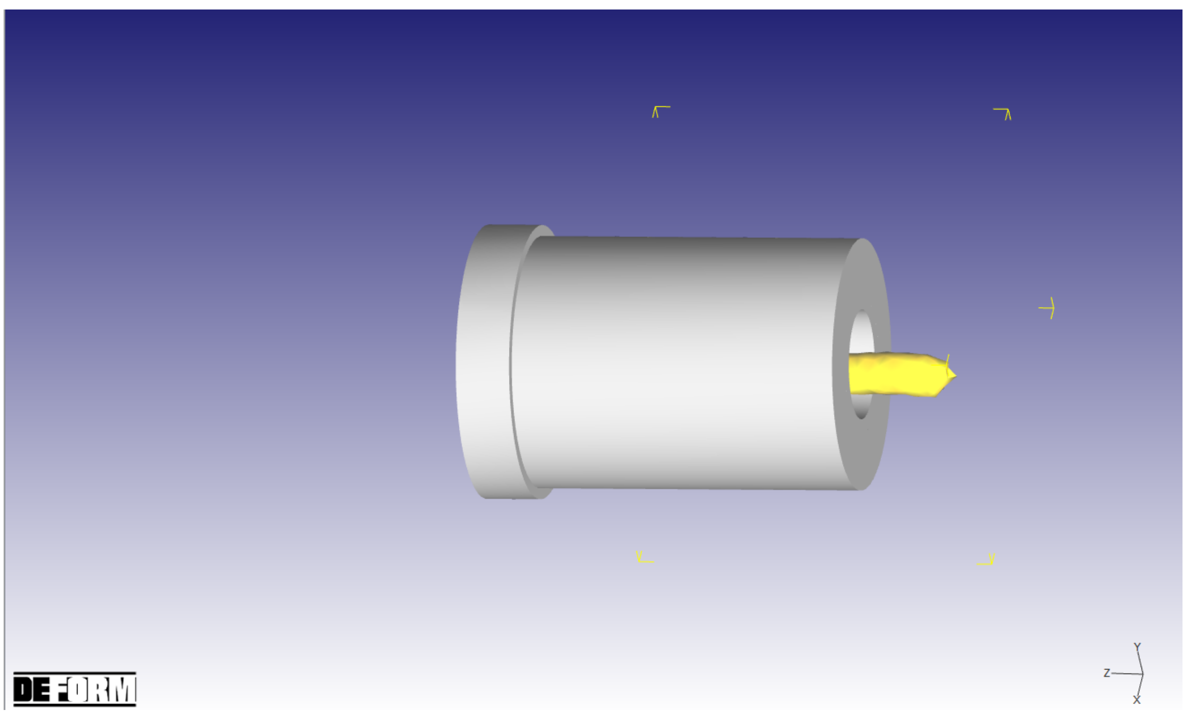


Figure 3.38: Result of the Simulation

3.8.2 - Angular velocity

As can be seen in the graph, during the simulation process the angular velocity of the billet has constant value of 100 RPM which is equal to 10.471 rad/s. The main reason behind the constant angular velocity during all the simulation process is to be seeing the effect of speed and extrude diameter during the constant angular velocity condition. See the **Figure 3.39.**

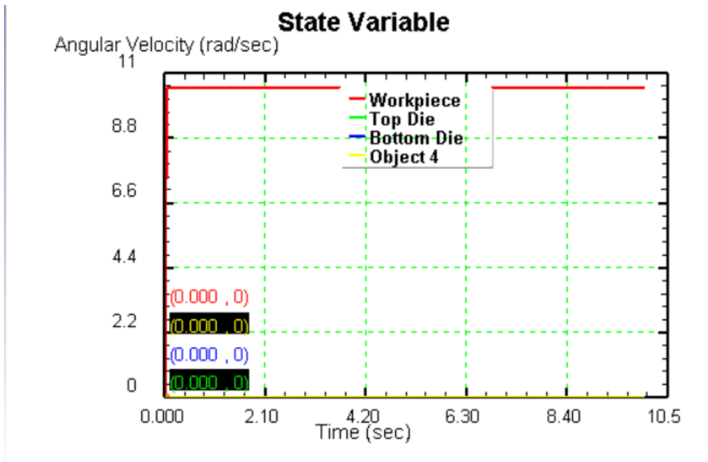


Figure 3.39: Angular velocity of the billet

3.8.3 – Load Prediction

For load prediction 3 part of the die considered. Those parts are rotor, placer and shaper. The load on the billet has not consider. The graph of the load prediction can be seen in the **Figure 3.40**. As can be seen in the figure the loads on the element increased immediately after the program started. Then after this point the loads on the parts have been increased up to $6.21x10^6\ N$ then extrusion continues the load on the parts decreased slightly as can be seen in the figure. After 15 second later which is the last second of the extrusion the loads on the parts have decreased $4.06x10^6\ N$ for same element that the highest load measured which is rotor. So, in 15 second load on the rotor has decreased 35%. Also, the load on the shaper has measured as $5.84x10^6\ N$ as highest load on the shaper. Again in 30 second the load on the shaper has decreased but not as much as in the rotor. In shaper's case the load decreased to $4.24x10^6\ N$ so in this case there was 28% decrease in the load. And for placer there was no load at first place after the cavity filled the load on the placer has increased up to

$0.836x10^6\ N$.Then as the simulation process continues the load on the placer decreased up to $0.286x10^5\ N$. This also expected because when the simulation continues the pressure on the placer will be decreased and upper points of the shaper will not have load. The reason behind the drop in the middle of the simulation is the memory failure of the system.

