JURNAL

MACHINE DESIGN INJECTION MOLDING SIMPLE TO USE SOFTWARE SOLIDWORKS

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MACHINE DESIGN INJECTION MOLDING SIMPLE TO USE SOFTWARE SOLIDWORKS

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Abstract. Injection molding is a way to make a product from plastic material, about 30% of all plastic components are produced with injection stamps and 80% of engineering plastic products are manufactured with injections. The working principle of injection molding starts with filling, then packing, cooling and the last step is output. Injection molding machines are generally large-scale in the market, making them less effective for making small-sized products. Design injection molding using solidworks software and for analysis using Ansys software. Thermal analysis is used to analyze the heat as a test used to look at the chemical, physical, and structural changes of materials due to temperature changes so that the highest distribution of temperature on the surface of a barrel occurs at the surface between the barrel and the heater, which is 300,55°C, and well below the melting temperature limit of 903 K. Statistic simulation is a type of constant decomposition, used to describe a system where time is not affected by failure. The calculations showed the highest voltage of 9.17 Mpa at a load of 1000 N, still below the yield strength of 178 Mpa. The injection pressure obtained was 54 bar with an injections time of 2.03 seconds, a shrinkage of 0.269, and a glass weight of 15.05 grams

Keywords: *Heat Analysis, Injection Molding, Shrinkage, Solidworks, and Static Analysis.*

1. INTRODUCTION

Waste to waste disposed of will lead to problems such as air, water and soil pollution as well as greenhouse gas emissions. Indonesia is a country in Asia with a population of 237,641,326 people, making it the fourth largest in the world. Due to its large population, Indonesia ranks as the world's second largest producer of plastic waste at sea with a production of more than 3.22 million tons annually, and that number continues to rise. By 2022, Indonesia is estimated to produce approximately 20,270.094,62 tons of garbage. Of that amount, only 10,09.067,22 tons have been disposed of, or about 49.38% of it. About 18.4% of it is mostly plastic.

The manufacturing process used to make a product from a plastic material is called injection molding. Has a high level of efficiency that can produce complex components but keeps the cost low. Currently, more than 30% of all plastic components are produced by injection molding and 80% of engineering plastic products are manufactured by injectable molding. Plastics represent lightweight characteristics, low maintenance requirements, weather resistance, low toxicity, transparency, and affordability, which facilitate the application of plastics in a variety of industrial, commercial and agricultural activities. The Injection Process is perfectly suited for the production of mass-produced plastic components with complex shapes that require precision dimensions with a variety of materials to be used, Examples of products that include car front/back lights, children's products, cell phone covers, writing tools products, hand tools, cushions, etc.

Injection molding consists of two main groups: one is the hole group, which is the fixed side of the mold, and the other is the core group, that is, the moving side. One of the main methods of industrial processing. Most of the injection machines used in the industry today are injector types. During the injection, hot plastic is forced into a relatively cold mold. As the leech flows through the cold part of the mold, the heat is continuously taken from the plastic material. Plastic that borders directly with the cold mold walls will immediately freeze. Thermal analysis can be defined as testing used to evaluate chemical, physical, and structural changes in materials due to temperature changes.

2. LITERATURE REVIEW

Several researchers designed injection molding machines and suggested different methods to optimize their parameters for different products made of different materials.

(Cechmánek et al., 2023) They revealed that in order to avoid the problem of defects in the functionality of the injection mold it is recommended to perform analysis and simulation on the molding of injections using the autodesk inventor application.

(Alfauzi et al., 2024) conducting research on the Design and Analysis of Autoloader Equipment to assist the Loading Process of Polypropylene Plastic Seeds in Injection Printers. From this research they revealed that to avoid a waste of time the process of transferring plastic pellets due to the high hopper. The solution obtained was to use a vacuum autoloader platform that was designed using solidworks 2020 applications. The result of this research is a percentage difference before innovation and after that, which is 95.68%.

(Ramadan, 2024) conducting research on the design and simulation of polymer needles for production with injection printing machines. They revealed that to avoid small needles on injection molding that are difficult to clean and expensive because they are often used repeatedly. The solution is obtained from five different polymer materials (PS, PP, PLA, PC, ABS) with mold flow analysis to make the right product is a micro injection moulding machine.

