ME 475 FINAL PROJECT REPORT

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For the class for Manufacturing Enterprises Systems, we were to design, simulate and mold a part of our choosing as a project under the guidance of our Professors and Lab Instructors. The design that I chose was a custom screw with a few modifications that would prove to be both a challenge as well as a good learning experience for me. The features of the screw were :-

- It was symmetrical in design
- It had a cylindrical base
- A flower shaped head
- A shell on top
- Hollow on the inside

1.1 CAD DESIGN

My initial CAD design done on Solidworks came as shown below in the diagram. The length of the body was 2.5 inches and the maximum diameter of the flower head was 1.75 inches. The part volume was around 1.15 inch^3 .

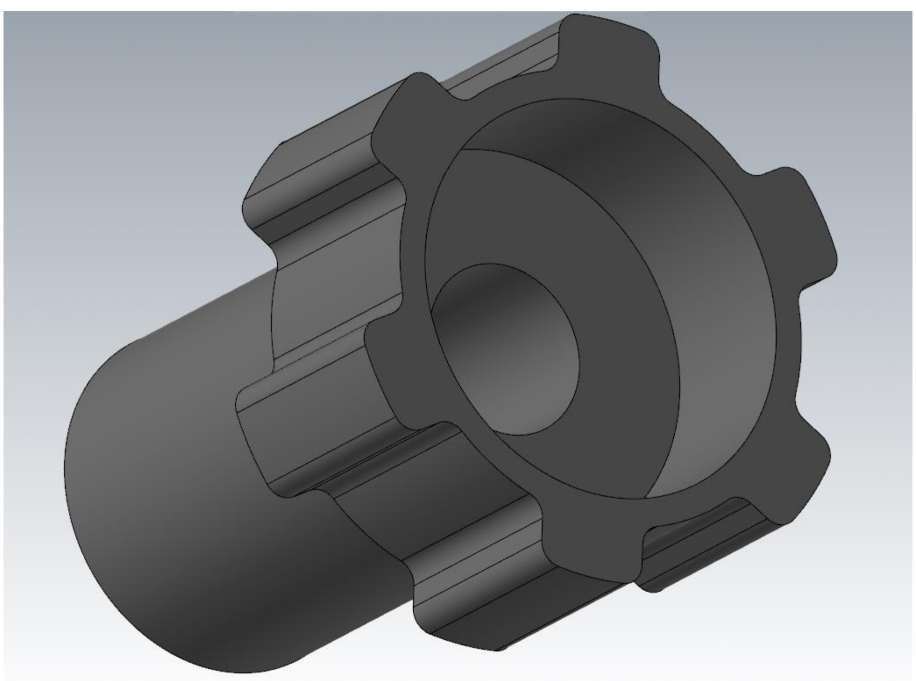

Figure 1 - The Isometric View of the CAD Design of the Screw

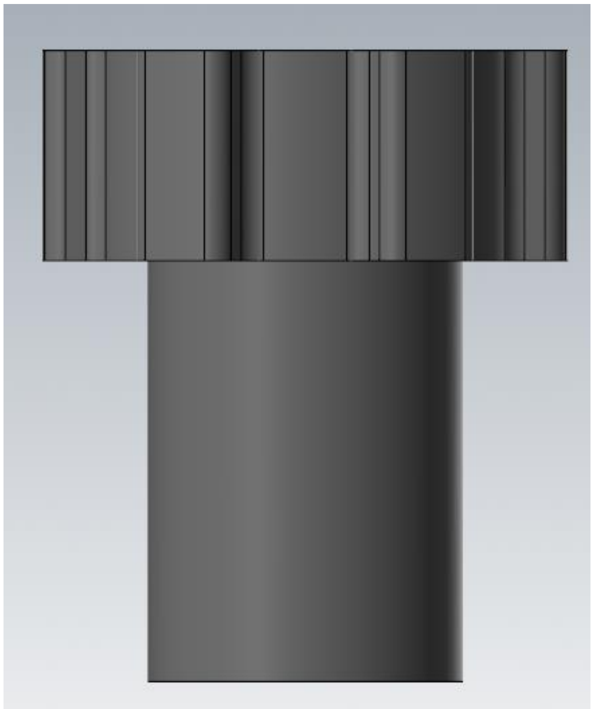

Figure 2- The Side view of the Screw

Based on these designs, I Simulated my design on Solidworks Plastics,

1.2 CAE SIMULATION

The simulations on CAE provided a satisfactory result. The material I used for simulation was ABS- P generic Material set at a temperature range of 50-230 °C .

The simulation only showed a shrinkage of 2% with a fill time of 4.6625 seconds. The simulation was done with a maximum pressure of 19.12 Mpa .