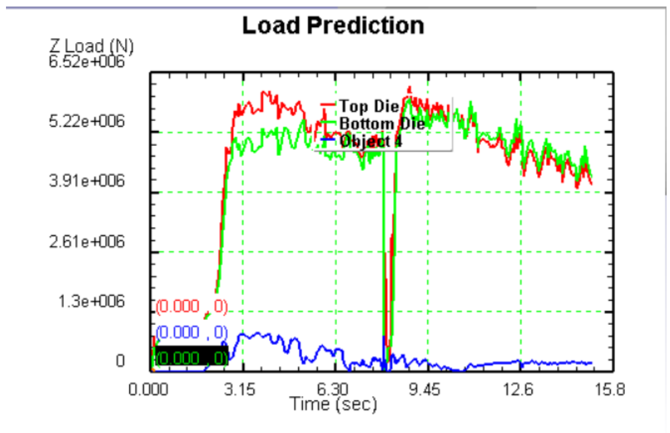


Figure 3.40: Load Prediction of the Die

3.8.4 – Velocity

The velocity of the billet has set as a 10 mm/s but at the tip of the billet the velocity value expected to be higher. And for this purpose, a node selected from tip of the billet and velocity analysis has started. After 15 second later final speed of the tip of billet calculated as 31.14 mm/s along z axis. Which is quite expected. And speed values at every axis can be seen in the following figure.

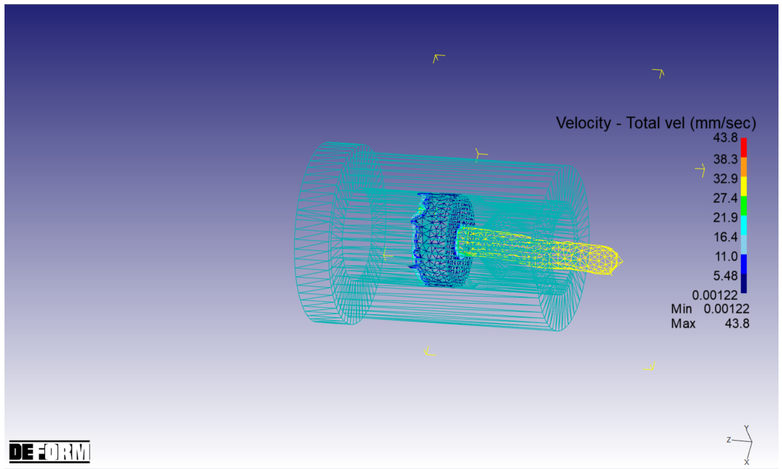


Figure 3.41: Velocity Values of the Billet

3.8.5 – Displacement

Also, the displacement at the tip of the billet can be shown in the **figure 3.5.** At the tip of the billet displacement amount moves to 233 mm.

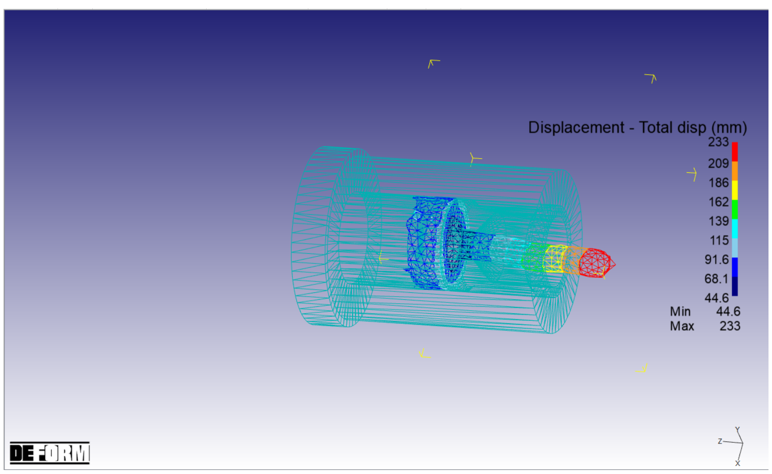


Figure 3.42: Displacement Value of the Billet

Also Strain, stress diagram and energy graph will be given in the appendix section.

3.9 – 80 mm Diameter and 15 mm/s Speed

Firstly, as mentioned before, a 80 mm shaper has called. And system assembled. Then all the steps that are mentioned in section 2.3 are applied on the system. Then, 200 mm billet has called, and 32000 mash nodes has generated, and movement value has set for billet. Those movement values are rotation and translation. For rotation 100 RPM angular speed has set along z axis. And for translation 15 mm/s has set along -z axis. Then connection nodes selected, and tolerance values has set as 0.162. Then simulation duration determined for 10 seconds. The reason behind the selection of 10 second is the rotor has to move 150 mm to complete extrusion process. Therefore 10 second input for duration was the right. Then Simulation database generated, and simulation started.

When simulation started process whole process monitored using simulation graphics that provided by Deform 2D/3D program the simulation graphics can be shown below. Also, main reason of monitoring all the process is checking any possible mistake.

After program completed post processor has opened in order to checking all the necessary information. And load prediction, angular velocity, rotated angle, Surface area graphics generated using Deform 2D/3D program. Also speed value was monitored for different point on the billet. Also strain point, stress points, billet displacement and billet velocity have been saved at the middle of the program and at the end of the program.

