Effect of coolant temperature on product quality on injection molding machines using Autodesk Moldflow adviser software

Akhmad Wildan, Andoko Andoko*
Mechanical Engineering Department, State University of Malang
Semarang 5, Malang 65145, Indonesia
*Email: andoko.ft@um.ac.id

Abstract. Injection molding is a manufacturing machine that processes the production of small to large plastic packaging that does not have a cavity like a bottle. This study aims to analyze the effect of variations in mold cooler temperature and injection time on the quality of plastic products in multi cavities. The cooling system in the injection molding process affects the quality of plastic products, if the mold is too hot then the melt or liquid plastic will experience a slowdown in the freezing process resulting in defects in the product. This research uses the simulation method, the simulation is carried out to simplify the numerical approach analytically because in simulation it is not only part model, but also injection mold design can be checked and optimized by simulation with the Finite Element Method approach. The software used is ANSYS to obtain the Molding temperature and Autodesk Moldflow Adviser to get product quality. The variations used are temperature 16, 17, 18 with Melt temperature 230 and injection time of 2.4 seconds.

Keywords: simulation, cooling temperature, injection molding, finite element method, product quality

1. Introduction
Plastics are one of the most widely used chemical polymeric materials because plastics have advantages over other polymer materials including light weight but strong, transparent, waterproof and relatively cheaper and formed from polymerization of small molecules (monomers) of hydrocarbons that form chains that long with a rigid structure. The type of plastic used in the injection molding process is a type of thermoplastic [1]. The Plastic Injection Molding Process, a plastic product is produced by forcing a resin made of high pressure application plastic material into a mold where it is cooled, allowed to harden and after that it is removed from the mold by opening and dragging the die part.

The effect of the cooling system on product quality is very large. The production process of plastic packaging but the cooling system in the molding does not work or an error by the technician after installing the molding to the machine in the form of forgetting to open the cooling water valve will affect the temperature in the molding. The molding temperature is too hot, it will make the product or part difficult to freeze or solidify [2].

The flow type molding cooling system is very good for cooling, namely the turbulent flow type because this flow can dissipate the heat temperature in the molding wall better than laminar
flow type [3]. According to the molding process design, what must be considered is the use of the type of cooling circuit, the thickness of the cooling walls, the distance of the cooling holes and the diameter of the cooling holes [4].

The use of injection molding simulation provides a method for analyzing part models, but also the injection mold design can be checked and optimized by simulation. Most of the injection molding simulation software uses the finite element method to analyze heat transfer which is similar to the boundary integral of the formulation and in this study the temperature distribution rules in the injection mold, especially in the corners were analyzed by Autodesk Moldflow Insight 2011. The uneven cooling causes anisotropic shrinkage in the affected parts. is a major cause of angular deformation [5]. According to Amran’s research, injection time can affect the weight of the product, so that the percentage difference in product weight that occurs is a minimum of 0.35% and a maximum of 1.43%. [6] Finite element analysis provides a way to carry out an easy and efficient study of various parameters used by design and manufacturing which is easy to evaluate [7,8].

2. Method

2.1 Method
The Finite Element Method is used to analyze the average temperature in the cavity. Finite element analysis provides a way to carry out easy and efficient research on a variety of used parameters with easily evaluated design and manufacturing conditions [9,10]. Differential equations are often used to model problems in engineering. The core process of MEH is to divide a complex problem into small parts or elements from which simpler solutions can be easily obtained [11-13]. The solution of each element when combined will be a solution to the overall problem. Along with the development of computer devices, the problems that can be solved are increasingly varied and various computer programs are written. This study uses ANSYS software and AUTODESK MOLDFLOW ADVISER as software for research using the FEM (Finite Element Method) method. and 42.83 then mold temperature data is used to get product quality using Autodesk Moldflow Adviser software with injection time of 2.4 seconds [14].

2.2 Simulation
The simulation used in this simulation uses ANSYS and AUTODESK MOLDFLOW ADVISER, ANSYS is a very widely used software because it has very good and detailed results, but to run this software is quite complicated in the process of setting - up the parameters to be studied. And AUTODESK MOLDFLOW ADVISER used to analyze the product on an injection molding machine. To analyze products on injection molding, you can use AUTODESK MOLDFLOW, MOLDEX 3D, ANSYS POLYFLOW software and so on. The advantage of this software is that the results produced are the same as in direct injection machines. Meshing is used with node 100 with molding temperatures 16, 17, 18 and melt temperature 230 to obtain the mold temperature which will be analyzed using Autodesk Moldflow adviser with the plastic point boundary conditions injected into the mold.

3. Result and discussion
Molding temperature data obtained from the results of the analysis using ANSYS software are presented in the Molding temperature table used for setting up the product quality analysis process. The product quality was analyzed using AUTODESK MOLDFLOW ADVISER software. Figure 1 shows the hot flow of liquid plastic that enters the cavity molding or the place where the product is formed according to the shape of the product cavity.
Figure 1. Colour Plot Liquid Plastic Heat Flow in Cavity Molding

| Tabel 1 Result Temperatur Molding |
|-----------------------------------|
| Temperatur $Melt$ ($^\circ$C) | Temperatur Pendingin ($^\circ$C) | Temperatur $Mold$ ($^\circ$C) |
| 230 | 16 | 41.07 |
| 230 | 17 | 41.98 |
| 230 | 18 | 42.83 |