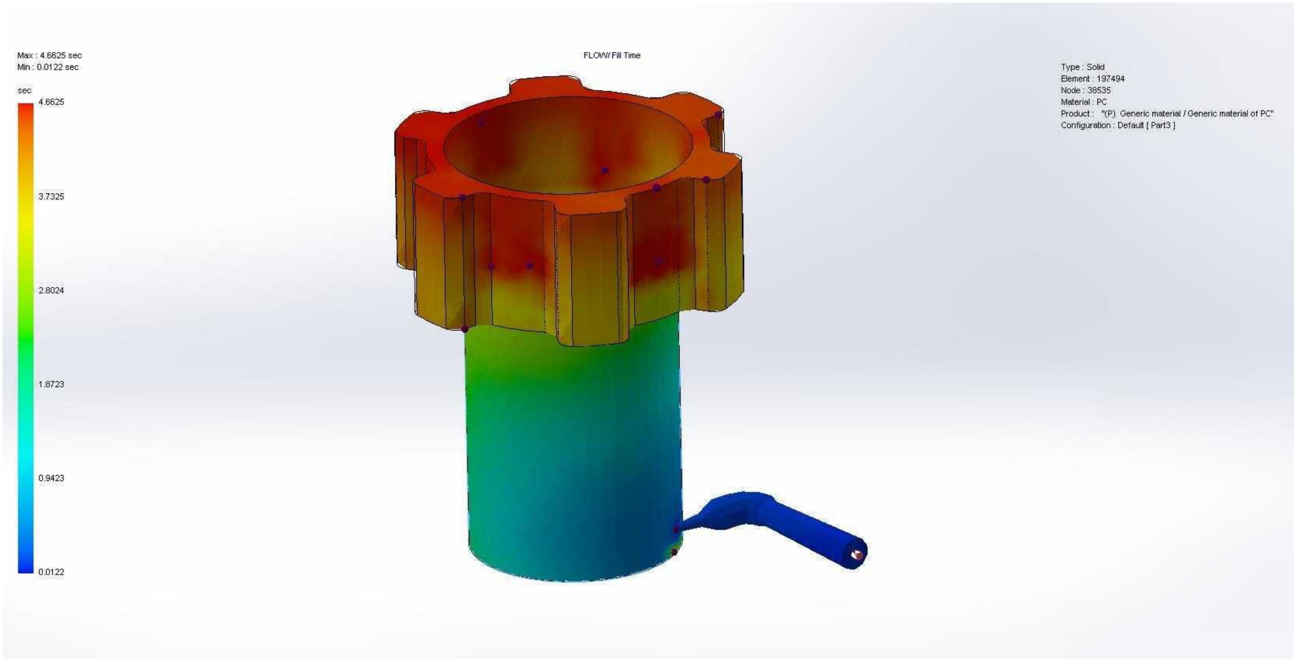

Figure 3 – The fill time of the part (4.6625 seconds)