3.9.1 – Visual Result of the Extrusion

As can be seen in the figure during the simulation process extrusion continued. After 30 seconds later simulation completed. And result visually checked. And no anomaly founded. Extrusion completed properly. The main problem with the extrusion is the when the extrusion process moves the tip of the billet moves outwards. The reason this unwanted error will be analyzed in the following section. See **Figure 3.43** in order to see final visual result.

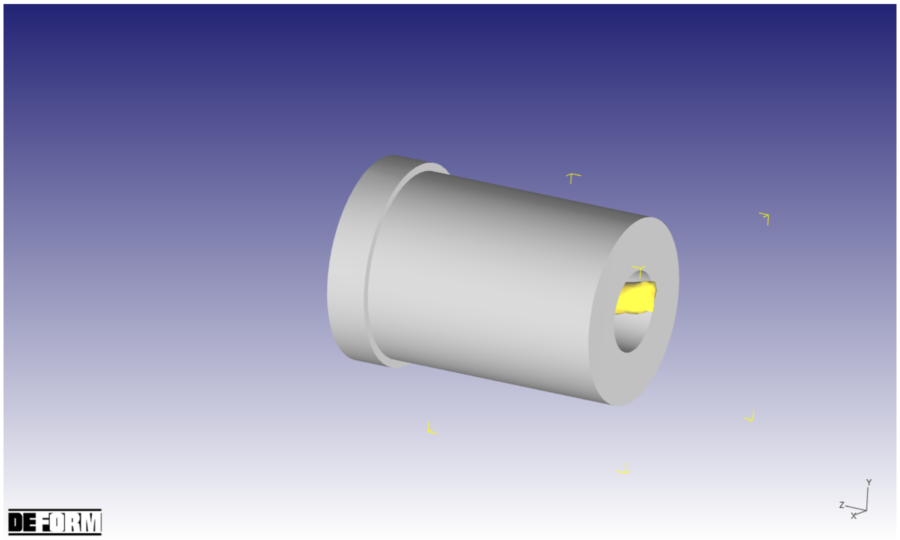


Figure 3.43: Result of the Simulation

3.9.2 - Angular velocity

As can be seen in the graph, during the simulation process the angular velocity of the billet has constant value of 100 RPM which is equal to 10.471 rad/s. The main reason behind the constant angular velocity during all the simulation process is to be seeing the effect of speed and extrude diameter during the constant angular velocity condition. See the **Figure 3.44.**

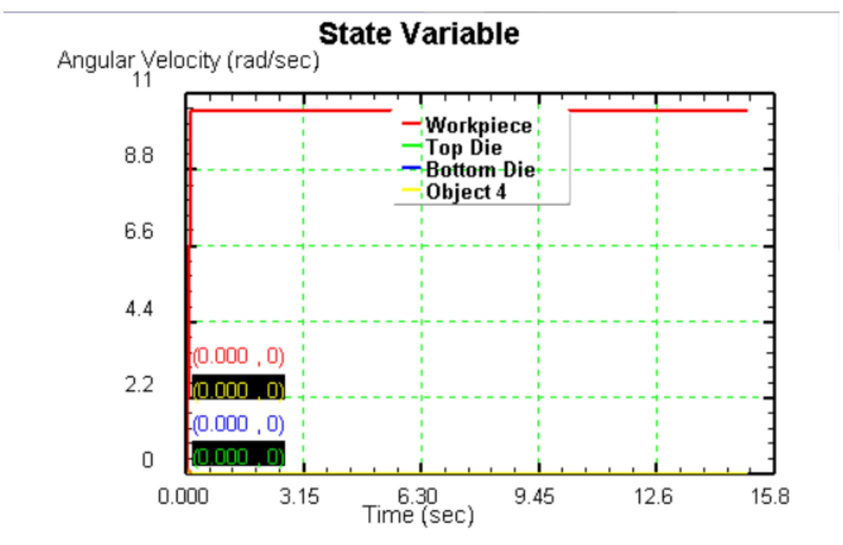


Figure 3.44: Angular Velocity of the Billet

3.9.3 – Load Prediction

For load prediction 3 part of the die considered. Those parts are rotor, placer and shaper. The load on the billet has not consider. The graph of the load prediction can be seen in the **Figure 3.45**. As can be seen in the figure the loads on the element increased immediately after the program started. Then after this point the loads on the parts have been increased up to $6x10^6\ N$ then extrusion continues the load on the parts decreased slightly as can be seen in the figure. After 10 second later which is the last second of the extrusion the loads on the parts have decreased $4.08x10^6\ N$ for same element that the highest load measured which is rotor. So, in 10 second load on the rotor has decreased 32%. Also, the load on the shaper has measured as $5.63x10^6\ N$ as highest load on the shaper. Again in 10 second the load on the shaper has decreased but not as much as in the rotor. In shaper's case the load decreased to $4.28x10^6\ N$ so in this case there was 24% decrease in the load. And for placer there was no load at first place after the cavity filled the load on the placer has increased up to $0.858x10^6\ N$.Then as the simulation process continues the load on the placer decreased up to $0.186x10^5\ N$. This also expected because when the simulation continues the pressure on the placer will be decreased and upper points of the shaper will not have load.

