Design and Analysis of Flat Dripper Mold

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Abstract - Drip irrigation is a popular solution to water shortages, and it is a major part of many proposed solutions. Earlier Inline and description drippers were used which had comparatively higher material cost & lower efficiency. Later on, Round Drippers came into use which had adequate efficiency but higher material cost due to the bigger size. So as an answer to this lately Flat Drippers have been introduced. Flat Drippers have a really small size hence less material cost. Flat Drippers are manufactured using the Plastic Injection Molding Process. Plastic Injection molding may be a process of melting plastic pellets (thermosetting/thermoplastic polymers) that once malleable enough, are injected at pressure into a mold cavity, which fills and solidifies to supply a product. Flat Drippers with zero runner wastage, zero rejections, and therefore the least possible cycle time. Hence, increasing the assembly rate as well as maintaining the quality and consistency of the product. The scope of this project mainly aims to style and Manufacture Injection mold (Hot Runner) for Flat Drippers to produce a standard discharge of 4 liters of water per hour in a single dripper. So, we've done the design and manufactured a mold of 32 cavities with 2 hot drops in such a way that the dripper meets the standard discharge parameters.

Key Words: Flat Dripper, Injection Moulding, Hot Drop, Cycle Time

1. INTRODUCTION

Injection molding is an ancient technology that has been used since the late 1800s. Injection molding machines incorporate an enormous screw to force molten plastic into the mold at high pressure. This screw drive method was invented in 1946 and remains the method used today. Injection molding machines definitely don't have the modern, high-tech feel of 3D printing technology. there's really nothing cool about injection molding, but nonetheless, it's a requirement for most hardware products. An injection mold consists of two halves that are forced together to make a cavity in the shape of the part to be produced. Hot, liquid plastic is then injected at high into this cavity. high is needed to ensure that the plastic resin fills in every crook and cranny of the mould cavity. Once the plastic has had time to chill, the 2 halves of the mould are pulled apart, and therefore the part is ejected.

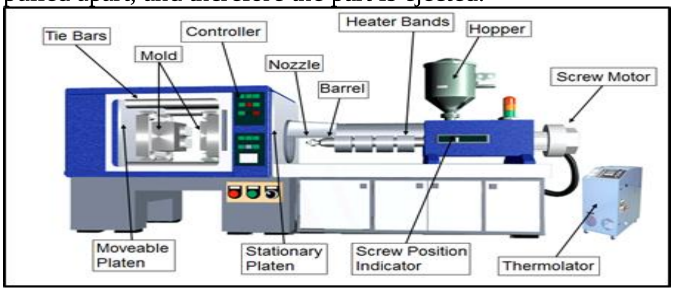


Figure 1: Injection Molding Machine

Although designing for injection molding are often quite complicated, and therefore the cost of the mould themselves are incredibly expensive, there's one huge reason why injection molding are expensive, and you'll presumably need a few of them, so their total cost are often quite significant. The more parts you would like to produce with the mould the more expensive the mould. this is often because the mould must be designed to withstand incredibly harsh conditions. Over and once again a mould is subjected to high temperature and high pressure. [8]

2. LITERATURE REVIEW

Injection moulding is that the most traditional plastic parts manufacturing procedure. Using injection moulding, an outsized range of items are made, varying in scale, complexity, and implementation. Hot runner is best than cold runner but is seldom utilized due to high cost and difficulty. Every substance needs a sophisticated set of parameters such as injection temperature, injection pressure, flow rate, mould temperature, ejection temperature, cooling rate, and cycle time. An improper set of parameters results in many flow lines, burn marks, and warping, vacuum voids/air pockets, sink openings, weld lines, and jetting. Few defects, including discolouration, plastic use, and delamination storage. Flash triggers and quick shots indicate poor design or repair. Process improvement and defect-removal data collecting are some of these criteria. The impact of those criteria on the moulding process and recommendations to generate defect-free components need more study.

Mr. P. Vinod, Mr. K. Vijay Kumar has designed multi-cavity injection mould with HRS and CRS. By comparing both designs, they researched the impact of runner systems, mould cooling and venting. Moulding analysis is administered using ANSYS [1].

G. Rajendra Prasad, Dr. S. Chakradhar Goud Studied dynamic characteristics like hot runner nozzle strain using analysis in FEA. N. Divya, Dr. S. N. Malleswara Rao, Dr. V. S. Parameswara Rao, concluded in their paper that the recent runner system accommodates the molten plastic. The consistency and productivity of the mould component are determined by the runner method. They performed structural and thermal analysis of the mould's original and updated designs concluding that the modified design produces the simplest performance [2].

Rashi. A. Yadav, S. V. Joshi, N. K. Kamble, recent studies to style and determine injection moulding method parameters. within the parameter environment for injection moulding, several test works were performed focused on various approaches. within the plastic injection moulding (PIM) industry, optimum process parameter settings are critically suffering from performance, consistency, and price of output [2].

A. Demirer, Y. Soydan, unlike the conventional runner approach, hot runner machine effects on. The qualities of injection products and the injection molding process were investigated. They used data from method parameters experiments. Temperature and injection pressure might vary greatly. Higher weight samples had a somewhat lower injection pressure during the hot runner procedure. If the temperature of the process increases, shrinkage and warpage increases, reducing with increase injection pressure and happening at a low level where the sample weight was high [3]

Gurjeet Singh, Ajay Verma Studied primary molding conditions from design creation to product manufacturing. On the basis of processing parameters, they looked at many elements. It is concluded that when efforts are focused on enhancing quality, efficiency suffers. Parameters must be optimised to ensure good quality and efficiency. Authors analyzed different responses to injection molding process quality based on output parameters and methods [3]

Mehdi Moayyedian, Kazem Abhary, the injection molding method implemented a new gate geometry. It was observed that current edge gate corners create turbulence of molten plastic leading to internal and external defects. To decrease the internal and external defects of injected parts, new geometry was included. The study's goal was to make the final piece easier geometry, which eliminates the last part's apparent blemish after de-gating [4].

V.Chandra Sekhar, N. Jaya Krishana Suggested design for two circular flat plate 1 mm wide. This research made a contribution by altering the current edge gate geometry by removing rectangular edge gate corners to reduce the likelihood of junk bits being inserted. Smooth plastic flow through cavities often prevents internal and external defects. The result reveals no shot-filling cavities. With the revised edge gate design, no sink marks, meld lines, or weld lines were found. The experiment ends with an added portion of the initial edge gate step, less noticeable than the current edge gate [5].

