Terbit *online* pada laman web jurnal : https://metal.ft.unand.ac.id

METAL: Jurnal Sistem Mekanik dan Termal

| ISSN (Print) 2598-1137 | ISSN (Online) 2597-4483 |

Research Article

The Manufacturing Process of Aluminum Hammer Molding Using CNC 3 Axis for Waste Plastic in the Injection Molding Machine

Reski Septiana[a], Dio Restu Putra Ardhika[a], Hendra[a], Hernadewita[b], Rahmayetty[c], Rispandi[d], Hermiyetti[e], Gusri Akhyar[f]

[a]*Department of Mechanical Engineering, Universitas Sultan Ageng Tirtayasa, Jl. Jendral Sudirman KM 3 Cilegon Banten, 42435, Indonesia*
[b]*Master Program of Industrial Engineering, Universitas Mercubuana, Jl Meruya Selatan, Jakarta, 10650, Indonesia*
[c]*Department of Chemical Engineering, Universitas Sultan Ageng Tirtayasa, Jl. Jendral Sudirman KM 3 Cilegon Banten, 42435, Indonesia*
[d]*Department of Mechanical Engineering, Faculty of Engineering, Universitas Andalas, Padang, West Sumatera 25163, Indonesia*
[e]*Faculty of Economics, Universitas Bakrie, Jl. H.R. Rasuna Said Kuningan, Jakarta, 12920, Indonesia*
[f]*Department of Mechanical Engineering, Universitas Lampung, Jl. Prof. Dr. Sumantri Brojonegoro No. 1 Bandar Lampung, 35145, Indonesia*

ARTICLE INFORMATION

Article History:
Received: 06 October 2025
Revised: 25 October 2025
Accepted: 31 October 2025

KEYWORDS

Injection Machine
Plastic waste
Recycle
Mechanical Properties
Quality of Product

CORRESPONDENCE

E-mail: hendra@untirta.ac.id

ABSTRACT

A process called injection molding involves cooling molten plastic after it has been injected into a mold to create a finished product. Polypropylene (PP) and polyethylene terephthalate (PETE), two basic ingredients used in plastic, are melted into a liquid and then injected into a mold. tests pertaining to the geometry of the molded product's shape and the mold's resistance at 150 °C. The mold material used in this study is aluminium 6061, and the techniques used are modeling and experimentation. The 6061-aluminum material has good temperature resistance and yields dimensional results, thickness, and shape that are almost identical to the design developed based on geometry features, which makes it suitable for use in the plastic injection process, according to the test findings.

1. INTRODUCTION

Because plastic goods are flexible and inexpensive to produce, their application is growing across a range of industries. By turning plastic trash into products from plastic melts, the injection molding technique aims to address Indonesia's excessive waste problem. The injection molding method is one of several processes used in the production of plastic materials. Polyethylene Terephthalate (PETE) and the material are used in this process. This material is strong, lightweight, and corrosion-resistant. This material is appropriate for applications requiring high temperature resistance because it is also resistant to high temperatures.

https://doi.org/ 10.25077/metal.9.2.139-145.2025

This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License

Correctly adjusting pressing, holding, pressing time, and holding duration during the injection molding process can increase product quality and save manufacturing costs. This is because the process parameters those hydraulic systems often function within are one of the most important factors that need to be considered in order to succeed [1].

In order to manufacture items or components in the desired shape and size, this mold is a useful tool [2]. The most crucial component in the process of creating plastic melt products are molds, which can facilitate the production of goods in big quantities. This mold's creation involves multiple steps and makes extensive use of software to support the research's design, materials, and design simulation. The CNC 3 AXIS machine used in this study makes it simpler to create program code for the CNC 3 AXIS machining process. By transforming the Computer-Aided Design (CAD) design into Computer-Aided Manufacturing (CAM), the research mold is produced as a hammer head product. Following the creation of technical drawings, the movements of the machine and the cutting tool are calculated to carry out the cutting operation automatically in compliance with the program. For the manufacturing of molded products, Autodesk Fusion 360 is used to simulate the machining process with the aim of acquiring the shape and dimensions according to the design in order to eliminate errors or flaws in machining with CNC 3 AXIS and avoid excessive production costs [3].

Previous studies on the many changes in the injection molding process [4-7], such as temperature, mold material, and plastic type, have yielded a number of conclusions [8-11]. Polypropylene (PP) and polyethylene terephthalate (PETE) have been utilized in earlier studies on mechanical qualities that make them appropriate for hammer head molds because they melt to generate material with a high enough tensile strength to be suitable for hammer head material. Based on references to previous studies and the melting point of the plastic type used, 150 °C is the temperature used in the injection molding process.