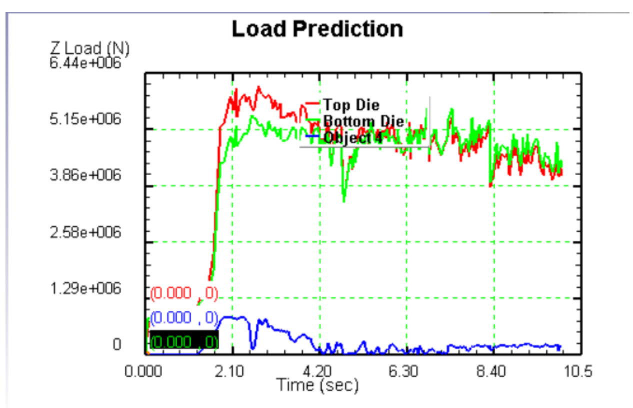


Figure 3.45: Load Prediction of the Die

3.9.4 – Velocity

The velocity of the billet has set as a 15 mm/s but at the tip of the billet the velocity value expected to be higher. And for this purpose, a node selected from tip of the billet and velocity analysis has started. After 10 second later final speed of the tip of billet calculated as 48.71 mm/s along z axis. Which is quite expected. And speed values at every axis can be seen in the following figure.

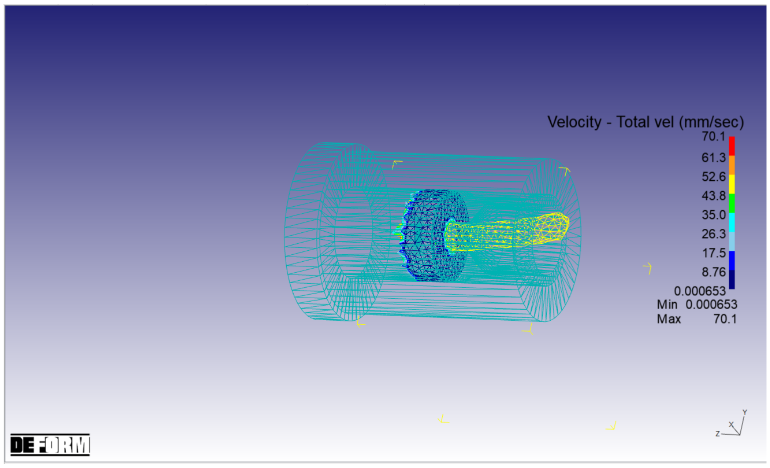


Figure 3.46: Velocity Values of the Billet

3.9.5 – Displacement

Also, the displacement at the tip of the billet can be shown in the **figure 3.5.** At the tip of the billet displacement amount moves to 178 mm.

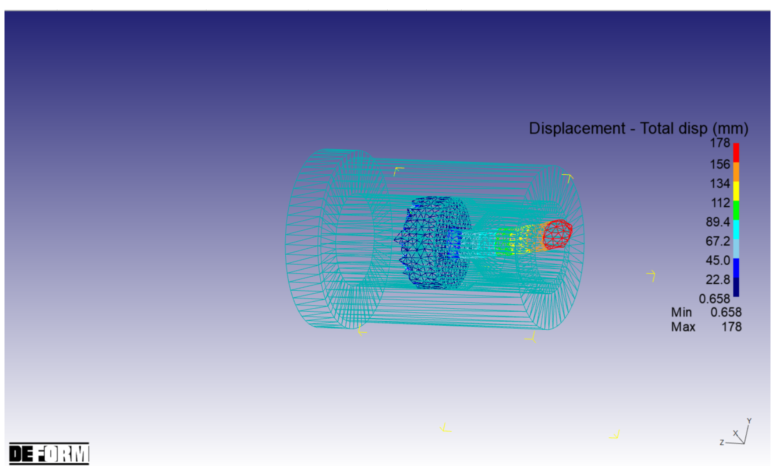


Figure 3.47: Displacement Values of the Billet,

Also Strain, stress diagram and energy graph will be given in the appendix section.

3.10 – Discussion

The velocity values and displacement values at the tip of the billet can be shown in the following table.

Table 3.1: Velocity and Displacement Results

Extrusion Diameter	Billet Speed	Speet at the tip (mm/s)	Displacement at the tip (mm)
40	5	16,840	213,000
40	10	31,140	233,000
40	15	48,710	178,000
60	5	10,504	304,000
60	10	22,400	328,000
60	15	45,700	373,000
80	5	8,740	269,000
80	10	23,300	273,000
80	15	29,400	336,000

As can be seen in the table billet speed and the speed at the tip of the billet moves correspondingly. There was no pattern founded about the relationship between the speed values. But when the speed of the billet increased tip of the billet increased up to 3 times. Also, this increasing is proportional with the extrusion diameter. When the extrusion diameter increased speed at the tip of the billet is decreasing. Consider 60 mm extrusion diameter and 15 mm/s billet speed and 80 mm extrusion diameter and 15 mm/s billet speed that given in table 3.1. When considering 60 mm extrusion diameter the velocity at the tip can be founded as 45.7. And when considering 80 mm extrusion diameter the velocity founded as 29.4. This of course expected because in the 60 mm case the extrusion pressure will be higher because of the smaller area at the shaper. But there as can be seen in the table 40 mm values collected but not correlate with the data that have been founded before the reason of this there were simulation error at the 40 mm section.

Also, table 3.1 shows as displacement value at the tip of the billet changes with speed of the billet. When speed of the billet increased the displacement amount at the tip of the billet increased slightly.

Then Load prediction consider. For this consideration a table generated.