Some techniques, for example, use moving motors to control valve gates, some need specific heaters, and some require unique mold tolerances to function properly. We investigated the effects of standard convection, low shear velocity, and high viscosity-dependent effects. Lee and Lin et al. built a multi-cavity mold runner and gating system. Use the Finite Element Theory (FEM) network. Optimal runner unit parameter used to minimize injection mold warp, FEM, Taguchi phase and adductive framework. Processes during mold filling, enhancing moulding condition. Model injection mold simulation at steady flow rate. Strong support for methodological solutions is provided by the finite differences approach. Different gate sizes and locations using flow simulation have been detected for defects reduction such as weld lines and air traps, air traps and war page can be managed by varying process parameters. Part flow-reducer studied using Autodesk Mold Flow tools. The mold flow analysis is used to predict the piece's deformation and change the design accordingly. The plastic toy building block section is analyzed; cycle time is successful for four cavities as filling and cooling time for four cavities does not improve in single cavity configuration. The outcome indicates that both parameters influence product consistency, Plastic Flow Simulation analyses the flow of molten plastic to optimize part and mold designs, reducing possible part defects. The ideal gate location was researched using simulations. Comparing two gate positions was achieved. Comparative analysis found the optimal gate location. A poor diet reduces a number of product defects. Comparative analysis of the use of different gate types and runner systems for the same job, resulting in a satisfactory reduction of molding defects and increased pressure in the component, which is also within limits [6]

3. SYSTEM DEVELOPMENT

3.1 Problem Statement

Flat drippers being rejected because of short molding brought on by injection through a single injection point and long runner paths thus resulting in higher cycle time and runner wastage ultimately reducing production rate and growing customer complaints We closely examined the manufacturing process when the product was produced using the outdated mould, and we identified some significant flaws.

1. Short molding - A short moulding is when a mould cavity is only partially filled, producing an unfinished component. The plastic does not fill the void if a part is short shot. Before the flow routes are fully filled, the flow stops.
2. Flashes - Excess plastic that develops on the surface of injection-molded objects is known as mould flash, sometimes known as flashing. The separating line is where this undesired material is typically driven out of the mould cavity, although it can also come from other places.
3. Waste of material
4. Extended runner's path
5. Longer cycle times
6. Low pace of output
7. Margin of profits

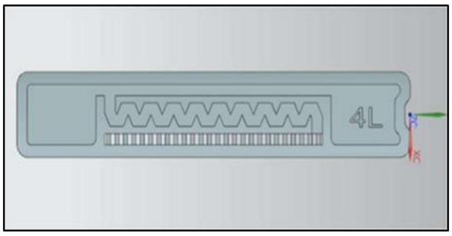
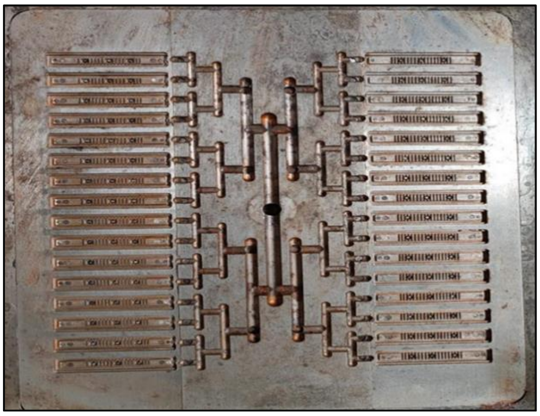


Figure 2: Flat Dripper

3.2 Problem Solution

1. The product that is being manufactured on this current working mold is called the flat dripper.
2. It has a discharge of 4 liters/hour and is widely used in the agricultural sector which is why it is in demand.
3. The current working mold shown in photograph 3.4 was not able to meet the production rate required which is why a new mold design with necessary modification is needed.
4. The new mold shown in photograph 3.5 has a very short runner path which reduces the material wastage by a huge margin and also reduces the cycle time.
5. There was a problem of short moulding which means incomplete filling of cavities and another problem of flashes which means excess material was being moved in cavities.
6. So, to resolve this issue and to increase the efficiency of the mold, hot drop technology will be used in the new mold.
7. The new mold has two separate cavity plates, each with 16 cavities and an injection point respectively. Unlike the old mold which has a single injection point for 32 cavities.



Photograph 3: Old Mold

Photograph 4: New Mold

3.3 Hot Drop Technology

Hot runner system delivers liquid plastic to variety of mold cavities in order to create a plastic product. it's an injection molding assembly that uses a heated manifold to keep plastic in a molten state. This heated plastic travels from the molding machine nozzle through internal channels called runners and may be delivered directly into multiple cavities at the same time.

Hot runners inject plastic directly into the cavities, as against the sprue and runner system used in a cold runner system. one among the biggest advantages to a hot runner system is that the plastic in the runners will never solidify. This decreases the cycle time, with faster processing. Another advantage of this system is a reduction in plastic waste, because the material does not harden until the mold is filled. The shortage of a sprue system substantially cuts down on the amount of trimming required to smooth the final product. Hot runners operate through a further manifold which is bolted to the mold assembly.

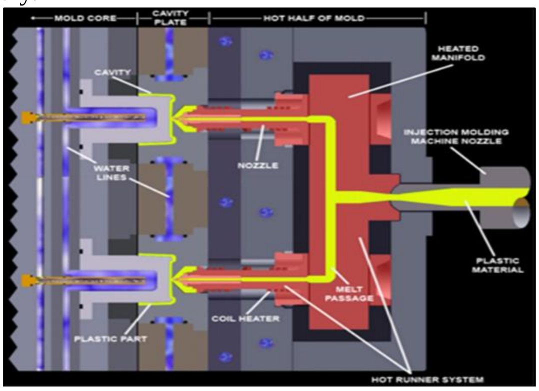
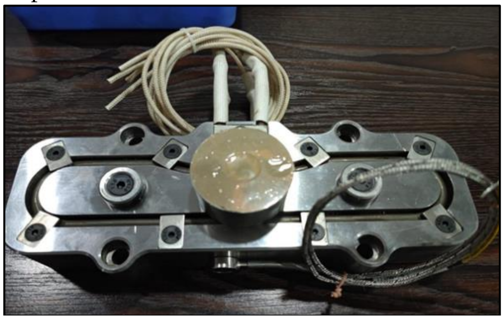


Figure 5: Hot Drop Technology

3.3.1 Use of Hot Runner Manifolds

Plastic, no matter application, begins during a mold that is classified as a cold or hot runner. Although there are advantages and drawbacks of each, many injection molding system manufacturers prefer the recent runner systems. for decent runner molds, the manifold system heats plates that melt plastic. From there, the plastic is shipped to nozzles that fill the cavities in the mold. Sometimes there are "heater bands" which keep the fabric warm inside the runner system prior to entering the mold itself. Although there are various sorts of hot runner systems, the 2 primary ones are internally heated and externally heated. the most important advantage of internally heated systems is that the flow of plastic is better controlled. However, when handling polymers that are sensitive to variations in heat, externally heated systems are the well-liked choice.

By using the recent runner manifold process for injection molding, cold runner slugs are completely eliminated. due to this, regrind and recycling performed with virgin plastics haven't any impact on cycle times, additionally, to faster cycle times, the recent runner systems do not require any robotics for removing the runners, larger parts are often accommodated, and there's less risk for potential waste. Additionally, electronic control is feasible through sequential valve gate technology that allows plastic to be deployed in a controlled sequential fashion into the part that may further improve cycle time, minimize warpage on cooling, and permit maximum processor control.