(Kalami & Urbanic, 2019) conducting research on the cost of making low-volume production molds using high-temperature materials. The solution is to use the ideal low-cost additive manufacturing (AM), and enable fast design, assembly, and production, whatever the size.

(Liparoti et al., 2019) They conducted tests with polypropylene injection (iPP) to analyze the influence of the evolution of the surface temperature of the cavity. The results obtained from the test were using a very thin heater, activated by the joule effect and placed under the surface of a cavity, with limited temperature increases achieving extremely rapid heating and cooling,

(Hasan et al., 2023) conducting research on robust and reliability-based Multidisciplinary Design Optimization of Injection Printing Systems. They focus on optimizing the design of injection injections of multi-string injectors, taking into account the multidisiplinary nature of the injetion printing system. use applications (e.g., Autodesk Moldflow, SolidWorks Plastics) for design creation. The results of this research include the use of multidisciplinary resistance design (RDO/AOO) as well as multidisiplinary based design optimization (RBDO/ AOO) that provides optimal design solutions for flexible multi-hole inserts. Users can choose any combination of cycle time and pressure reduction as needed.

(Singh S., 2019) conducting research on progress in design and manufacture of conformal cooling channels for enhanced plastic injection. They focused on conventional cooling channels that provide unequal cooling due to variations in channel distances, resulting in defects such as sinking tents, curvature and thermal residual voltage so that the cycle time is longer. The results of this study show that modifying the cooling channel using square crossings and long square circles and applying conformal refrigeration, which is the latest approach that is more effective in increasing heat discharge because temperatures can be controlled accurately, thus result in shorter cycle times.

(Jinping Chen, Yanmei Cui, 2023) conduct research on Parametric Design and Optimization of Injection Processes Using Statistical Analysis and Numerical Simulation. They applied the Taguchi and Analog Analysis (ANOVA) methods to determine the most effective parameters in generating curves during the printing process using SolidWorks applications through numerical approaches. The results show that the ambient temperature and melting temperature are critical parameters that contribute to the warpage, with percentages of 42.115% and 41.278%, respectively. These findings could help reduce the waste of carbonated beverages and the rate of initial form rejection during the filling process, thereby improving the quality of the initial form.

(Sharifi et al., 2021) conducting research on Assessing the Adequacy of Free Shape Injection Prints for Low Volume injection prints section: Design Science Approaches. They focused on whether FIM can address the weaknesses of traditional IM, DAM, and software tools for pande series production. This research shows that FIM combines short waiting times, low initial costs, and Dam design freedom with IM versatility and scalability to bring low-volume products to the market faster with easy-to-launch adaptation.

(Zhang et al., 2023) conducting research on Plastic Print Design for One Direction Valve Chair Seafarer Pressure Pump Device Barrel. They focus on analyzing the one-directional valve adhesion process, studying the principle of plastic component printing and optimizing the design of the separation surface, with the adhesive which has a good structure easy to manufacture. This research, obtained results that the ASTM 1045 material showed good performance, simple mold structure, reduced production costs, as well as improved quality of plastic components.

3. RESEARCH METHODS

The research aims to design a simple plastic injection machine that is small and easy to move without the need for a tool.

The scope of this research starts from the initial planning stage, which involves surveys and data collection as the first step before designing concepts and design details. The limit of this research problem is that the device to be designed must be small in size with a maximum length of 720 mm, and capable of printing prints weighing a maximum of 3 grams in a single printing process.

3.1. Tools and Materials.

In this design, the following equipment is used:

1. Laptop Hp.
   The laptop used is a Hp Laptop with Hp 14s-fq0021AU series that has AMD Ryzen 3 3250U processor and 8 GB RAM. This laptop is used to operate design software such as SolidWorks, Mastercamx5, Ansys, and Inventor.
2. Software Solidworks 2022.
   SolidWorks 2022 was released on September 16, 2021 and is the latest version of the software. Dassault Systèmes SolidWorks Corporation has developed a CAD (Computer-Aided Design) design. Solidworks 2022 has been upgraded to provide a better user experience in its users. SOLIDWORKS 2022 also provides significant performance improvements, such as faster loading times, more effective response times, and better overall performance. So, users can do work with more complex designs without diminishing.