The results of product analysis in the form of fill time, gate pressure, quality prediction, weld line, and product cooling time are presented in Table 2. Color plot fill time, gate pressure, quality prediction, weld

| Table 2. Data Fill Time, Gate Pressure, Quality Prediction, Weld Line |
|---------------------------------------------------------------|
| $T \ Mold$ ($^\circ$C) | $t \ Inject$ (s) | $Fill \ Time$ (s) | Injection Pressure (MPa) | Quality Prediction | Weld Line |
|-----------------|------------|-------------|----------------------|------------------|-----------|
| 41.07           | 2.4        | 2.464       | 8.785                | 96.1%            | 0.7930°   |
| 41.98           | 2.4        | 2.453       | 6.847                | 99.3%            | 0.0069°   |
| 42.83           | 2.4        | 2.469       | 6.644                | 99.4%            | 0.0016°   |
The fill time or time the liquid plastic enters the product cavity is different from the injection time. The cause of this time difference is that when the plastic is injected into the molding, the plastic will pass through the gate cavity, because the gate diameter is small so that the filling time of the liquid plastic is longer than the injection time.

The injection pressure is influenced by the injection time, if the injection time is faster, the pressure will drop quickly, this is because the liquid plastic that is injected has a rapid drop in pressure because the time to push the liquid plastic is short.

The quality prediction parameters are fill, fill time, temperature, and ejection time. The product analysis process that has been carried out has obtained the highest percentage of product quality predictions, namely 99.6% and the smallest 96.1%. The highest percentage was at a molding temperature of 42.83 °C with an injection time of 2.4 seconds which resulted in a predictive percentage of product quality of 99.6%, while the smallest percentage was at a molding temperature of 41.07 °C with an injection time of 2.4 seconds which was 96.1 %. The results of this study did not differ in the value of the weld line. The toothbrush head product that has been analyzed has a weld line angle of 0.7930°. The biggest weld line angle that occurs is 135°.

4. Conclusion
Analysis of the molding temperature and product analysis that has been carried out are obtained data that have been presented in the previous section. The simulation results found no products that have no defects, the cooling temperature in the molding affects the product filling process or
The liquid plastic process enters the product cavity in the cavity. Errors in the injection time setup on the injection molding machine will cause product defects. The defect will affect the volume of plastic in the product and the weight of the product, the greater the occurrence of the defect, the lighter the product’s weight and the reduced plastic volume.

In this study, the optimal molding cooler temperature setup and injection time were used, namely using a coolant temperature of 42.93°C with an injection time of 2.4 seconds which has the product quality is 99.6% medium.

5. References
[1] A. S. Singha and R. K. Rana, “Preparation and properties of agave fiber-reinforced polystyrene composites,” J. Thermoplast. Compos. Mater., vol. 26, no. 4, pp. 513–526, 2013, doi: 10.1177/0892705711425848.
[2] R. A. Malloy and R. A. Malloy, Plastic Part Design for Injection Molding. 2010.
[3] S. M. Miner, Flow Analysis of injection mold, vol. 7, no. I. 2001.
[4] R.-Y. C. Maw-Ling Wang, “Molding Simulation Theory and Practice.”
[5] J. G. Kovács and B. Sikló, “Investigation of cooling effect at corners in injection molding,” Int. Commun. Heat Mass Transf., vol. 38, no. 10, pp. 1330–1334, 2011, doi: 10.1016/j.icheatmasstransfer.2011.08.007.
[6] M. A. M. Amran, N. Idayu, K. M. Faizal, M. Sanusi, R. Izamshah, and M. Shahir, “Part weight verification between simulation and experiment of plastic part in injection moulding process,” IOP Conf. Ser. Mater. Sci. Eng., vol. 160, no. 1, 2016, doi: 10.1088/1757-899X/160/1/012016.
[7] Andoko and N. E. Saputro, “Strength analysis of connecting rods with pistons using finite element method,” MATEC Web Conf., vol. 204, pp. 1–5, 2018, doi: 10.1051/matecconf/201820407009.
[8] A. Andoko, P. Puspitasari, and A. Permanasari, “Analysis of Strength of Glass Fibre Composite Leaf Spring Using Finite Element Method,” J. Mech. Eng. Sci. Technol., vol. 1, no. 1, pp. 1–8, 2017, doi: 10.17977/um016v1i12017p001.
[9] S. Efendi and Andoko, “Design and Simulation of Cracks in A Four-Cylinder Engine Crankshaft Using Finite Element Method,” IOP Conf. Ser. Mater. Sci. Eng., vol. 494, no. 1, 2019, doi: 10.1088/1757-899X/494/1/012004.
[10] A. Andoko, P. Paryono, R. Prasetya, R. P. Jeadi, P. Kurniawan, and D. R. Pradica, “Simulation of the effect of energy absorption on crashbox with full crash initiator and without crash initiator,” in AIP Conference Proceedings, 2020, vol. 2262.
[11] Andoko and P. Puspitasari, “Characteristics of leaf spring strength of material 65Si7 and material C17000 using finite element method,” AIP Conf. Proc., vol. 1778, no. October, 2016.
[12] A. Andoko et al., “The influence of crash initiator placement towards the application of energy crash box due to impact load,” in AIP Conference Proceedings, 2020, p. 040016.
[13] A. Andoko et al., “Simulation on CNC 5 axis milling spindle bolt using finite element method,” in AIP Conference Proceedings, 2020, vol. 2262.
[14] Autodesk, “Quality prediction result,” 2018.