Photograph 6: Manifold

3.3.2 Use of Thermocouple

Thermocouples are the most extensively used bias to measure temperature in the injection molding assiduity. They correspond of a welded(hot) junction, between two super eminent cables of different essence (generally iron and constantan, Type J) and a reference junction at the other end of the lead cables. At the reference junction, an electrical current produced by the hot junction can be measured. This dimension corresponds to a specific temperature, which provides affair reading or control switching. Advantages of using thermocouples include the capability to measure a wide temperature range, continuity at high temperature, fast response time, and low cost.

Photograph 7: Nozzle with Thermocouple

3.4 Design consideration

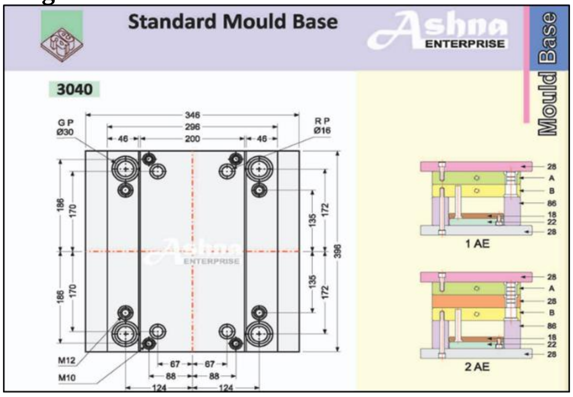


Figure 8: Standard Mold Base from Ashna Enterprise

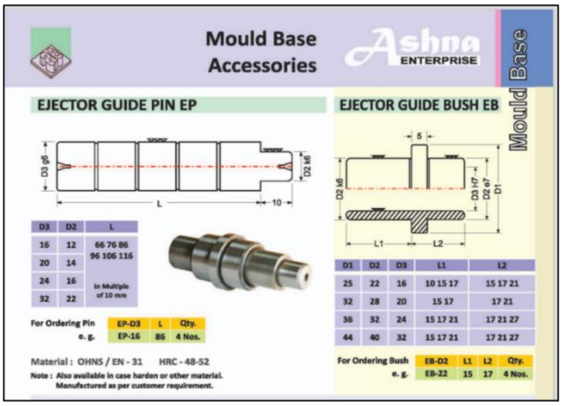


Figure 9: Standard size for Ejector Guide Pin and Ejector Guide Bush

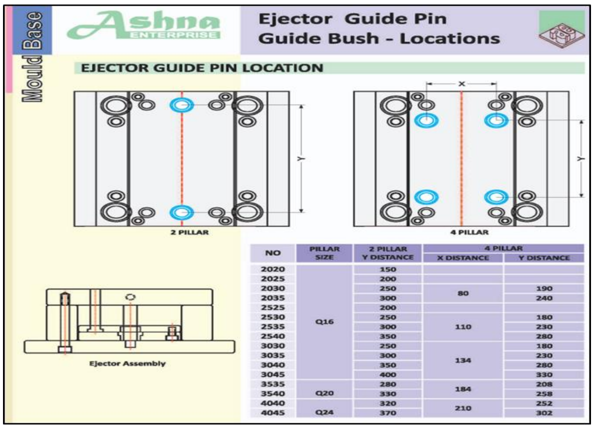


Figure 10: Standard Ejector Guide Pin and Guide Bush Locations

3.5 Runner Calculations

Runner Diameter (D) = ((W^½) * (L^¼)) / 3.7…… … (R.G.W. Pye Book)

Where, W = weight of component in gm

L = length of runner in mm Here, W = 0.000503 kg = 0.503 gm

L = 150 mm

So, D = ((0.503*16) ^½ * (150) ^¼) / 3.7 D = ((8.048) ^½ * (3.499)) / 3.7

D = 2.683 mm

Since D is less than 3 mm, we use modified formula, D = (((W) ^½ + (L) ^¼)) / 3.7) + k

D = 2.683 + 0.06 … (when D<3, we consider k=0.06) D = 2.741 mm

Therefore, D ≈ 2.75 mm (for safety)

3.6 Material Selection

3.6.1 C-45

1. Medium carbon steel with a moderate tensile strength is called C45 grade steel.
2. Limited parts of the material can be through-hardened by quenching and tempering, but the material can also be Hrc 55 induction- or flame-hardened.
3. This grade comes in a number of variations (denoted by additional letters) that offer modest adjustments to the chemical composition and is most frequently delivered in an untreated or normalized form.
4. Weldability is decreased, but machinability should be comparable to that of mild steel.

3.6.2 H-13

1. Chromium-molybdenum hot work steel H13 tool steel is a versatile material that is frequently utilised in both hot work and cold work tooling applications.
2. H13's hot hardness (hot strength) prevents thermal fatigue cracking, which develops as a result of repeated cycles of heating and cooling in applications involving hot work tooling.
3. H13 is employed in more hot work tooling applications than any other tool steel due to its exceptional combination of high toughness and resistance to thermal fatigue cracking (also known as heat checking).
4. H13 is employed in numerous cold work tooling applications due to its high toughness and excellent heat treatment resilience.
5. H13 outperforms conventional alloy steels like 4140 in these applications in terms of hardenability (through hardening in high section thicknesses) and wear resistance.
5. Additionally, offered as items that have been vacuum-arc-remelted (VAR) and electro-slag-remelted (ESR).
6. The chemical homogeneity is enhanced, the carbide size is refined, and the mechanical and fatigue properties are therefore enhanced by the remelting processes.

3.7 Process Sheets

3.7.1 Top Plate

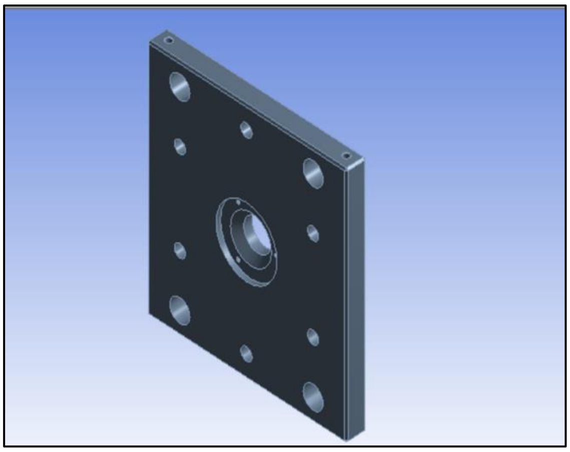


Figure 11: 3D view of Top Plate

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Table 1: Process Sheet for Top Plate

Mould Name: Flat Dripper 32 cavity (Hot Drop)
Part Name: Top Plate **Plate Size:** 360 X 380 X 36
Material: C45 **Quantity:** 1

Sr. No.	Operation	Machine Used	Tool Used	Time (Hours)
1	Milling	Milling Machine	Mill Cutter	4.5
2	Surface Grinding	Surface Grinding Machine	Grinding Wheel	2
3	Drilling	VMC Machine	VMC Drill	2