3.2. Material Aluminium 5052

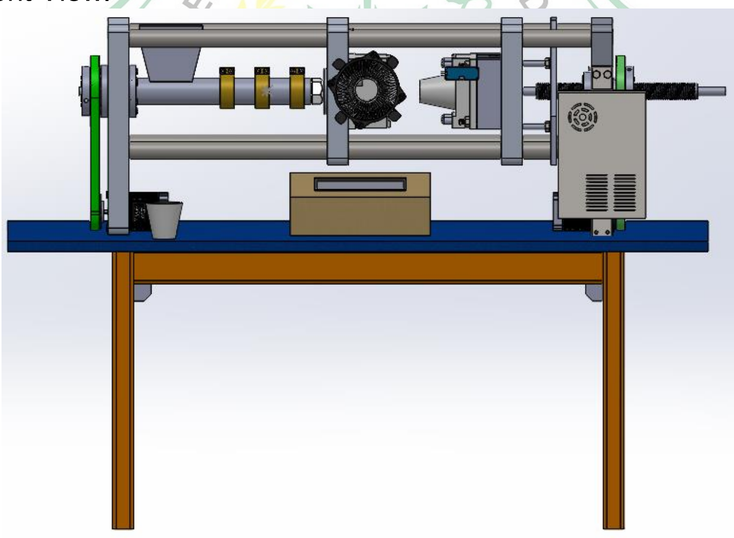
aluminium and copper showing lightness and high rigidity and corrosion resistance. This mixture is known as duralumin because it has a high degree of durability. Durability is the material has the ability to withstand shock loads, which can increase the product life due to fatigue.

aluminium properties

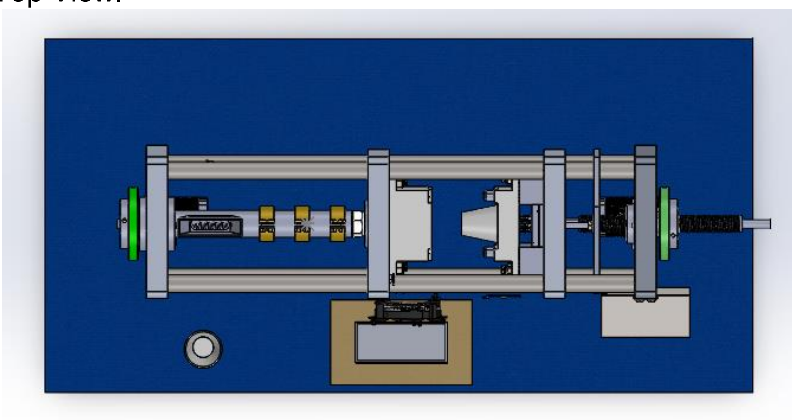
Aluminium 5052		
No	Material Trademark	5052
1	Density (kg/m3)	2.700
2	Young Modulus (Gpa)	70
3	Yield Strength (Mpa)	178
4	Poisson's ration	0,33
5	Constituive relation	$\sigma = 27,5\varepsilon^{0.16}$
6	Reference Strain Rate (S-1)	10^{-1}
7	Reference Temperature (K)	293
8	Melting Temperature (K)	903
9	Transition Temperature (K)	616

3.3. Design

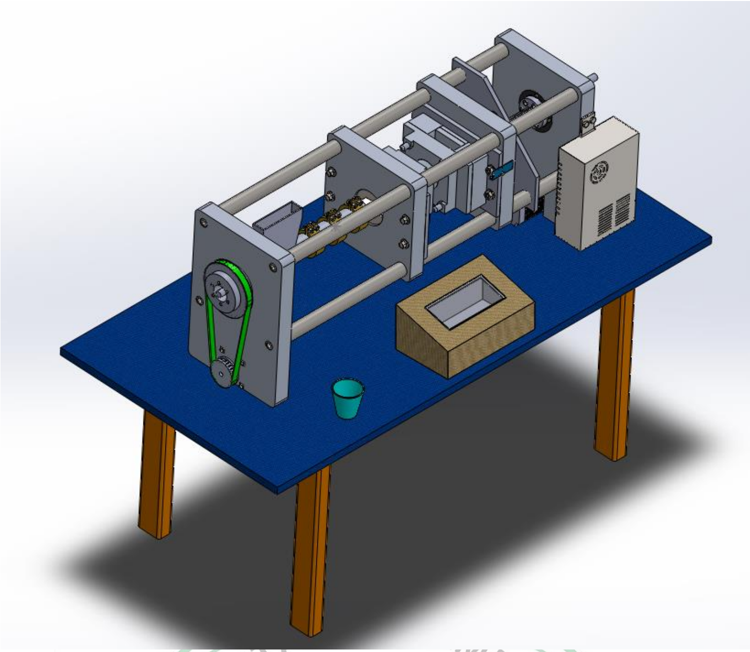
1. Front View.