Table 3.2: Load prediction table

Extrusion Diameter	Billet Speed	Max Load Prediction in Rotor (N)	Min Load Prediction on the Rotor (N)	Max Load Prediction in Shaper (N)	Min Load Prediction on the Shaper (N)
40	5	$5.95x10^6$	$4.17x10^6$	$5.39x10^6$	$4.56x10^6$
40	10	$6.21x10^6$	$4.06x10^6$	$5.84x10^6$	$4.24x10^6$
40	15	$6x10^6$	$4.08x10^6$	$5.63x10^6$	$4.28x10^6$
60	5	$5.43x10^6$	$3.44x10^6$	$4.61x10^6$	$3.54x10^6$
60	10	$5.76x10^6$	$3.28x10^6$	$4.94x10^6$	$3.37x10^6$
60	15	$5.93x10^6$	$3.47x10^6$	$5.14x10^6$	$3.60x10^6$
80	5	$4.23x10^6$	$2.51x10^6$	$3.42x10^6$	$2.55x10^6$
80	10	$4.32x10^6$	$3.01x10^6$	$3.45x10^6$	$3.03x10^6$
80	15	$4.57x10^6$	$3.47x10^6$	$3.67x10^6$	$3.56x10^6$

As can be seen in the above table when the extrusion diameter decreased the load on the die elements increased also when speed of the billet increased also the load on the die element increases.

3.11 Cost Analysis

Production of Die Parts

Shaper: Shaper is made from Steel. Also, a price offer received from a local manufacture. The offer was 80 Euro. And all the costs included in the price.

Placer: Placer is made from Steel. Also, a price offer received from a local manufacture. The offer was 35 Euro. And all the costs included in the price.

Holder: Holder is made from Steel. Also, a price offer received from a local manufacture. The offer was 70 Euro. And all the costs included in the price.

Standard Equipment

Also, extrusion machine for this process costs around $90,000 and $120,000 and we can assume as a $105,000.

Total Cost

As a result, we can assume the approximate total cost of the system as $150,200.

Chapter 4 – Conclusions

The main purpose of this paper is to be seeing the effect of the extrusion diameter and extrusion speed. Under some specific conditions. Those conditions are constant rotation, aluminum friction on the wall of the die. For this purpose, a die has been designed. For this design many extrusions technique has been analyzed. And the best design concept determined. After determination of the concept of the design, the design process started. Firstly, a shaper designed in order to give the desirable extrusion diameter. Then billet length and diameter determined. After billet determination a rotor has designed. But the rotor didn't design in detail because rotor accepted as a standard equipment. Then in order to prevent any unwanted movement a placer has been designed. Also, in order to prevent failure in the die system a holder designed and integrated to the system. All the design process can be founded in Chapter 2.

After Design process completed a basic design has designed in order to reduce the simulation time. But this basic design didn't compromise any of the properties of the die. After the basic design simulation process started. And speed values changed between the 5 mm/s to 15 mm/s with 5 mm/s increment. Also, three different diameters have selected for extrusion process. Those values were 40 mm, 60 mm and 80 mm. And constant rotation value has set for billet. This rotation value was 100 RPM. Then simulation started. All the simulation settings can be seen at chapter 2.

After Simulation completed some graphs and figures taken from the program and all the outputs compared with each other. Firstly, speed and displacement values at the tip of the billet compared. And as expected speed at the tip of the billet increases when the billet speed increased. Also, when extrusion diameter decreased the speed at the tip of the billet increases. This result shows the simulation that used in this paper works properly. Also, the results of the simulations have been compared with real life solution and all the simulation corresponds with the real usage.

After speed and displacement results load prediction at the die was analyzed. And this analysis shows when the extrusion diameter decreased the load on the wall of the die increased significantly. Then all the results compared with real usage and all the results have been founded usable in the real usage.

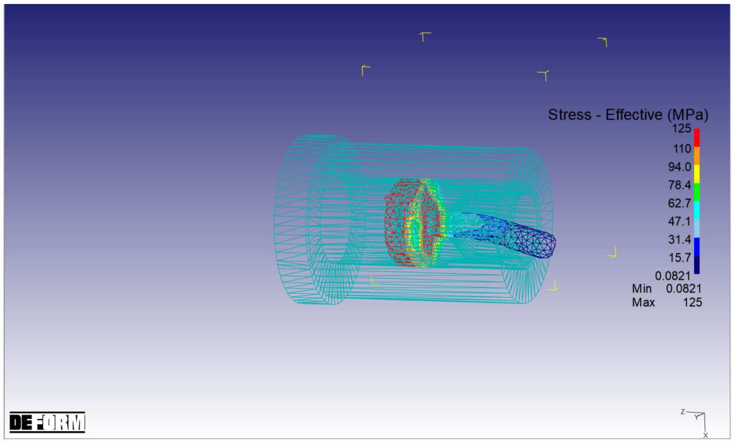
References

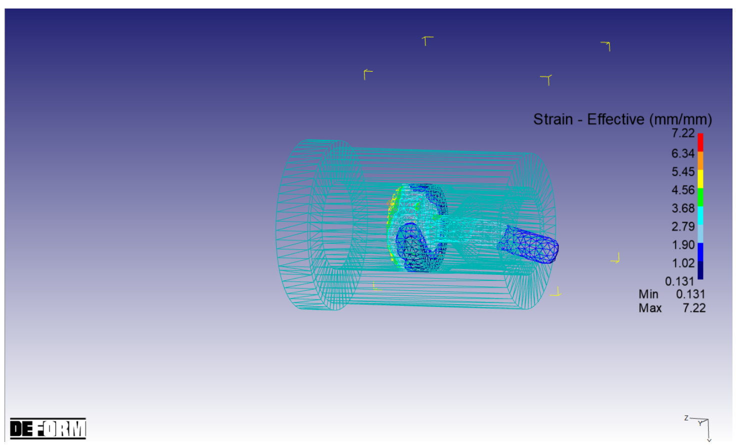
- https://www.researchgate.net/publication/281362696_Extrusion_of_short_aluminium_billets_-_Simulation_and_semi-pilot_test/link/5751712108ae6807faf95768/download
- https://www.sciencedirect.com/science/article/pii/S2452321618304402
- https://pubs.aip.org/aip/acp/article-abstract/2283/1/020063/948076/Optimizations-of-extrusion-semidie-angle-and?redirectedFrom=fulltext
- https://www.sciencedirect.com/science/article/pii/S0261306904003152
- https://www.degruyter.com/document/doi/10.1515/mt-2021-2114/html?lang=de
- https://link.springer.com/article/10.1007/s00170-021-06760-w
- R. C. Hibbeler – Mechanics of Materials
- Shigley's mechanical engineering design