2. METHOD

Both experimental and simulation techniques are used in this study; simulation is used to calculate the mold temperature resistance thermal value and before the CNC 3 AXIS machining process. Conduct SolidWorks and Autodesk Fusion 360 simulations, review injection molding mold literature, and perform testing and machining operations. Figure 1 shows the design of the hammer head mold.

2.1 Research Methods

In order to determine the thermal value of the hammer head mold material resistance when subjected to heat treatment, as well as to simulate CNC 3 AXIS cutting prior to machining, this study employs both simulation and experimental methods. Figure 2 depicts the hammer head mold's design.

2.2 Design Parameters of Hammer Head Mold

The following elements are essential to the design of the head mold.

a. Material, Since the mold will be heated to create the product, the material used to make the mold must behave in a certain way. 6061 aluminum is the main material used to manufacture molds because it satisfies the requirements by having properties that make it difficult for it to corrode and a high heat tolerance.
b. The Mold Design, the mold design should be built to ensure the best possible flow of plastic melt into the mold chamber, in addition to creating a cooling system to prevent product defects.
c. Product Design, the simplicity of plastic flow must be considered in the shape of this mold product, and the most important prerequisite is that the mold wall has a minimum standard thickness of 4 mm. The mold will be destroyed if the wall is too thick.
   1. Hammerhead mold design

https://doi.org/10.25077/metal.9.2.139-145.2025

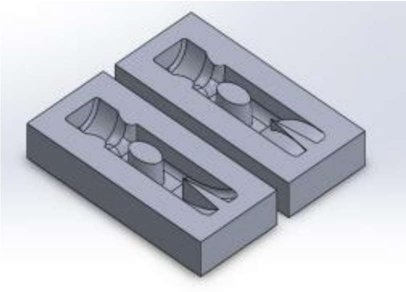

Figure 1. Hammer Head Mold

2. Hammer Head Mold Design Dimensions

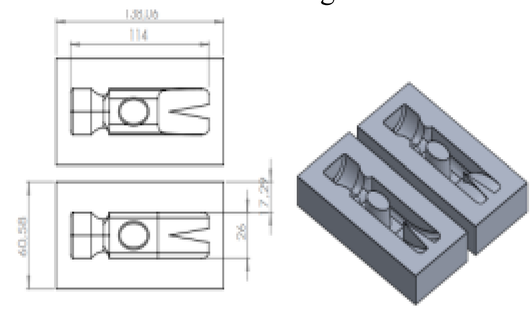

Figure 2. Hammer Head Mold Design

2.3 Steps in the Creation of a Hammer Head Mold

There are multiple steps involved in creating this hammer head mold product, including

1. Hammer Head Mold Design and Simulation, Using SolidWorks software, hammer head molds are designed and simulated with the goal of reducing costs and streamlining the mold machining process. or faulty mold products. Using the simulation feature and choosing the material, aluminum 6061, the hammer head mold design is also thermally simulated at 150–200 °C. The outcomes of this thermal simulation are shown in Figure 3.
2. Hammer Head Mold Design and Simulation, using SolidWorks software, hammer head molds are designed and simulated with the goal of reducing costs and streamlining the mold machining process. or faulty mold products. Using the simulation feature and choosing the material, aluminum 6061, the hammer head mold design is also thermally simulated at 150–200 °C. The outcomes of this thermal simulation are shown in Figure 3.
3. The simulation's goal is to determine whether the 6061 aluminum material can tolerate high temperatures without affecting the mold's shape or dimensions. Figure 3 illustrates the thermal that occurs in the material, which can reach a maximum temperature of 158 °C.

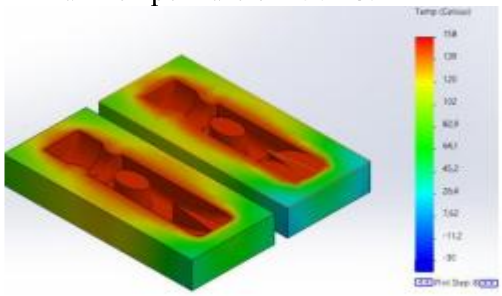

Figure 3. Thermal Simulation of a Hammer Head Mold

4. Developing the NC Program and Cutting Simulation, design findings are converted from CAD to CAM when a program is created for CNC 3 AXIS machining needs. The objective is to identify the toolpath that was utilized prior to the feeding process, write program code to ensure that no flaws arise throughout the feeding process, and simulate the cutting using the created dimensions. Software called Autodesk Fusion 360 is used for this (CAM) technique. Figure 4 will show the simulation display that follows.