Photograph 12: Top Plate

3.7.2 Bottom Plate

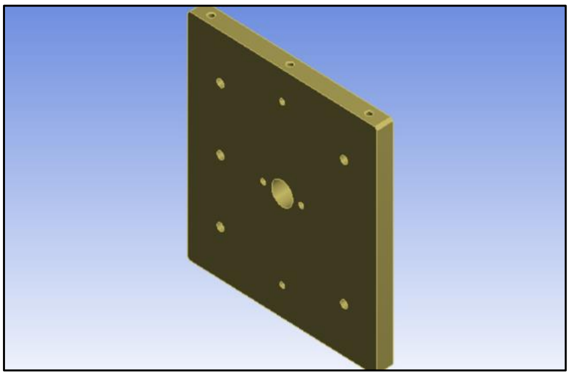

Figure 13: 3D view of Bottom Plate

Table 2: Process sheet for Bottom Plate

Mould Name: Flat Dripper 32 cavity (Hot Drop)
Part Name: Bottom Plate **Plate Size:** 360 X 380 X 30
Material: C45 **Quantity:** 1

Sr. No.	Operation	Machine Used	Tool Used	Time (Hours)
1	Milling	Milling Machine	Mill Cutter	4.5
2	Surface Grinding	Surface Grinding Machine	Grinding Wheel	2
3	Drilling	VMC Machine	VMC Drill	2

Photograph 14: Bottom Plate

3.7.3 Cavity Housing

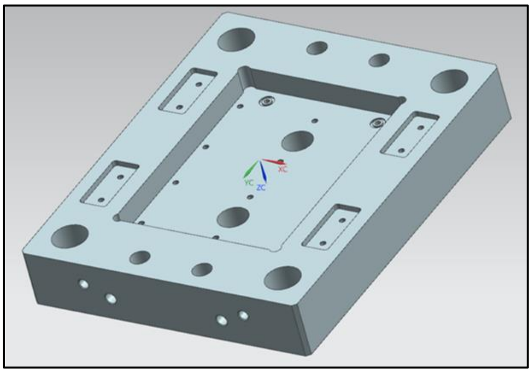

Figure 15: Cavity Housing Top view

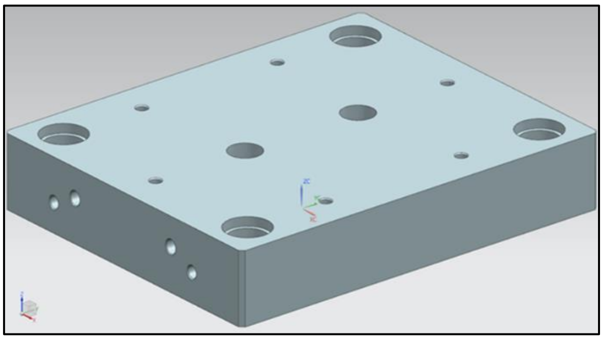

Figure 16: Cavity Housing Bottom view

Table 3: Process sheet for Cavity Housing

Mould Name: Flat Dripper 32 cavity (Hot Drop)
Part Name: Cavity Housing **Plate Size:** 310 X 380 X 62
Material: C45 **Quantity:** 1

Sr. No.	Operation	Machine Used	Tool Used	Time (Hours)
1	Milling	Milling Machine	Mill Cutter	6
2	Surface Grinding	Surface Grinding Machine	Grinding Wheel	3
3	Vertical Machining	VMC Machine	VMC Drills, Carbide Cutters, Boring Heads	12

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Photograph 17: Cavity Housing

3.7.4 Core Housing

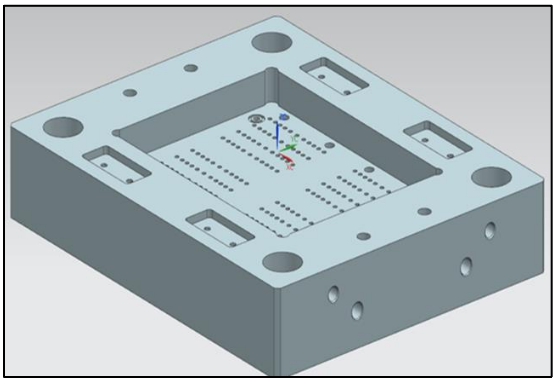
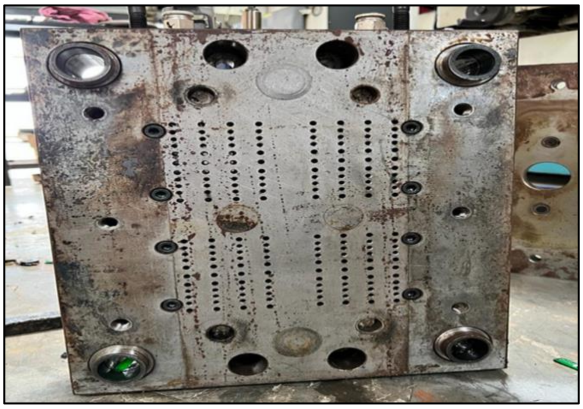


Figure 18: Core Housing Top view

Table 4: Process sheet for Core Housing

Mould Name: Flat Dripper 32 cavity (Hot Drop)
Part Name: Core Housing **Plate Size:** 310 X 380 X 66
Material: C45 **Quantity:** 1

Sr. No.	Operation	Machine Used	Tool Used	Time (Hours)
1	Milling	Milling Machine	Mill Cutter	6
2	Surface Grinding	Surface Grinding Machine	Grinding Wheel	3
3	Vertical Machining	VMC Machine	VMC Drills, Carbide Cutters, Boring Heads	12



Photograph 19: Core Housing

3.7.5 Spacer

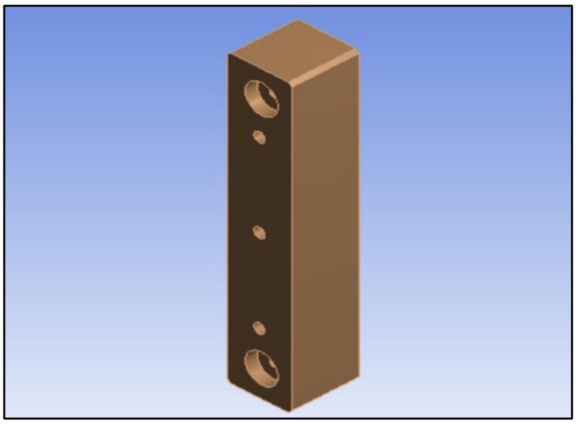


Figure 20: 3D view of Spacer

Table 5: Process sheet for Spacer

Mould Name: Flat Dripper 32 cavity (Hot Drop)
Part Name: Spacer **Plate Size:** 75 X 380 X 78
Material: C45 **Quantity:** 2

Sr. No.	Operation	Machine Used	Tool Used	Time (Hours)
1	Milling	Milling Machine	Mill Cutter	3
2	Surface Grinding	Surface Grinding Machine	Grinding Wheel	1
3	Vertical Machining	VMC Machine	VMC Drill	2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Photograph 21: Spacer