Appendix

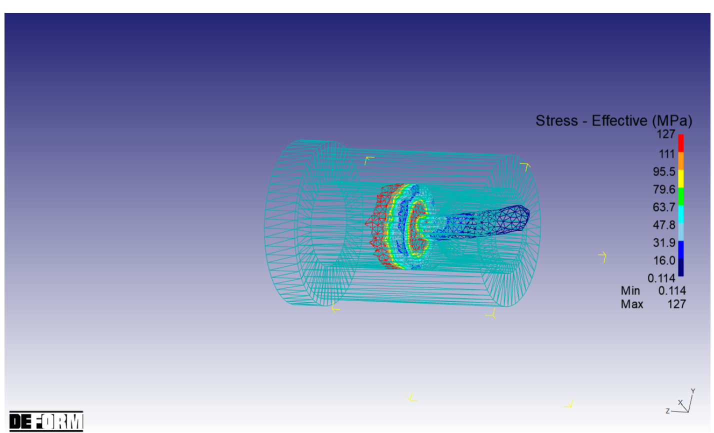
Stress and strain Values for billet

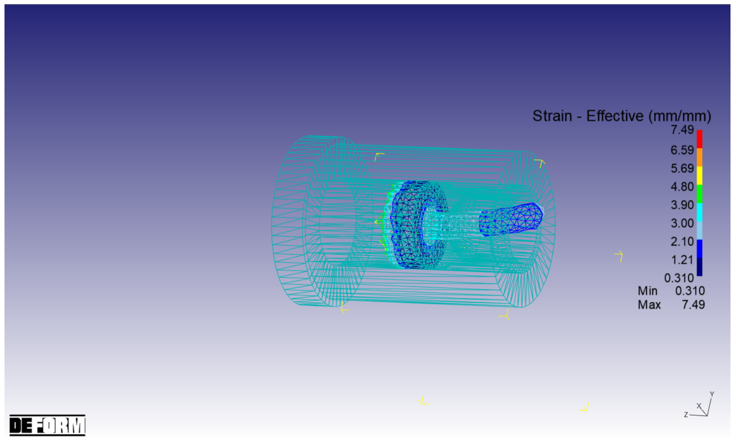
<u>40 mm and 5 mm/s</u>



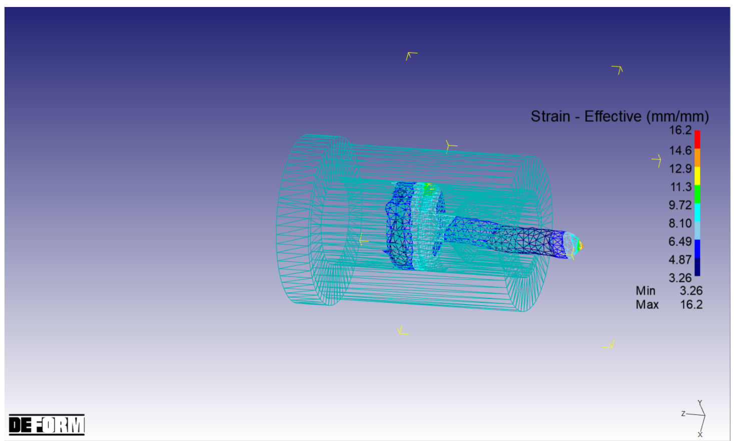


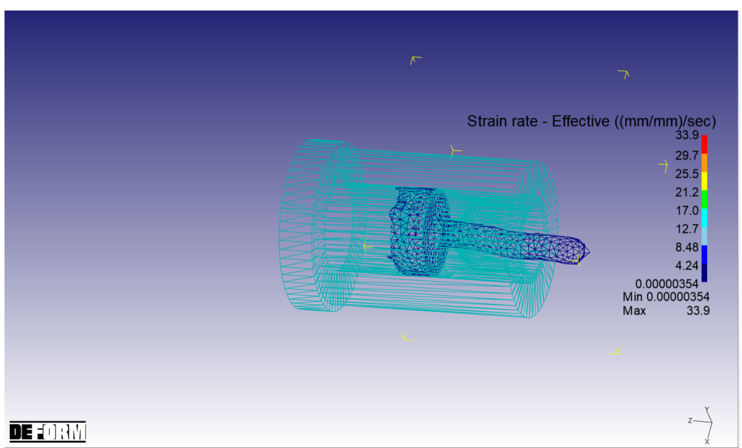
<u>40 mm and 10 mm/s</u>