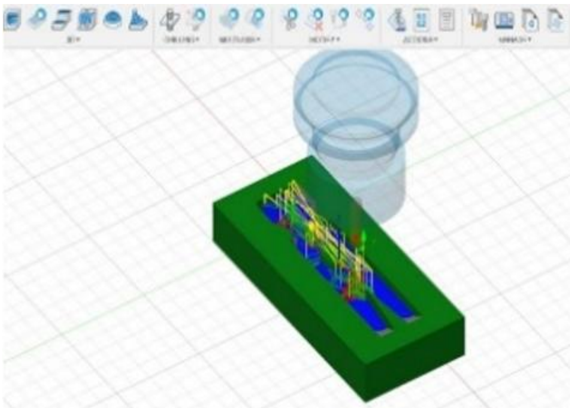

Figure 4. Simulation of Cutting

The results of the simulation indicate that the design of the hammer head mold requires a toolpath that employs a 2 mm diameter HSS ball nose tool for contour finishing and a 6 mm diameter HSS endmill tool for feeding. This hammer head mold is anticipated to cut in about 90 minutes. Choose the required tools to create a CNC 3 AXIS machining program after this toolpath has been determined.

5. Performing the NC Program Entry Process, the NC program created in the Autodesk Fusion 360 software is entered into the Mach 3 CNC software to translate the code results and perform feeding. The machining procedure is depicted in Figure 5.

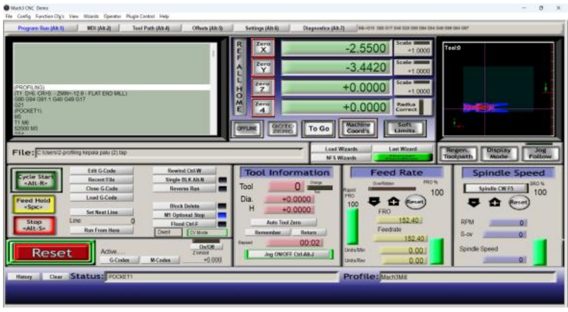

Figure 5. *Mach 3 CNC*

This shows the feeding process using Mach 3 CNC software, with the machine's spindle speed set at 2500 rpm and the feed rate set at 600 mm/min.

6. Performing the Machining Process, as shown in Figure 6, the CNC 3 AXIS machine will be utilized to finish the cutting process after all operations have been completed.

Figure 6. Machining Process

3. RESULT AND ANALYSIS

3.1 Calculation of Mold Machining Process

An HSS endmill tool with a 6 mm diameter and a finishing ballnose tool with a 2 mm diameter are used to mill the 26 mm thick workpiece. The following calculations are part of the machining process used to create molds.

a) Cutting Speed (Vc)
The following below is a systematic formulation.

$$Vc = \frac{\pi \,.\, d \,.\, n}{1000}$$

where:

Vc = Cutting Speed (mm/min)

d = Tool Diameter (mm)

n = Spindle Rotational Speed (rev/min)

Then,

d = 6 mm

n = 600 rev/min

$$Vc = \frac{3{,}14 \,.\, 6 \,.\, 600}{1000} = 11{,}3\ mm/min$$

b) Feeding Speed (V_F)
Formulation to determine the feeding speed.

$$Vf = f \,.\, z \,.\, n$$

where :

Vf = Feeding Speed (mm/min)

f = Feeding Rate (mm/min)

z = Number of Cutting Tool Blades

n = Machine Turn (Turn/min)

then,

f = 0,25 (mm/min)

z = 1

n = 600 rev/min

$Vf = f \,.\, z \,.\, n$
$= 0{,}25 \,.\, 1 \,.\, 600$
$= 150\ mm/min$

c) Cutting Length and Cutting Time
To calculation of cutting length and time using the formula:

$L = l_n + l_w + l_v$

$t_c = \frac{L}{Vf}$

where:

t_c = Cutting Time (min)

L = Cutting Length (mm)

l_n = Overall Feeding Distance (mm)

l_w = Initial Cutting Distance (mm)

l_v = End of Cutting Distance (mm)

then,

l_n = 200 mm

l_w = 600 mm

l_v = 600 mm

 https://doi.org/10.25077/metal.9.2.139-145.2025

$$L = l_n + l_w + l_v = 200 + 600 + 600 = 728\ mm$$

$$t_c = \frac{L}{Vf} = \frac{728\ mm}{150\ mm/min} = 9{,}3\ min$$

3.2 CNC 3 AXIS Machine Parameters

The CNC 3 AXIS machine settings utilized in the two machining processes—roughing and finishing—to make this hammer head mold out of 6061 aluminum are listed in Table 1.