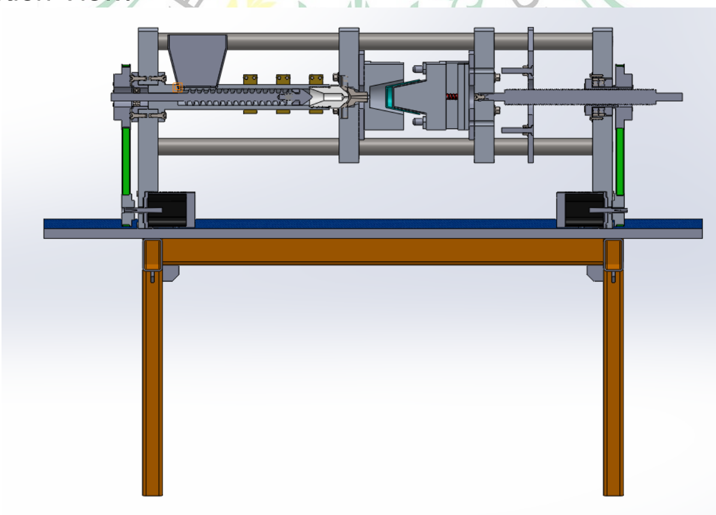
2. Top View.



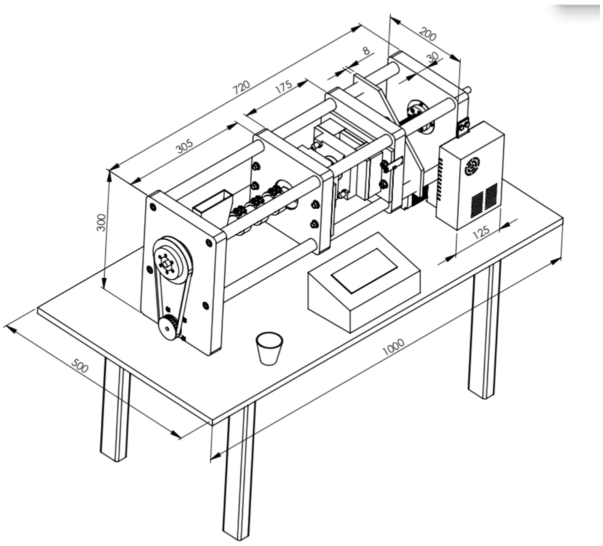
3. Isometri View.



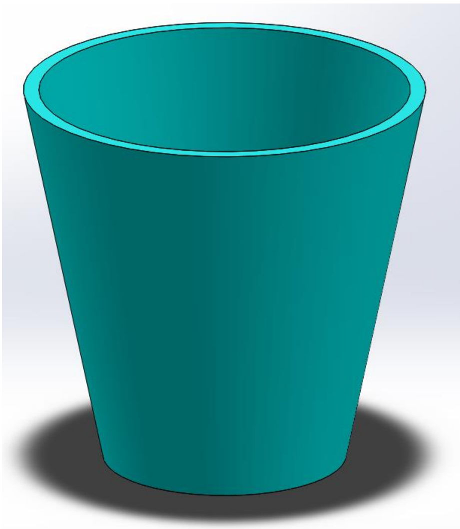
4. Section View.