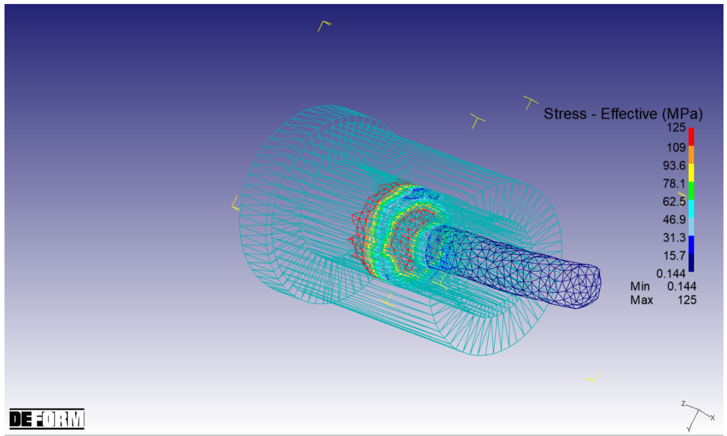


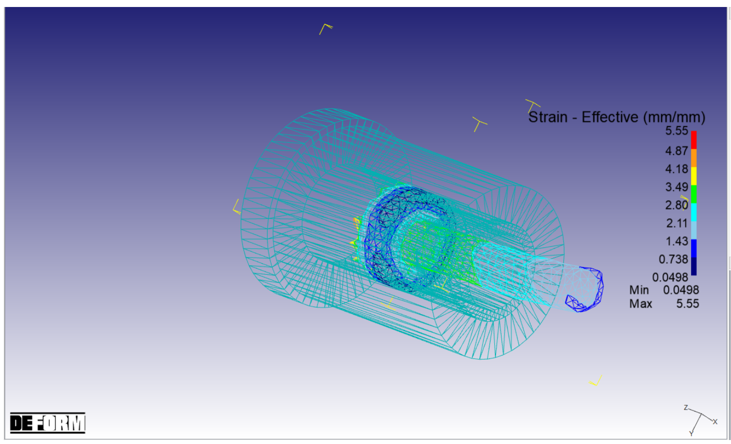
<u>40 mm and 15 mm/s</u>



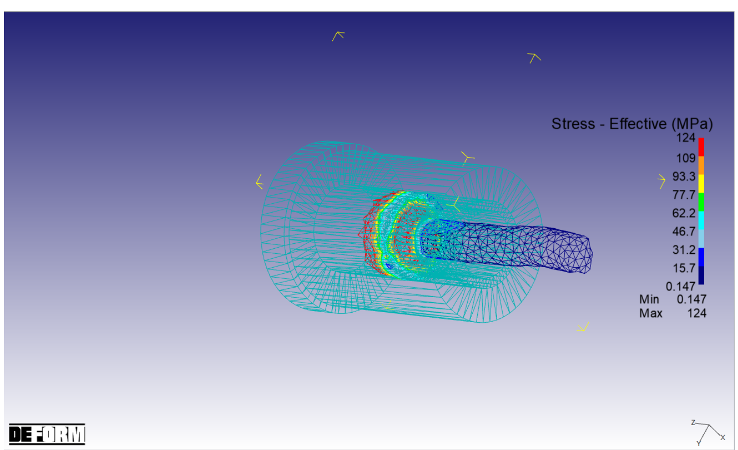


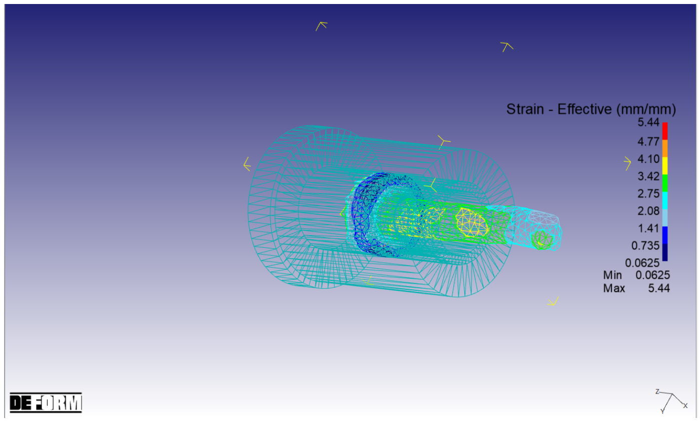
60 mm and 5 mm/s



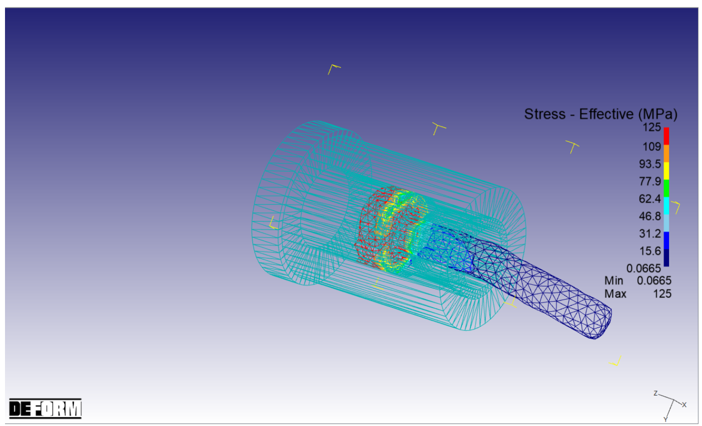


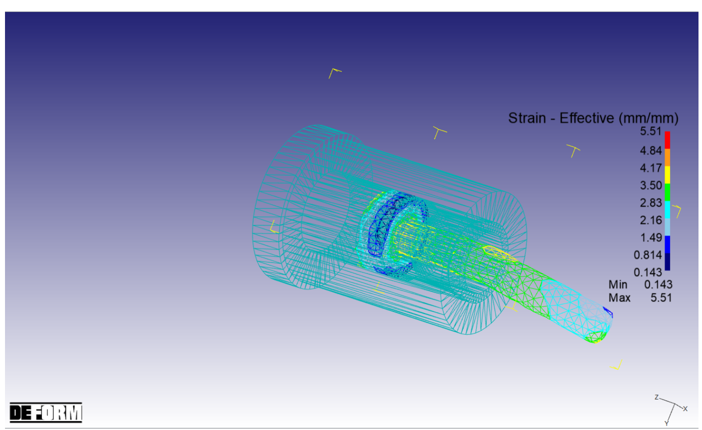