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3.7.6 Core Block

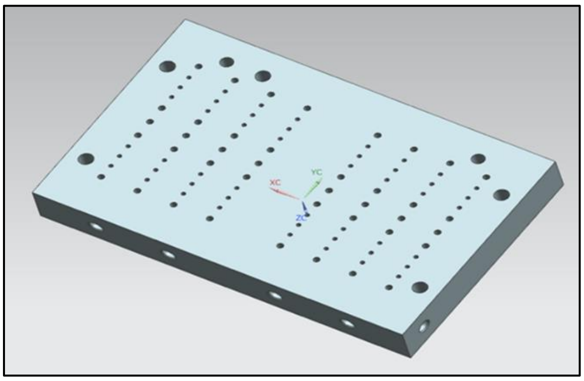


Figure 22: Core Block Bottom view

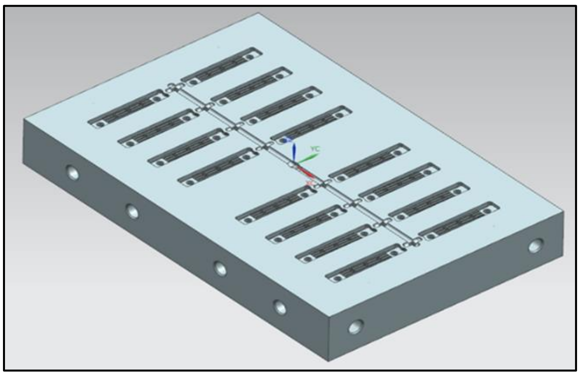


Figure 23: Core Block Top View

Table 6: Process Sheet for Core Block

Mould Name: Flat Dripper 32 cavity (Hot Drop)
Part Name: Core Block **Plate Size:** 184 X 120 X 26
Material: H13 **Quantity:** 2

Sr. No.	Operation	Machine Used	Tool Used	Time (Hours)
1	Milling	Milling Machine	Mill Cutter	3
2	Surface Grinding	Surface Grinding Machine	Grinding Wheel	2
3	Soft Vertical Machining	VMC	VMC Drills, Carbide Cutters, Boring Heads	10
4	Drilling	DRO	Drill	10
5	Tapping	-	Metric Taps	1
6	Heat Treatment	Furnace	-	3 days
7	Surface Grinding	Surface Grinding Machine	Grinding Wheel	4
8	Hard Vertical Machining	VMC	VMC Drills, Carbide Cutters, Boring Heads	10
9	Spark Drilling	Spark EDM	Copper Electrodes	180
10	Wire Cutting (Wire EDM)	Wire Cut EDM	Single Strand Metal Wire	30
11	Vertical Machining	VMC	VMC Drills, Carbide Cutters, Boring Heads	10
12	Spark EDM	Electronic Discharge Machine	Copper Electrodes	20
13	Inspection	Trimos	-	-

Photograph 24: Core Block

3.7.7 Cavity Block

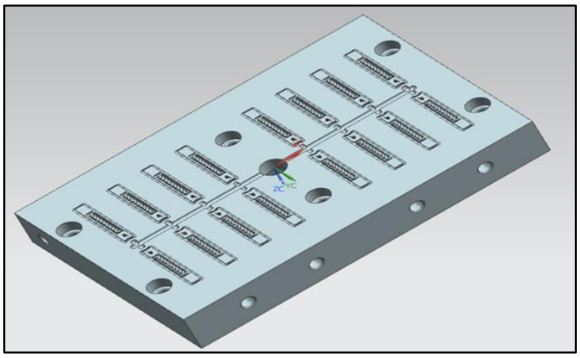


Figure 25: Cavity Block Top View

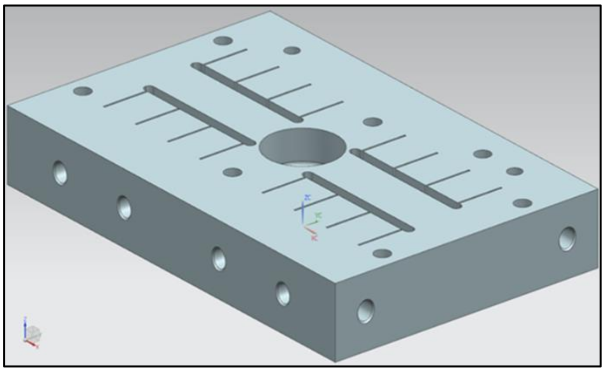


Figure 26: Cavity Block Bottom View

Table 7: Process Sheet for Cavity Block

Mould Name: Flat Dripper 32 cavity (Hot Drop)
Part Name: Cavity Block **Plate Size:** 184 X 120 X 26
Material: H13 **Quantity:** 2

Sr. No.	Operation	Machine Used	Tool Used	Time (Hours)
1	Milling	Milling Machine	Mill Cutter	3
2	Surface Grinding	Surface Grinding Machine	Grinding Wheel	2
3	Soft Vertical Machining	VMC	VMC Drills, Carbide Cutters, Boring Heads	10
4	Drilling	DRO	Drill	10
5	Tapping	-	Metric Taps	1
6	Heat Treatment	Furnace	-	3 days
7	Surface Grinding	Surface Grinding Machine	Grinding Wheel	4
8	Hard Vertical Machining	VMC	VMC Drills, Carbide Cutters, Boring Heads	10
9	Spark Drilling	Spark EDM	Copper Electrodes	180
10	Wire Cutting (Wire EDM)	Wire Cut EDM	Single Strand Metal Wire	30
11	Vertical Machining	VMC	VMC Drills, Carbide Cutters, Boring Heads	10
12	Spark EDM	Electronic Discharge Machine	Copper Electrodes	20
13	Inspection	Trimos	-	-

Photograph 27: Cavity Block

3.7.8 Ejector Plate

Table 8: Process Sheet for Ejector Plate

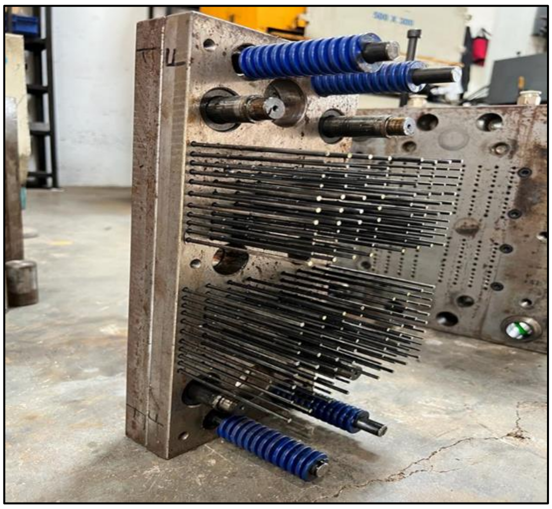
Mould Name: Flat Dripper 32 cavity (Hot Drop)
Part Name: Ejector Plate **Plate Size:** 156 X 380 X 22
Material: C45 **Quantity:** 1