5. 3D Dimension



6. Glass Products



3.4. Manual Calculation.

1. Nilai Volume Cavity.

$$V_{cav} = V_p(1+s\%)$$
$$V_{cav} = 75{,}16(1+0{,}5\%)$$
$$V_{cav} = 75{,}16(1{,}005\%)$$
$$V_{cav} = 75{,}5358mm^3$$

2. Shrinkage Value.

$$S = \frac{(\text{Mold Length} - \text{Product Length})}{\text{Mold Length}} x100\%$$
$$S = \frac{(7 - 5{,}131)}{7} x100\%$$
$$S = \frac{1{,}869}{7}$$
$$S = 0{,}269$$

3. Injection Pressure.

$$P_{spesific} = P_{hydrolic} \times \frac{A_{piston}}{A_{plunger}}$$
$$A_{piston} = \frac{\pi \times d^2}{4}$$
$$A_{piston} = \frac{\pi \times 30^2}{4}$$
$$A_{piston} = 706{,}5mm^2 = 7{,}065cm^2$$

$$A_{plunger} = \frac{\pi \times d^2}{4}$$
$$A_{plunger} = \frac{\pi \times 50^2}{4}$$
$$A_{plunger} = 1962{,}5mm^2 = 19{,}625cm^2$$

$$P_{spesific} = P_{hydrolic} \times \frac{A_{piston}}{A_{plunger}}$$

$$P_{spesific} = 150 bar \times \frac{7{,}065}{19{,}625}$$

$$= 54 bar$$

4. Injection Time.

$$t_{injeksi} = \frac{V}{Ca}$$

$$t_{injeksi} = \frac{80,272,74 mm^3}{39,532,06 mm^3 / s}$$

$$t_{injeksi} = 1,09 s$$

5. Machine Flow Capacity.

$$ca = a \times v$$

$$ca = 2,289,06 \times 17,27$$

$$ca = 39,532,06 mm^3 / s$$

6. Barrel Width.

$$A = \frac{\pi}{4} \times D^2$$

$$A = \frac{\pi}{4} \times 54^2$$

$$A = 2,289,06 mm^2$$

7. Wide Screw.

$$V_{screw} = \frac{P \times N}{60}$$

$$V_{screw} = \frac{0,745 \times 1390}{60}$$

$$V_{screw} = 17,27 mm / s$$

8. Required Motor Power.

$$N_o = \frac{Q \times L \times W_o}{367} - \text{Sin}\,\beta$$

$$N_o = \frac{200 \times 0,3 \times 4}{367} - \text{Sin}\,18$$

$$N_o = 0,34493 Kw = 0,46255 Hp$$

$$0,46255 Hp = 1 Hp$$

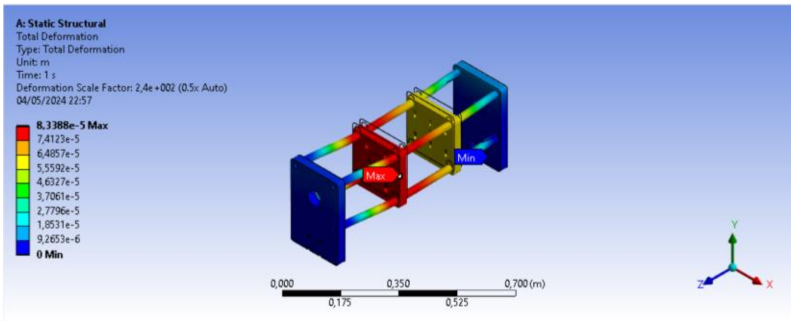
4. RESULTS AND DISCUSSION

In this study, the design of an injection molding machine unit for glass products using ABS material has been carried out.

4.1. Frame Loading Analysis.

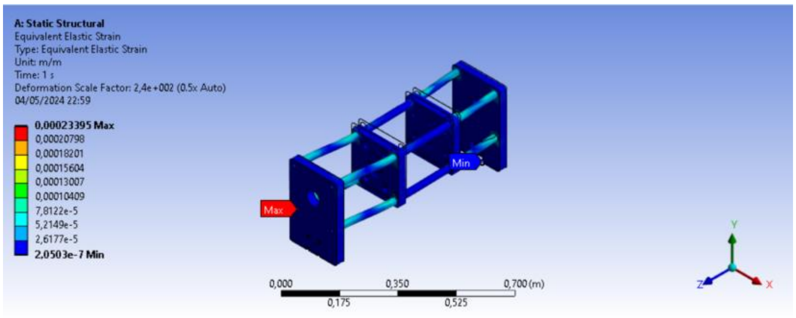
1. Total Deformation.