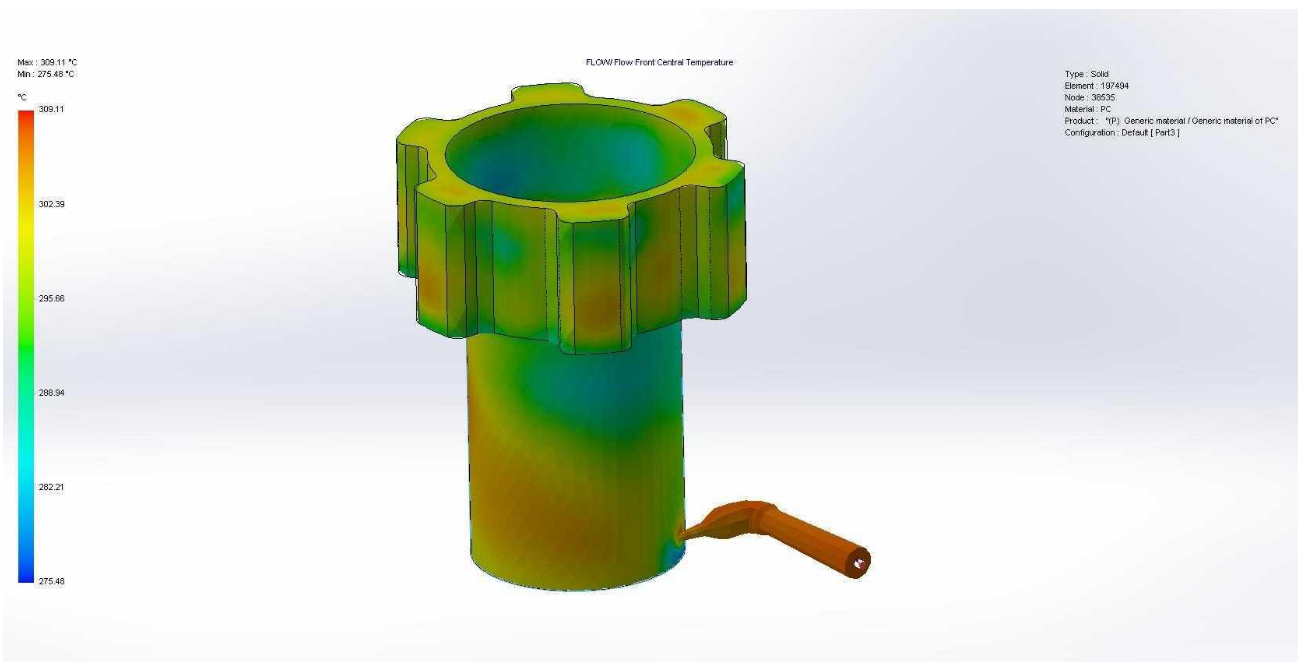

Figure4 - Flow Temperature for the Simulation

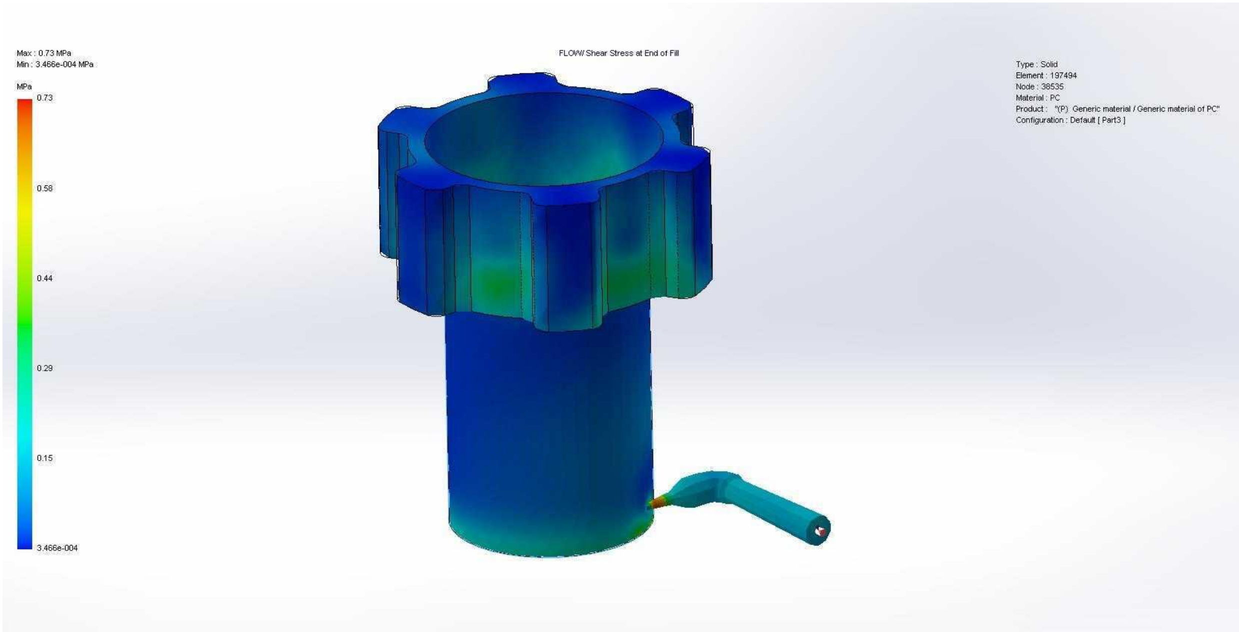

Figure 5 – Shear stresses in the Mold

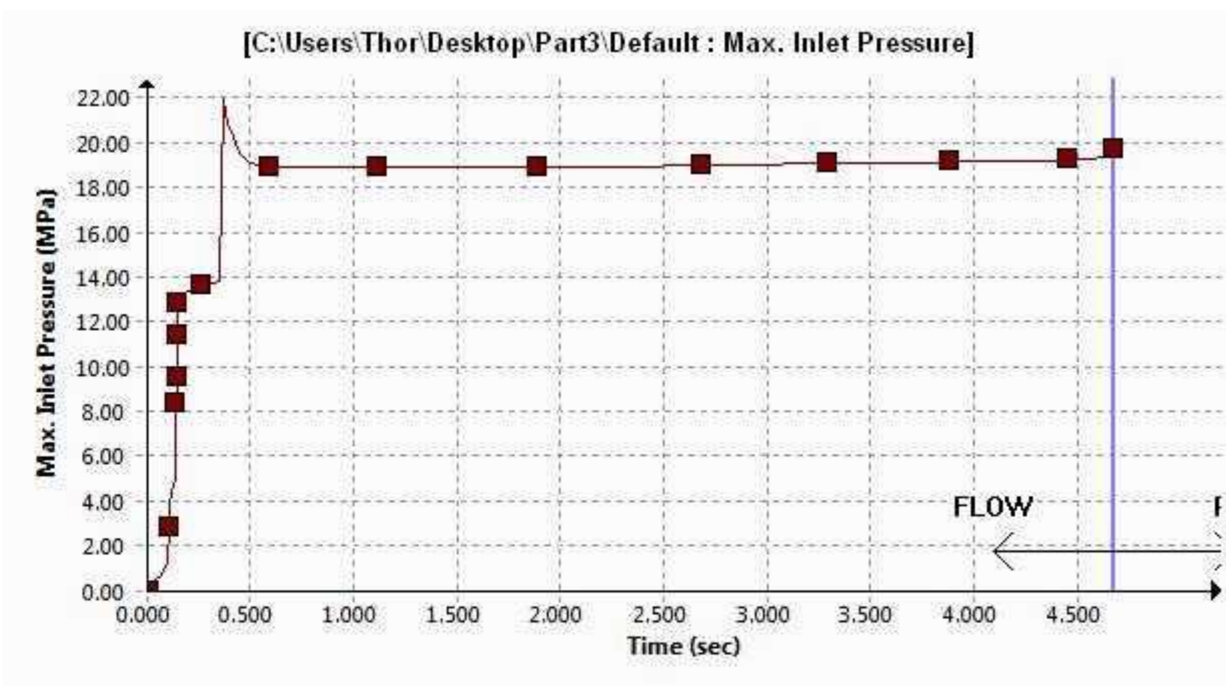

Figure 6- The maximum pressure in the Simulation

1.3.1 CAM TOOLPATH

After the CAE Simulation , I converted my Solidworks Part file on my design into a .step and began my Toolpath simulation on Mastercam 2018. However, there were a few complications I faced that my lab instructor Kurt Hutchinson helped me through.

- The primary hurdle was that in order to create a hollow design, I had to make another part, that would mimic the shape of my hollow structure. This mimic, “Arbor” would then go inside my mold dye during injection molding and the dye would fill around it and complete the part. Once the injection molding would be complete, the arbor would then be pushed out and the initial design will be completed.
- This also meant that I had to make my arbor tapered for easier removal and make the inner cylinder of my Mold dye tapered as well.
- The final hurdle was that the shape of my flowerheads, when being cut by the tools would exert excessive pressure on them and not only would the tool retrieval process be difficult, but it would also break the tools. Due to this, I modified my design a little to make it simpler for the tool cutting process.
- The edges were also filleted for ease of removal of the arbor and the mold dye.

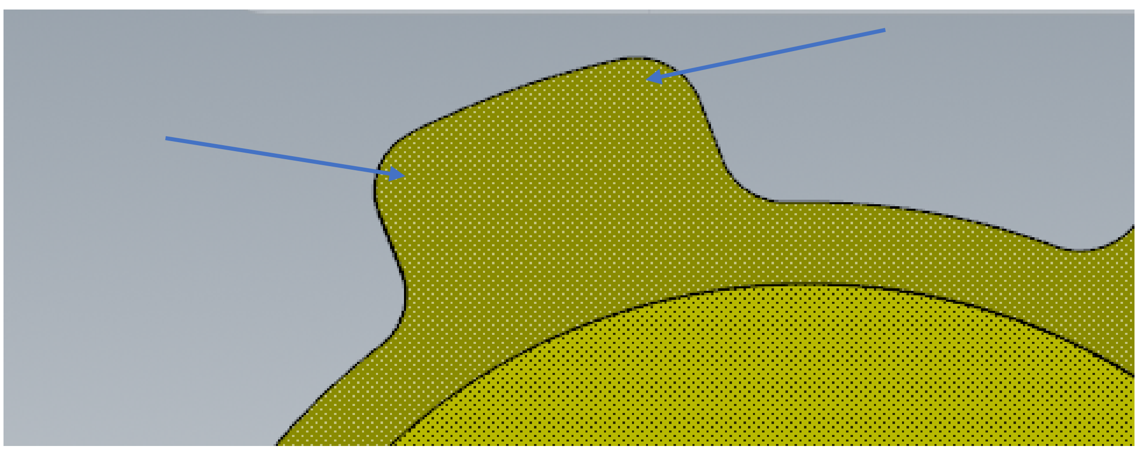

Figure 7 - The points on the mold where there would be excessive stress during tool cutting