Sr. No.	Operation	Machine Used	Tool Used	Time (Hours)
1	Milling	Milling Machine	Mill Cutter	3
2	Surface Grinding	Surface Grinding Machine	Grinding Wheel	2
3	Vertical Machining	VMC Machine	VMC Drills, Carbide Cutters, Boring Heads	3.5

Table 9: Process Sheet for Ejector Back Plate

Mould Name: Flat Dripper 32 cavity (Hot Drop)
Part Name: Ejector Back Plate **Plate Size:** 156 X 380 X 25
Material: C45 **Quantity:** 1

Sr. No.	Operation	Machine Used	Tool Used	Time (Hours)
1	Milling	Milling Machine	Mill Cutter	3
2	Surface Grinding	Surface Grinding Machine	Grinding Wheel	2
3	Vertical Machining	VMC Machine	VMC Drills, Carbide Cutters, Boring Heads	4.5



Photograph 28: Ejector Plate

3.8 Accessories of Mold

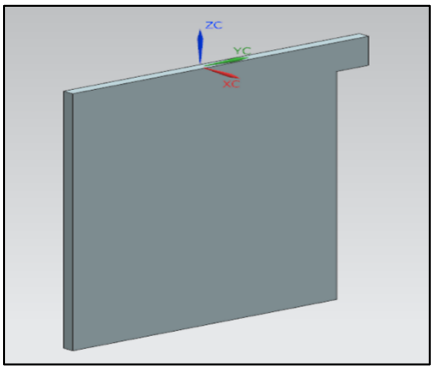


Figure 29: Cavity Insert

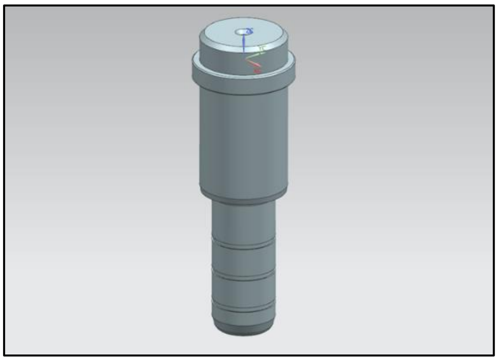


Figure 30: Guide Pillar

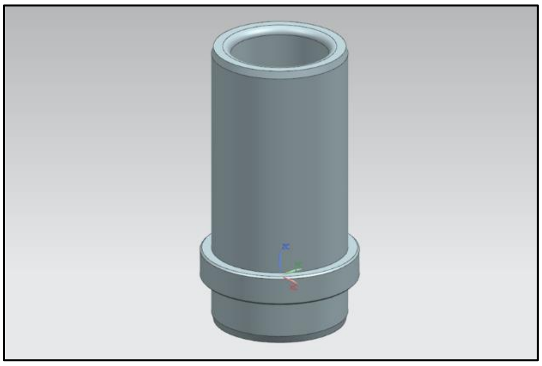


Figure 31: Guide Bush

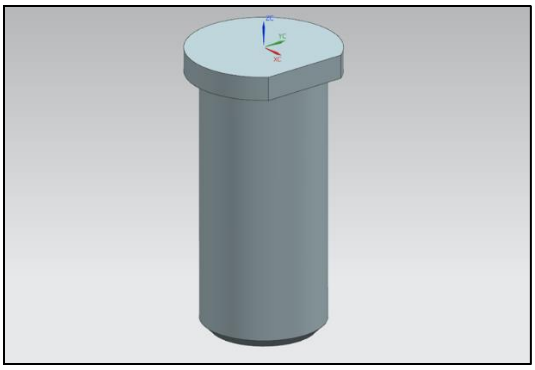


Figure 32: Ejector Rod

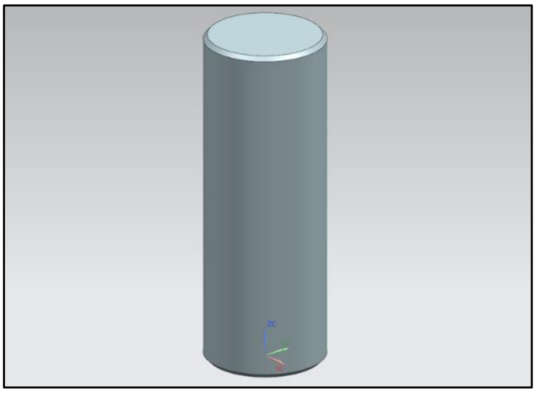


Figure 33: Support Pillar

3.9 Assembly of Mold

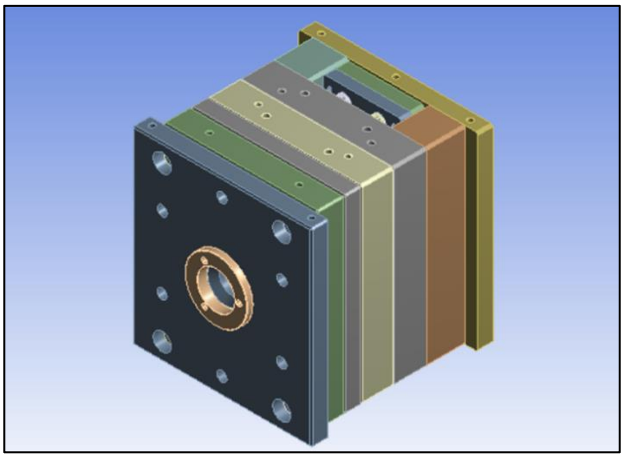


Figure 34: Assembly of Mold

3.10 Exploded view of Mold

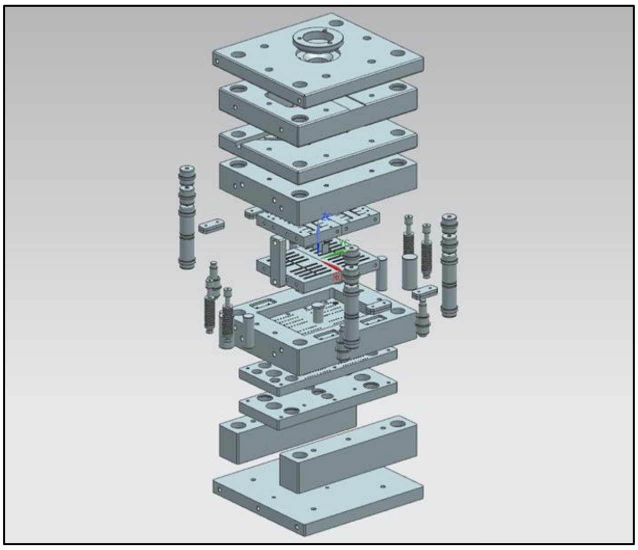