   The element method is used to calculate the total deformation. Simulation of the overall deformation indicates that the area with the heaviest load is marked in red. A safe area can be recognized by a color no darker than blue. The total deformation of the frame structure is a change in the shape, dimensions, and position of the material or object. Based on the maximum value, the frame undergoes slight changes in the structure, size and position. The maximum size of the deformations experienced by the frame due to a load of 100 kg (1000N) is 8,3388e - 5 m and the minimum deformity is 0 mm. For more information, please see the illustration result of the analysis of the total deformation of the structure as follows:



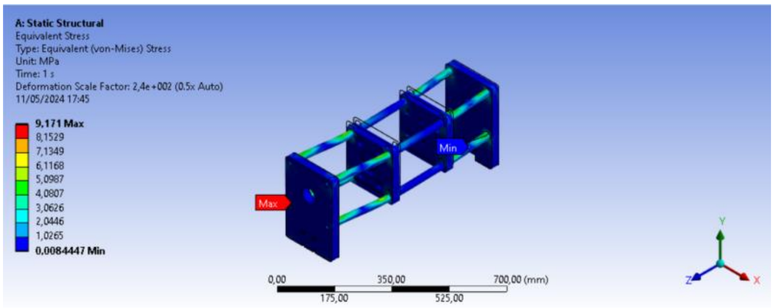
2. Equivalent elastic strain (von-mises).

   An elastic stretch simulation with a load of 100 kg (14000N) showed a maximum von-miss value of 0,00023395 mm/mm and a minimum of 2,0503e-7 mm/ mm. The equivalent elastic tension refers to the von-Mises approach, the elastic stretch is set as the threshold for the tension value in which the object will return to its original shape after the load is removed. The elastic boundary is the point at which an object changes from elastic behavior to plastic behaviour on a voltage-tension curve. Examples of equivalent elastic stretch analysis:



3. Equivalent stress (von-mises).

   In an equivalent stress simulation, a combination of elastic and axial loads occurs. The equivalent voltage that occurs in the frame area when loaded 100 Kg (1000N) is 9,171 Mpa maximum and 0,0084447 Mpa minimum, where the voltage is well below the allowable voltage (178 Mpa) shown in the figure:

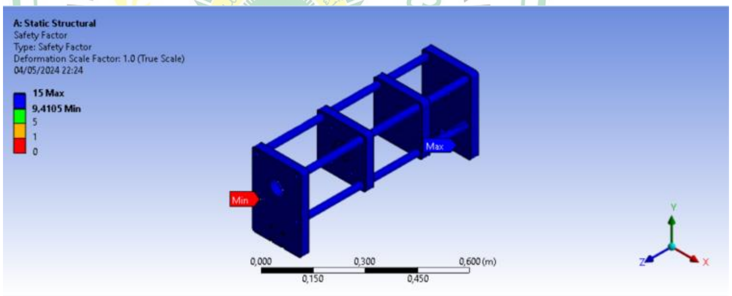


4. Safety factor

Safety factor is an important parameter in construction design. The safety factor is calculated by dividing the permission voltage by the actual voltage. For frames with a load of 100 Kg (1000N), the safety factor values range from 9,4105 to 15. The safety factor value range (sf) depends on the type of load applied:

- Static Load : 1,25 – 2,0
- Dynamic Load : 2,0 – 3,0
- Shock Load : 3,0 – 5,0

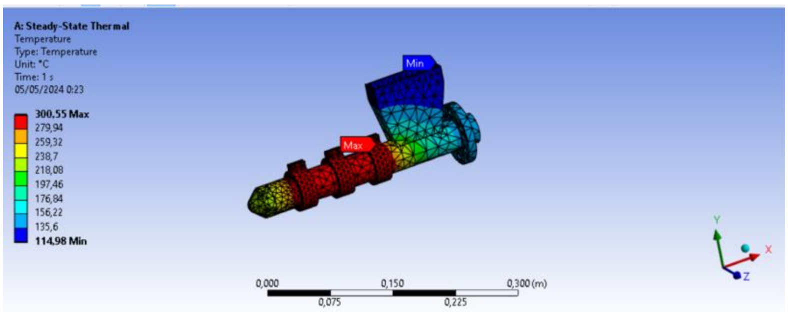
Based on the aforementioned guidelines, the Safety Factor simulation results show that the construction of the frame of injection molding is considered safe if the load received by the frame does not exceed 100 Kg.