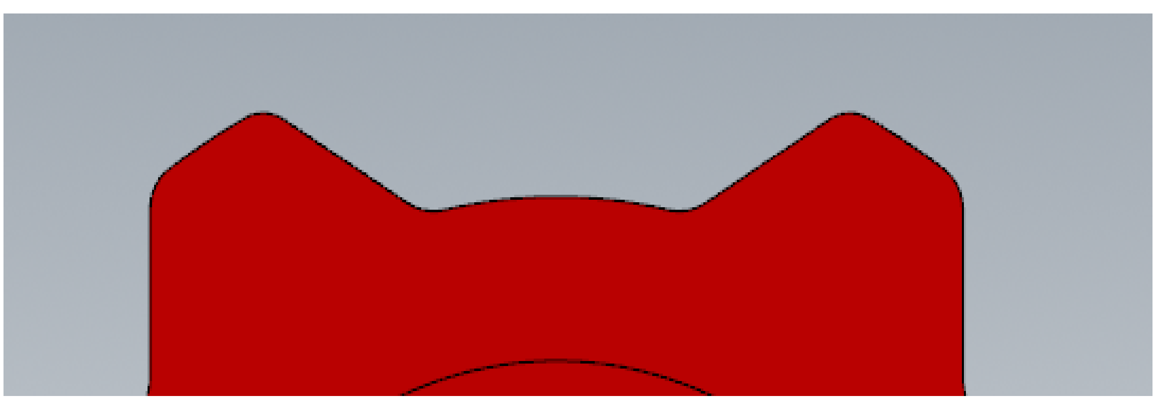

Figure 8 - The refined design that would allow easier tool cutting

Based on these design modifications, My final part looked as follows :-

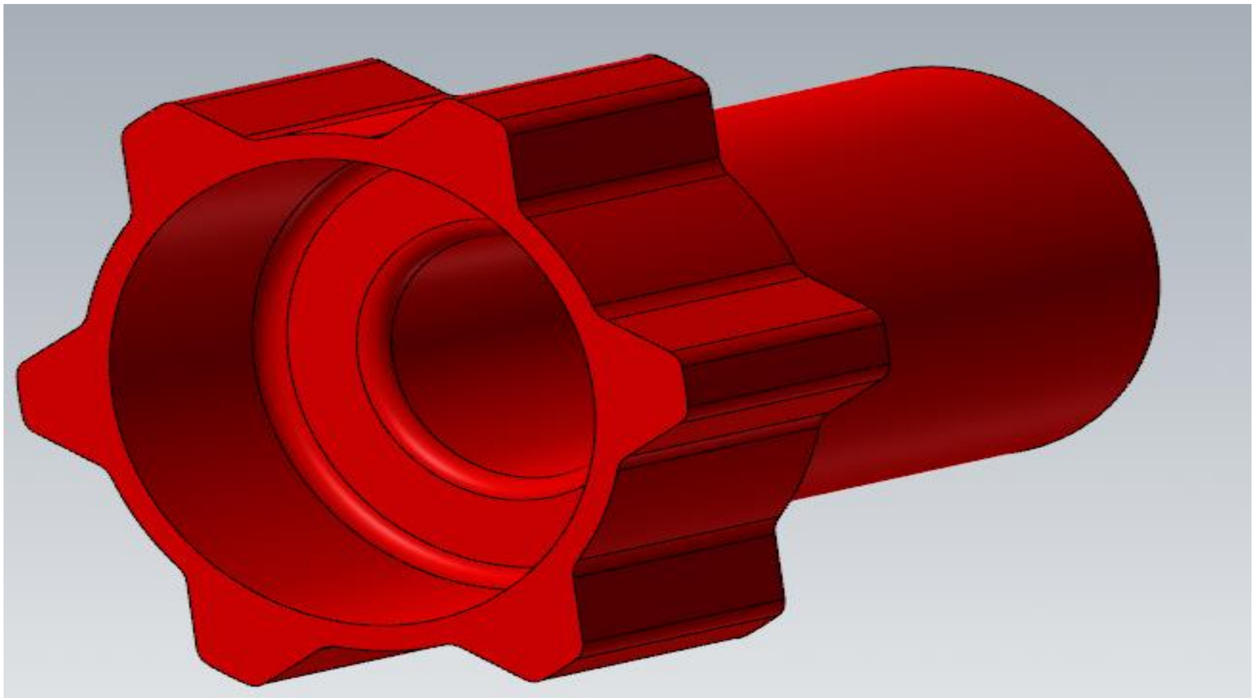

Figure 9 – The final part design

<u>1.3.2 THE ARBOR</u>

The arbor was made on a lathe machine, using the same material as used in the mold dye i.e., Aluminum 6061 -T6.

The arbor simulation was done on Mastercam using a Turning tool and a Boring tool.