Figure 35: Exploded view of Assembly

4. SYSTEM PERFORMANCE

4.1 Total deformation and stresses induced in all the plates.

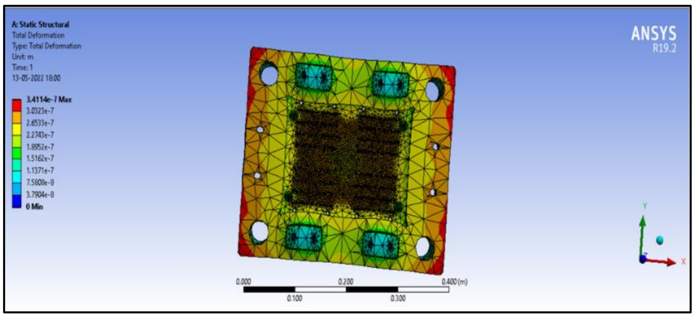


Figure 36: Total deformation of Core Housing

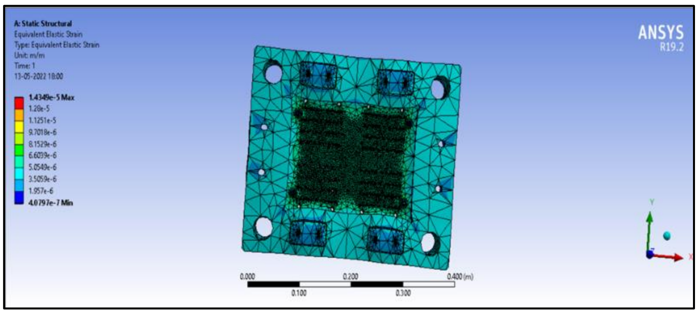


Figure 37: Stress induced in Core Housing

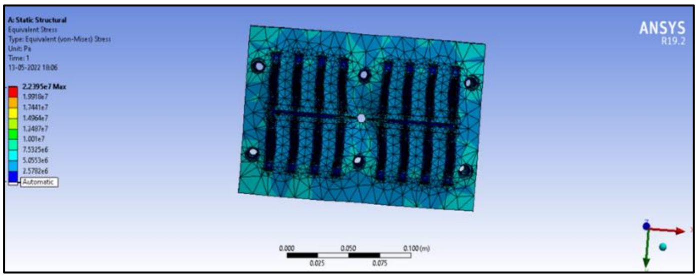


Figure 38: Stress induced in Cavity Block

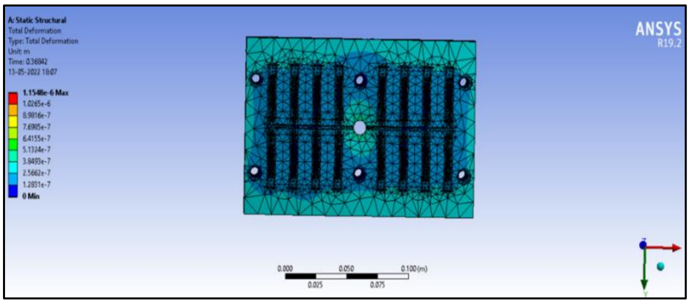


Figure 39: Total deformation of Cavity Block

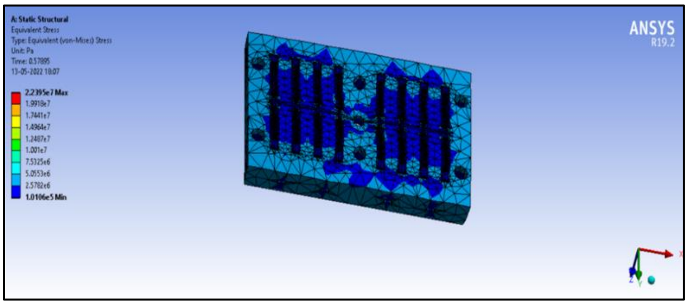


Figure 40: Equivalent stress induced in Cavity Block

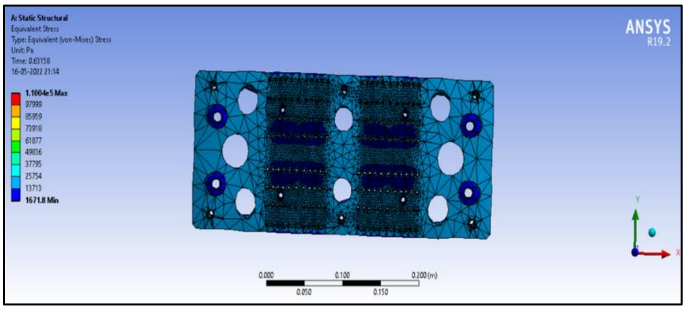


Figure 41: Stress induced in Ejector Plate

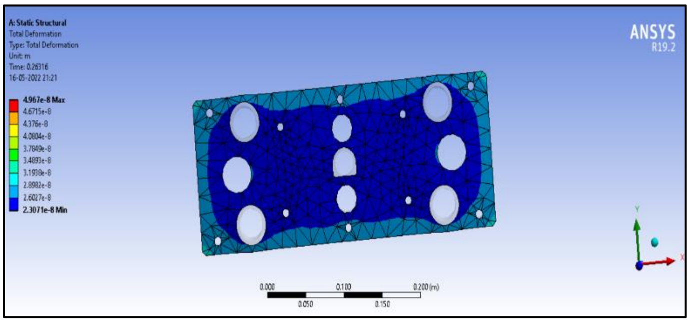


Figure 42: Total deformation of Ejector Back Plate

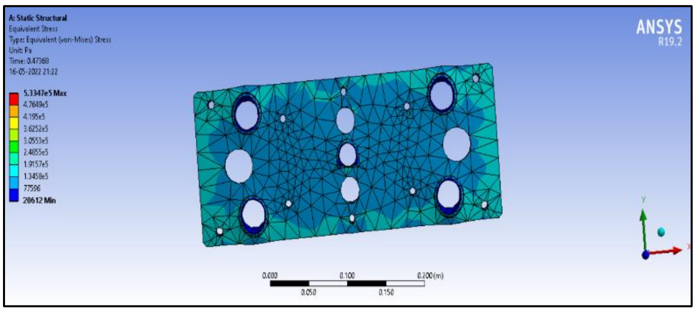


Figure 43: Stress induced in Ejector Back Plate

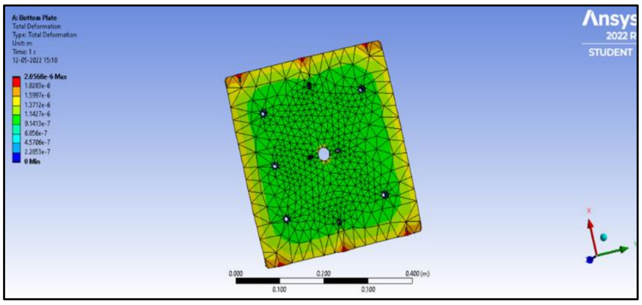


Figure 44: Total deformation of Bottom Plate

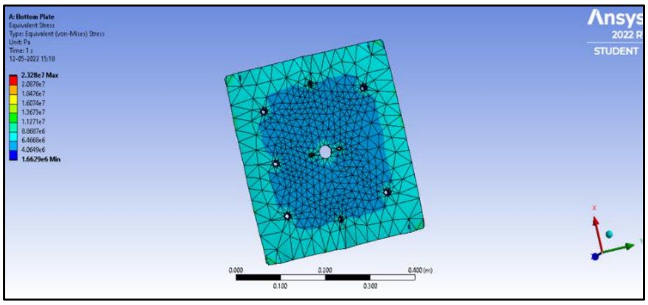


Figure 45: Stress induced in Bottom Plate

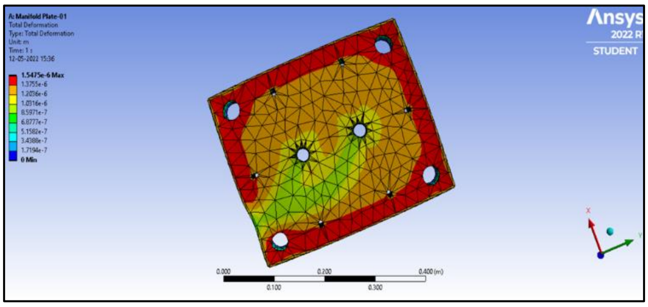


Figure 46: Total deformation of Nozzle Plate

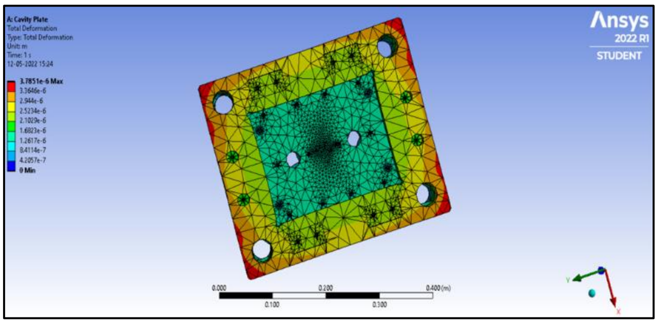


Figure 47: Total deformation of Cavity Housing