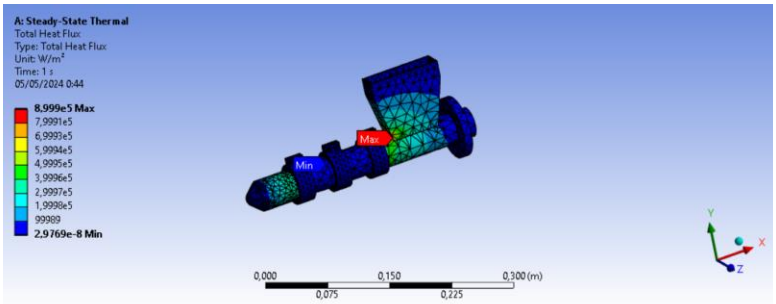
4.2. Heat Analysis of the Barrel.

1. Temperature.

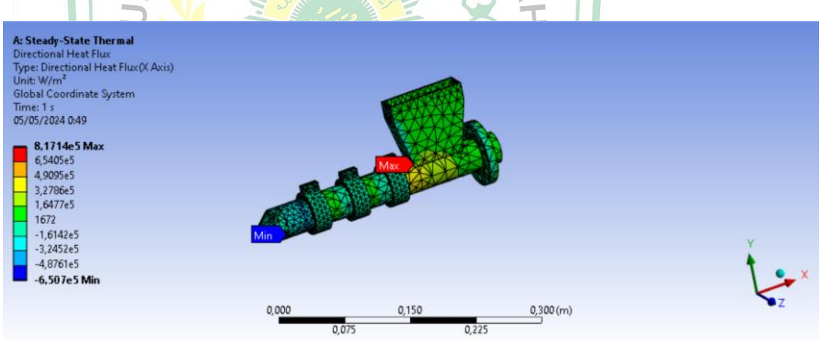
The distribution of the surface temperature of a barrel reaches its peak between the barrel and the heater, which is 300,55°C, but remains below the melting temperature limit of 903 K. Later, it reaches a state of equilibrium at 114.98°C. A state where the temperature of the system is equal to the ambient temperature



2. Total Heat Flux..
   Total Heat flux is the rate of heat energy transfer through a surface and out through a different surface. Heat flow is tangencial to the outer surface of a solid object (blade material), indicating that the direction of the heat flow will be towards a lower temperature surface. The data showed the highest total heat flux of 8,999e5 W/mm2 and the lowest of 0,010757W/mm2.



3. Directional Heat Flux.
   Heat flux directional is the rate of heat energy transfer through one surface and out through another surface. Heat flow is tangencial to the outer surface of a solid object (the knife material), indicating that the direction of the heat flow will be towards a surface with a lower temperature. The graph shows the magnitude of the heat flux in the direction of the X-axis, where the highest directional heat flow is 8.1714e5 W/mm2 and the lowest directional heat flow -6.507e5W/mm2.



CONCLUSION

Based on research, it can be concluded that after a plastic injection design with a thermoplastic material containing ABS, the design process of plastic injections uses solidworks 2022 software to create 3D designs and machine drawings. By manual calculation, injection pressure of 54 bar or 783,204 psi, engine flow capacity of 39,532,06 mm3/s, screw speed of 17,27 mm/s, barrel width of 2,289,06 mm2, engine power of 0,34493 Kw or 0,46255 hp (1 hp), injector time of 1,09 S, cavity volume of 75,5358 mm3, and Shrinkage value of 0,269 were obtained. With an analysis using an ansys application, an equivalent of Stress (Von Mises) frame of 9,171 Mpa with a load of 100 kg, a Yield Strength of 178 Mpa, and a temperature on a barrel of 300,55°C with a melting temperature of 903 K were obtained.

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