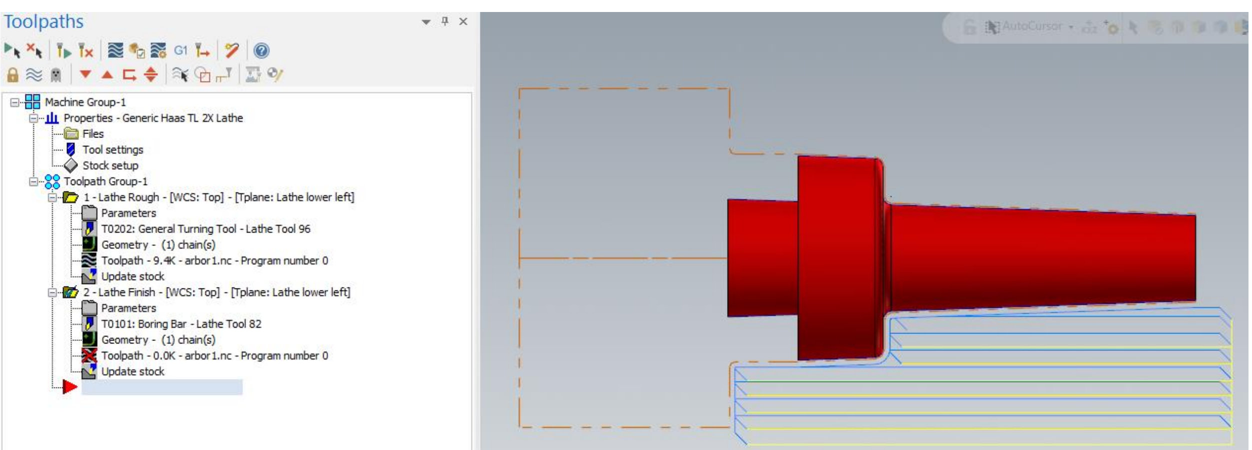

Figure10- The Arbor Simulation on Mastercam

Based on these simulations, the Arbor was machined on Lathe. There were a few cuttings done on the tapered edges of the Arbor so as to fit snugly inside the mold dye.

Figure 11- The Arbor Design

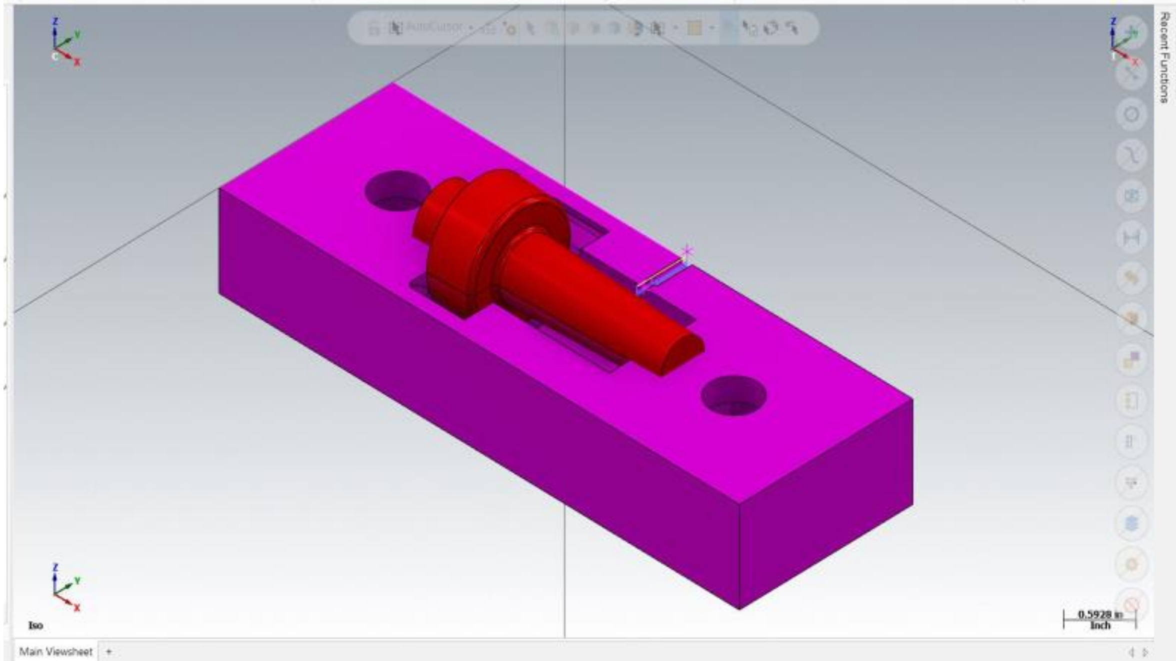

Figure12- The Arbor and The Mold

Now that the Arbor was ready, The toolpath was ready to be simulated on Mastercam :-