Table 1. Parameters of CNC 3 Axis Machine

Parameters	Detail	
	Roughing	Finishing
Cutting Tool	HSS Endmill Dia. 6 (mm)	HSS Ballnose Dia. 2 (mm)
Depth Of Cut	0,25 (mm)	0,2 (mm)
Feed rate	600 (mm/min)	50 (mm/min)
Spindle Speed	2500 (rpm)	1500 (rpm)
Duration	90 (min)	10 (min)

According to the results of the hammer head mold's machining process, the mold's surface is challenging to smooth due to the extremely small cavity or gap, which makes the finished product less than perfect. However, the dimensions and shape remain same and match the design.

3.3 Temperature Resistance Testing

Determining the temperature that is received in the mold during the filling of the plastic melt into the mold is the aim of the temperature resistance testing on this mold. The temperature is monitored using two types of previously calibrated K-type thermocouples. The following image shows the K type thermocouple installation on the hammer head mold shown in Figure 7.

Figure 7. Thermocouple setting point

The thermocouple's probe placement positions are shown in Figure 7. The test uses 6061 aluminum, which by its very nature can tolerate temperatures of up to 450 °C. The test temperature is 150 °C. The test results are shown below.

Testing Mold Temperature Resistance 150 °C.
A temperature of 150 °C connected to the probes of two calibrated K-type thermocouples is used in this test to determine the hammer head mold's temperature resistance. The melting points of PP and PETE polymers are 130 °C and 150 °C, respectively, and 150 °C is the temperature at which they melt. To determine the injection time needed to fill the mold, a simulation is run prior to the temperature resistance testing procedure. The simulation figure is shown below.

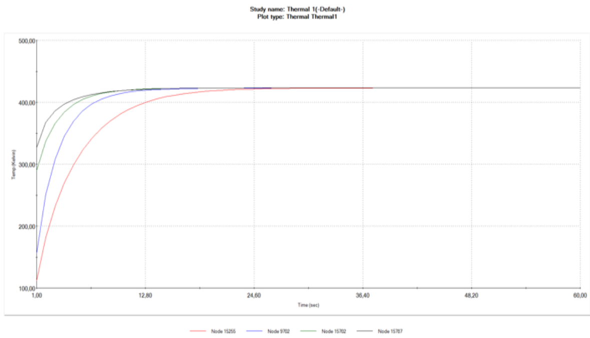

Figure 8. Testing Mold Temperature Resistance 150°C

The injection time versus temperature graph in Figure 8 illustrates that the longer the injection time, the higher the temperature. This is because the injection process uses two molds to retain heat in the mold, which causes the mold temperature to rise automatically as the plastic melts. Table 2, which follows, will display the actual data from the mold's temperature resistance test at 150°C.

Table 2. Temperature Change Result Temperature 150°C

Temperature 150°C				
Temperature changed at dies (dT)				Time (minutes)
T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)	
30	32	33	34	2
49	51	53	55	4
53	54	58	60	6
61	66	68	70	8
76	78	80	84	10
88	90	91	92	12
95	99	102	104	14

It is evident from Table 2 data that the longer the injection period, the higher the temperature in this mold, as the longer the duration, the more material is injected into the mold. The following data findings will be shown in the graph below once the mold is fully filled for 14 minutes at 150°C.

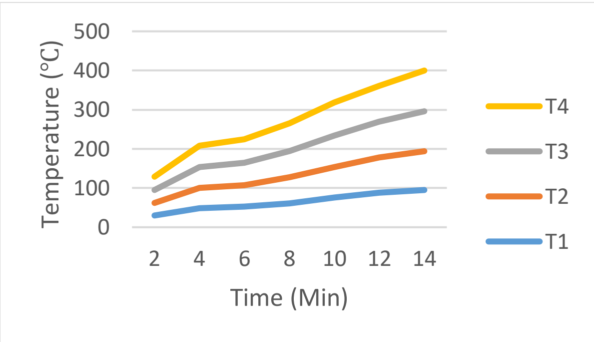

Figure 9. Temperature 150 (°C) depend on Time

Figure 9 illustrates how the temperature rises with increasing time since the thermocouple cable is connected to the mold's upper wall. As the mold fills up, the temperature will continue to rise as the injection time increases. Too-low temperature changes can result in improper liquid flow into the mold, which can lead to short shot faults in the final product. Additionally, a shortage of materials may lead to subpar output.