60 mm and 10 mm/s



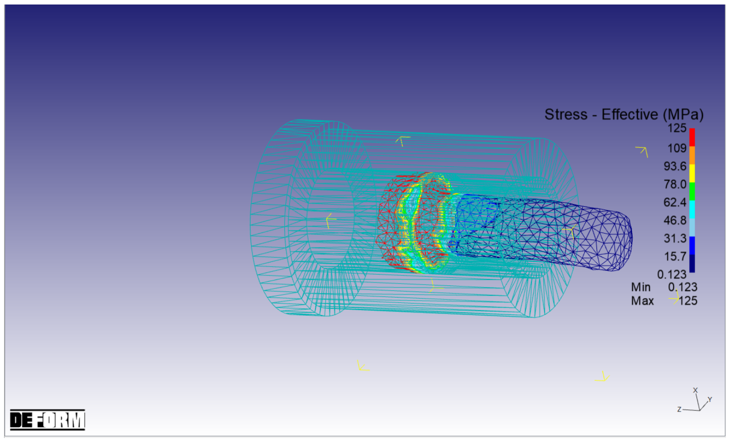


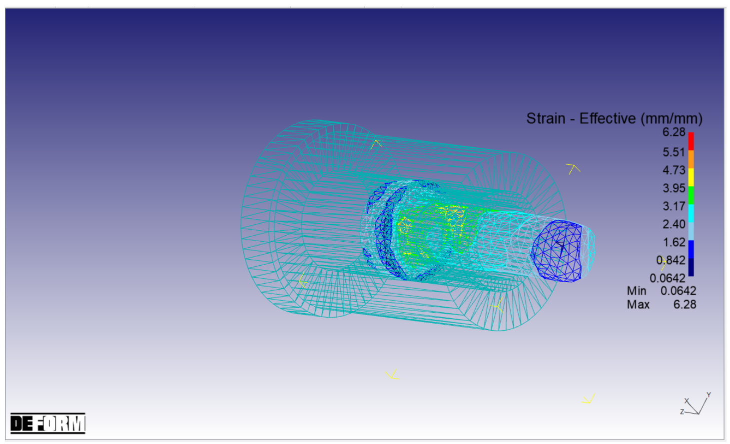
<u>60 mm and 15 mm/s</u>



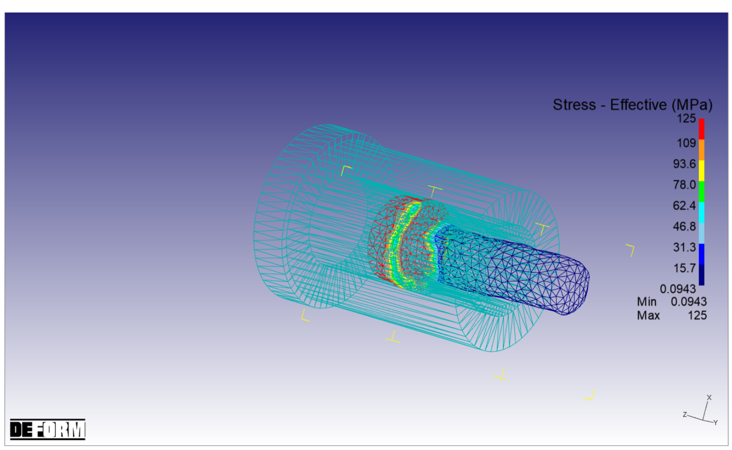


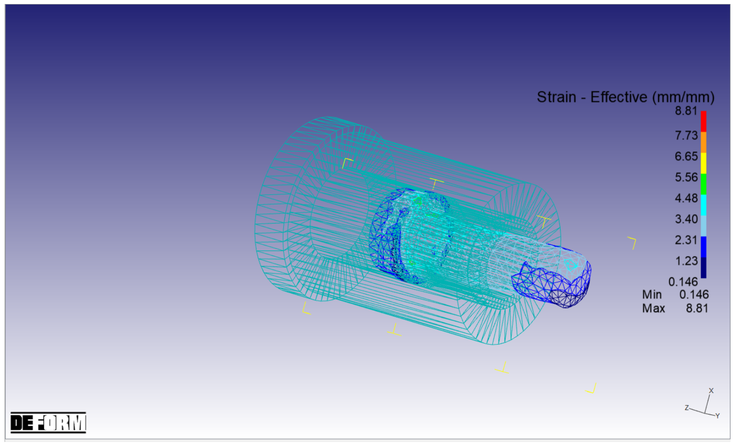
80 mm and 5 mm/s





80 mm and 10 mm/s





<u>80 mm and 15 mm/s</u>