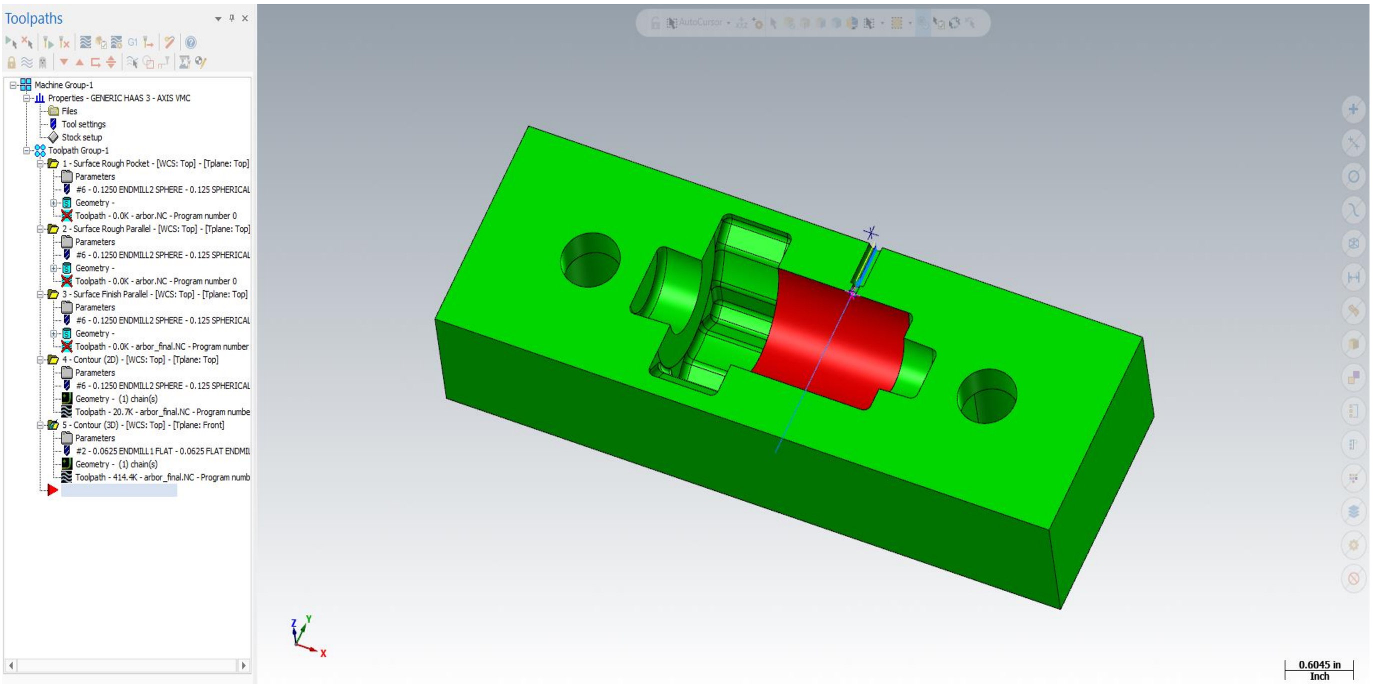

Figure 13- The Mold Design on MasterCam

The Mold design was as shown above –The mold was made on a part that was 6inch x 2inch x 1 inch in size. There were two molds made and since my design was symmetric, mirroring the toolpath provided the design for the other mold. There was a total of five operations that were conducted in making this mold which was done between two tools.

The tools that were used in making the mold were –

1.) A 1/8th inch Ball Nose end mill
2.) A 1/16th inch Flat End mill

The processes were as listed below :-

1.) A roughing operation – Pocket, Using 1/8th inch ball nose end mill
2.) A finishing operation – Parallel Cutting, Using 1/8th inch ball nose end mill
3.) A finishing operation – Parallel Cutting , Using 1/8th inch ball nose end mill
4.) A finishing operation - Contour Cutting , Using 1/8th inch ball nose end mill
5.) A finishing operation – Contour Cutting, Using 1/16th inch flat end mill

The total time for each mold operation was 4 hours and 35 minutes.

The machine report for each operation is as given below :-

Roughing – Pocket

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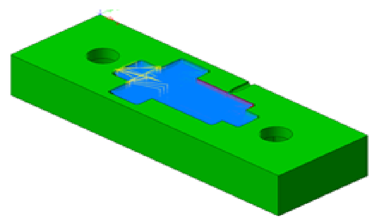
CYCLE TIME:	4 HOURS, 13 MINUTES, 42 SECONDS

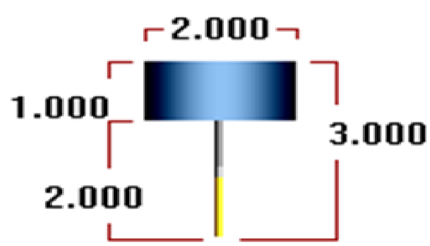
OPERATION LIST

OPERATION INFO	***1 - Surface Rough Pocket***
CYCLE TIME:	3 HOURS, 0 MINUTES, 0 SECONDS
COMMENT:	

PROGRAM NUMBER:	0
SPINDLE SPEED:	6000 RPM
FEEDRATE:	10.0 inch/min
CLEARANCE PLANE:	2.0
RETRACT PLANE:	0.25
FEED PLANE:	0.1
DEPTH:	NA
STOCK TO LEAVE:	0.01
COMP TO TIP:	YES
WORK OFFSET:	-1



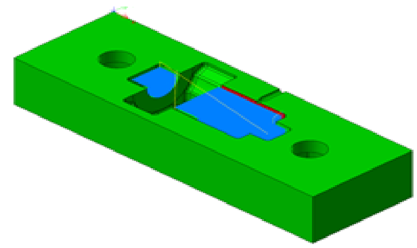
TOOL INFO	***0. 125 Spherical / Ball-Nosed Endmill***
TYPE:	Endmill2 Sphere
NUMBER:	6
DIAMETER:	0.125
CORNER RADIUS:	0.0625
LENGTH OFFSET:	6
DIAMETER OFFSET:	6
MATERIAL:	Carbide
NUMBER OF FLUTES:	4
FPT: 0.0013	SFM: 130.8901
MFG CODE:	
ASSEMBLY:	
HOLDER:	Default Holder
TIME:	03:00:00



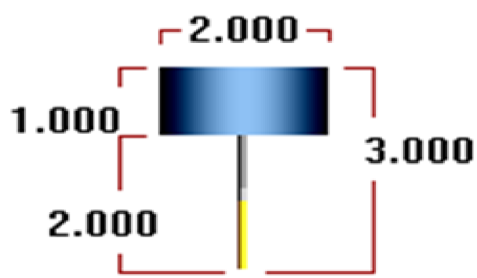
Finishing – Parallel Cutting

OPERATION INFO	***2 - Surface Rough Parallel***
CYCLE TIME:	1 HOURS, 13 MINUTES, 41 SECONDS
COMMENT:	

PROGRAM NUMBER:	0
SPINDLE SPEED:	6000 RPM
FEEDRATE:	10.0 inch/min
CLEARANCE PLANE:	2.0
RETRACT PLANE:	0.25
FEED PLANE:	0.1
DEPTH:	NA
STOCK TO LEAVE:	0.0
COMP TO TIP:	YES
WORK OFFSET:	-1



TOOL INFO	***0.125 Spherical / Ball-Nosed Endmill***
TYPE:	Endmill2 Sphere
NUMBER:	6
DIAMETER:	0.125
CORNER RADIUS:	0.0625
LENGTH OFFSET:	6
DIAMETER OFFSET:	6
MATERIAL:	Carbide
NUMBER OF FLUTES:	4
FPT: 0.0013	SFM: 130.8901
MFG CODE:	
ASSEMBLY:	
HOLDER:	Default Holder
TIME:	01:13:41