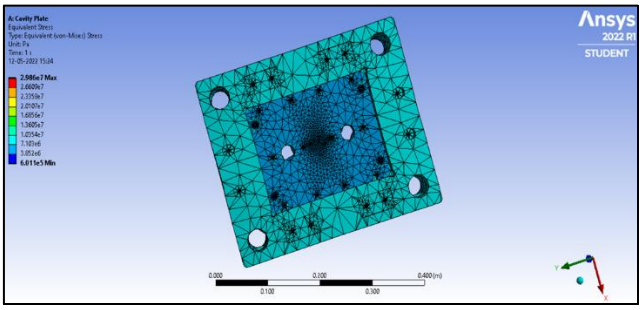


Figure 48: Stress induced in Cavity Housing

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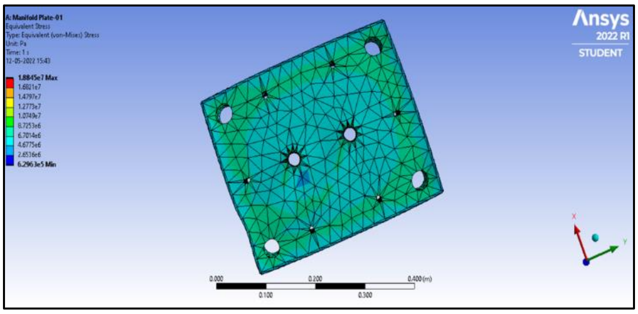

Figure 49: Stress induced in Nozzle Plate

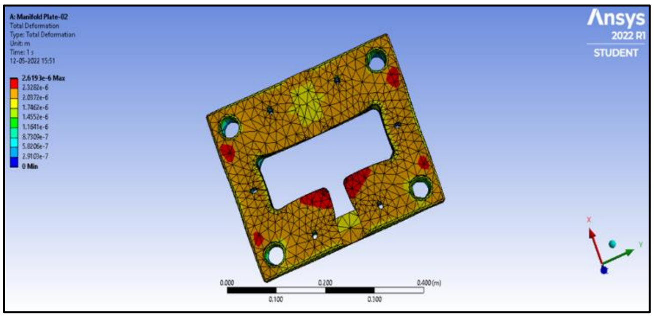

Figure 50: Total deformation of Manifold Plate

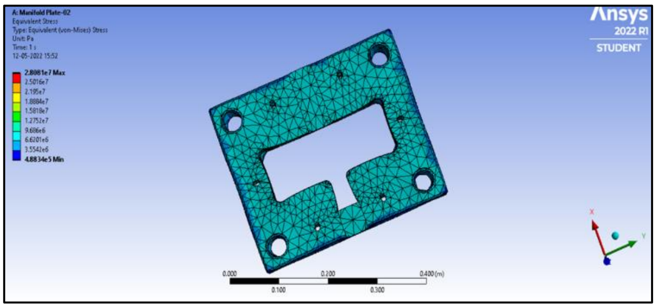

Figure 51: Total deformation Manifold Plate

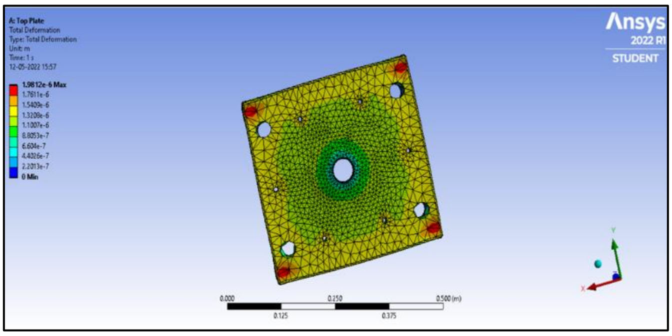

Figure 52: Total deformation of Top Plate

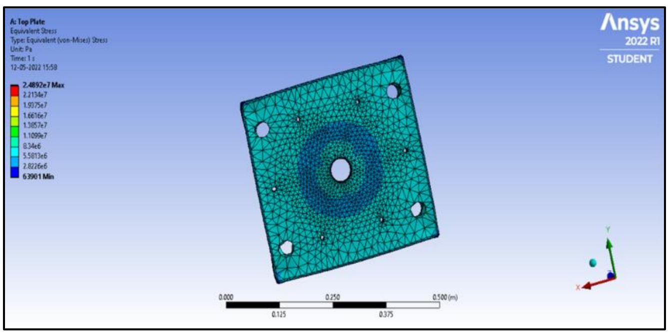

Figure 53: Stresses induced in Top Plate

5. ADVANTAGES

1. The main advantage of this process is that complex shape components having small wall thickness (5-15mm) can be easily molded and removed from the die without damage.

2. Injection-molded components offer good dimensional tolerance.

3. The major advantage of this technique is that the scrap produced by this is very less than compared to some other processes.

4. Investment cast iron and intricately machined pieces compete with parts produced through the injection moulding method.

5. Compared to other methods, this procedure produces goods at a high rate.

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