Finishing - Parallel

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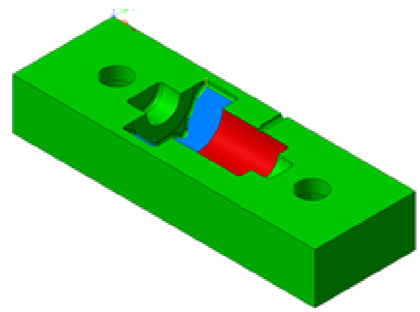
CYCLE TIME:	0 HOURS, 16 MINUTES, 3 SECONDS

OPERATION LIST

OPERATION INFO	***3 - Surface Finish Parallel***

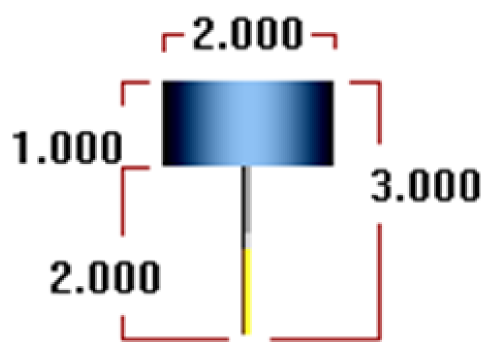
CYCLE TIME:	0 HOURS, 10 MINUTES, 56 SECONDS
COMMENT:	

PROGRAM NUMBER:	0
SPINDLE SPEED:	1069 RPM
FEEDRATE:	25.0 inch/min
CLEARANCE PLANE:	2.0
RETRACT PLANE:	0.25
FEED PLANE:	0.1
DEPTH:	NA
STOCK TO LEAVE:	0.0
COMP TO TIP:	YES
WORK OFFSET:	-1



TOOL INFO	***0.125 Spherical / Ball-Nosed Endmill***

TYPE:	Endmill2 Sphere
NUMBER:	6
DIAMETER:	0.125
CORNER RADIUS:	0.0625
LENGTH OFFSET:	6
DIAMETER OFFSET:	6
MATERIAL:	Carbide
NUMBER OF FLUTES:	4
FPT: 0.0013	SFM: 130.8901
MFG CODE:	
ASSEMBLY:	
HOLDER:	Default Holder
TIME:	00:10:56

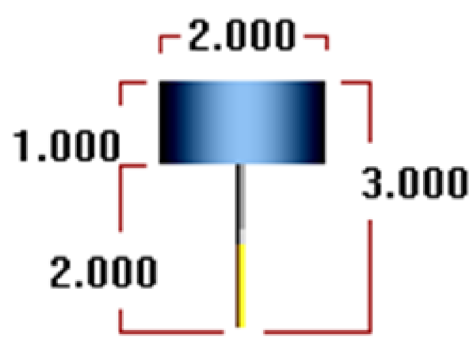


Contour Cutting - 1/8th Ball Nose EndMill

OPERATION INFO	***4 - Contour (2D)***
CYCLE TIME:	0 HOURS, 0 MINUTES, 21 SECONDS
COMMENT:	

PROGRAM NUMBER:	0
SPINDLE SPEED:	1069 RPM
FEEDRATE:	6.4176 inch/min
CLEARANCE PLANE:	2.0
RETRACT PLANE:	0.25
FEED PLANE:	0.05
DEPTH:	-0.0625
STOCK TO LEAVE:	0.0
COMP TO TIP:	YES
WORK OFFSET:	-1

TOOL INFO	***0.125 Spherical / Ball-Nosed Endmill***
TYPE:	Endmill2 Sphere
NUMBER:	6
DIAMETER:	0.125
CORNER RADIUS:	0.0625
LENGTH OFFSET:	6
DIAMETER OFFSET:	6
MATERIAL:	Carbide
NUMBER OF FLUTES:	4
FPT: 0.0013	SFM: 130.8901
MFG CODE:	
ASSEMBLY:	
HOLDER:	Default Holder
TIME:	00:00:21

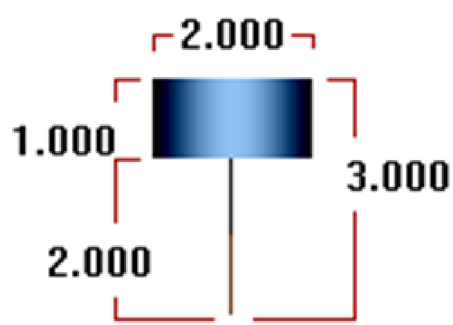


Contour Cutting - 1/16th Flat EndMill

OPERATION INFO	***5 - Contour (3D)***
CYCLE TIME:	0 HOURS, 4 MINUTES, 44 SECONDS
COMMENT:	

PROGRAM NUMBER:	0
SPINDLE SPEED:	8000 RPM
FEEDRATE:	3.0 inch/min
CLEARANCE PLANE:	2.0
RETRACT PLANE:	0.25
FEED PLANE:	0.05
DEPTH:	-0.0625
STOCK TO LEAVE:	0.0
COMP TO TIP:	YES
WORK OFFSET:	-1

TOOL INFO	***0.0625 Flat Endmill***
TYPE:	Endmill1 Flat
NUMBER:	2
DIAMETER:	0.0625
CORNER RADIUS:	0.0
LENGTH OFFSET:	2
DIAMETER OFFSET:	2
MATERIAL:	Carbide
NUMBER OF FLUTES:	4
FPT: 0.0013	SFM: 130.8901
MFG CODE:	
ASSEMBLY:	
HOLDER:	Default Holder
TIME:	00:04:44



1.4 MACHINE TOOL SETUP

The G1 code was generated and sent to the machines and the parts were set up on the machine. While the G1 code was generated automatically, we checked the generated code for the spindle speeds, feed rates and tool path changes.

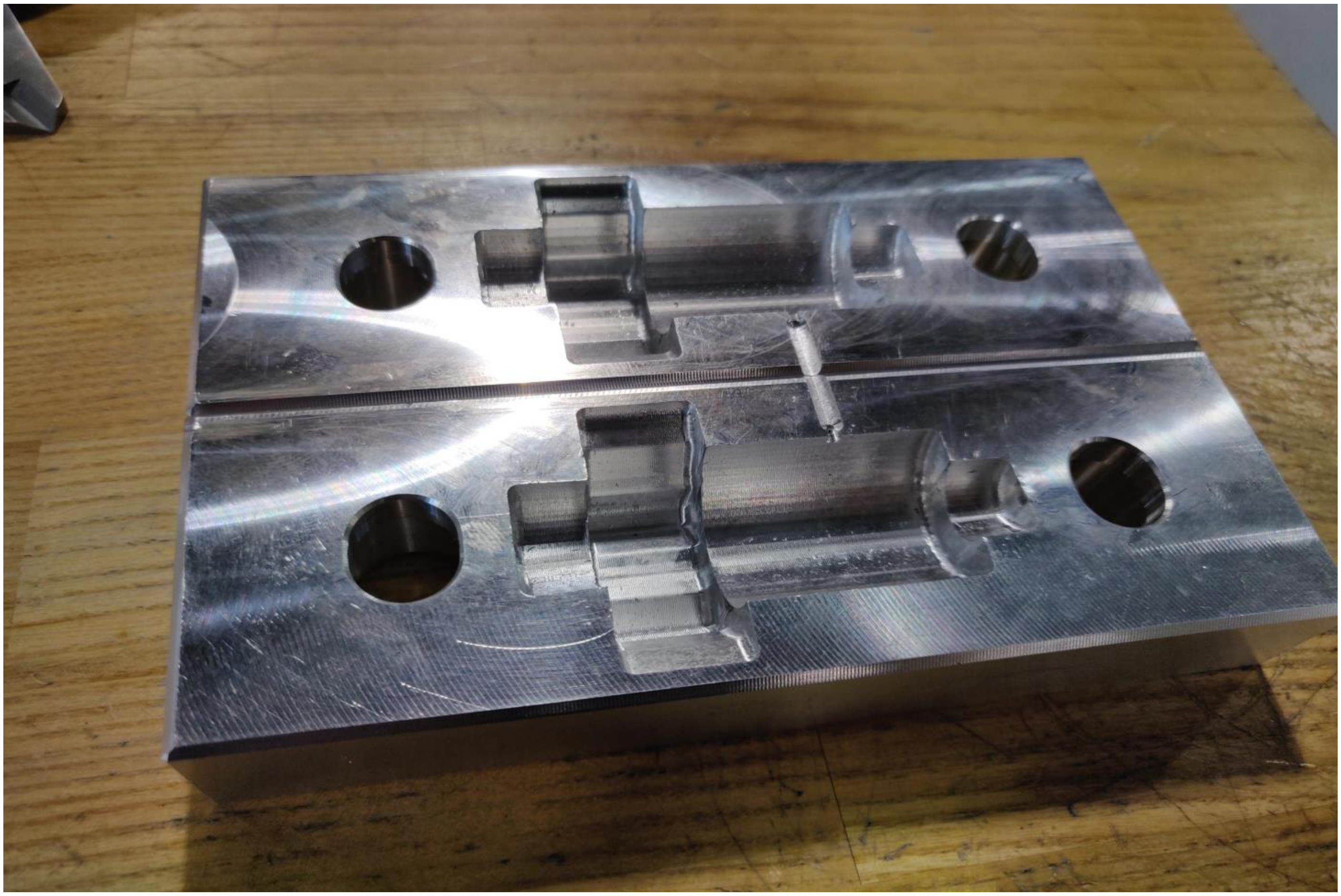
Following this process, The CNC G1 Code was generated. The two tools in operation were T2 ($1/6^{th}$ inch flat end mill) and T6 , ($1/8^{th}$ inch ball end mill).

The first four processes were conducted using T6 after which there was a tool change for the last process to T2.

Both the tools used in the making of my mold were added to the inventory of the machine. i.e. (T6 and T2). The machine itself was calibrated to the position of the part by setting the correct g54 location, which was the top left part of my mold. Similarly, both the tools were also calibrated to be correctly positioned to the mold.

In one of my earlier runs, the $1/8^{th}$ inch ball nose end mill tool broke during one of the finishing operations as the cut was deeper than the tool size. Due to this, we increased the length of the tool so that it would cut in deeper into the mold.

The final molds came as follows :-



1.5 INJECTION MOLDING

The final step was the Injection Molding process. The molds were placed underneath the Injector. The Injection was done by pressing the heated dye into the mold using the piston.

The material used in the dye was Polystyrene –

Since my part had a higher volume, It took me a few tries to get the right mold. I had to add extra means to make my mold fill up.

- Putting a material beneath the mold to elevate the mold height.
- Spraying the insides of the mold and Arbor with Mold Release Spray
- Heating the insides of the mold and Arbor with a blower at 200°F.
- Heating the dye to 450°F

1.6 RESULTS AND DISCUSSION

- The final part was pretty close to the initial design, with a maximum difference in design of approximately 1.02% . While the initial molds were not accurate in design, with proper preparation they showed more resemblance to the actual part.
- I used Polysterene for my initial tests at it was more fluid. I also tried using HDPE for my molds as it was more durable but their design was not as accurate as Polysterene so I decided to use the former as the material for my final Mold.

The dimensions of specific parts is tabulated below :-

Name	Simulation Size	Actual Size	% Shrinkage
Length of the Mold Dye	2.750	2.745	.181
Outer Diameter of the Flower of the Mold Dye	1.675	1.670	.298
Arbor Length	2.766	2.755	.39
Outer Diameter of the Bottom of the Mold	.975	.965	1.02
Outer Diameter of the Flower of the Mold	1.660	1.660	0
Inner Diameter of the Flower of the Mold	1.20	1.203	.25

The initial few designs came out as follows-

Figure 15 - Progression of Molds

Figure 16 – The final Molded Part

1.7 CONCLUSION

While the final part did not completely turn out to be what it was in the Simulation, I was completely satisfied with the design. The volume of the mold was very close to the maximum volume capacity of the Injection Molding Machine. Therefore, it was very difficult to get the exact part molded, but on taking extra measures the final part came out very close to the original.