3.4 Geometric Characteristic Testing

Dimensions can be measured and assessed with the use of geometric characteristic testing [11]. Regarding the geometry of the dimensions of this product measured with measuring tools like micrometers and calipers, the test method for determining dimensions refers to the ISO 1101 standard. The mold's detailed dimensions results are shown n Fig. 10.

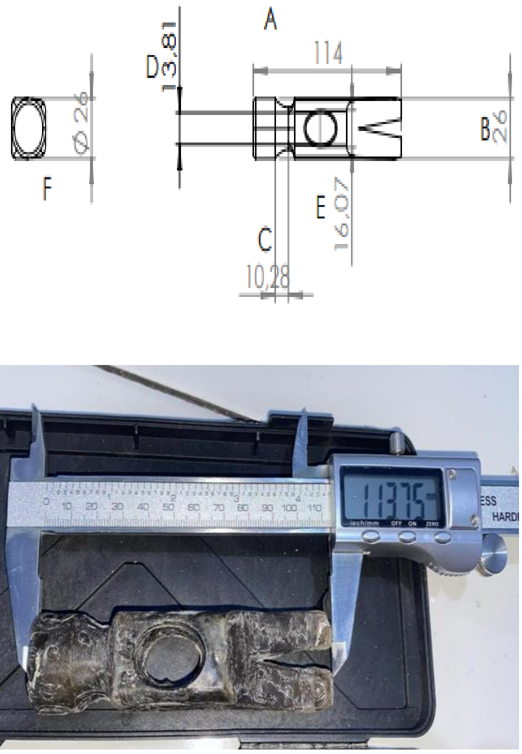

Figure 10. Mold Design Dimensions and Measurement Methods

The dimensions of the hammer head product are shown in Figure 10, and the thickness, shape, and dimensions of the plastic melt product are measured at points A through F.

4. CONCLUSIONS

This study evaluated the mold's resistance to temperature variations during the injection process in addition to testing the shape's geometry. The results of temperature resistance testing utilizing temperature variables of 150 °C showed that the temperature influenced the injection time and viscosity of the melted plastic, which sped up the flow process to fill the mold. Furthermore, due to shrinkage and variations in the actual product's dimensions, the measurement findings when this shape's geometry is evaluated differ from the design dimensions.

 https://doi.org/10.25077/metal.9.2.139-145.2025

ACKNOWLEDGEMENT
This research was conducted with the support and funded by Penelitian Unggulan Untirta (PUU) Alokasi Dana Relaksasi LPPM Tahun Anggaran 2025 (Grant Number B/711/UN.43.9/PT.01.03/2025).

REFERENCES

[1] Eidelweis,"The process of making preforms from polyethylene terephthalate material using an injection molding machine," *Jurnal Teknik Mesin, Majalengka*, 2021.

[2] Shieddieque, A. D., Nugraha, W. A., Mesin, S. T., Tinggi, S., & Wastukancana, T. (n.d.), "Mold Set Design of Car Door Handle Components Using Material Alumunium 6061," *Jurnal Teknologika*, 13(1), 9-19.

[3] Alfian, R. A, "Design and Construction of Souvenir Molding for the Padang State Polytechnic Logo on a 960 KG/CM² Pressure Injection Molding Machine," *Jurnal Ilmiah Poli Rekayasa*, Vol. 16, No. 2, 94-95, 2021.

[4] Aziz, M., & Saraswati, R, "Optimalisasi Parameter Mesin CNC Milling 3 Axis terhadap Waktu Produksi dengan Menggunakan Response Surface Methodology," Vol.1,No.46, 2022.

[5] Permana, H., & Anwar, S, "Produksi Proses Komponen Plastik Flip Flop Dengan Mesin Injeksi Molding Type Hidrolik Production Process of Flip Flop Plastic Components with Hydraulic Type Injection Molding," *Jurnal Baut dan Manufaktur*, Academia. 2021.

[6] Putra, I. A., Umardani, Y., Suprihanto, A, "Making injection molds to make crutch armpit pads from polypropylene material," *JURNAL TEKNIK MESIN,* vol. 11, no. 3, pp. 374-385, Jul. 2023.

[7] Fadhlurrohman, Umuran, K., Affandi, Nurdin, H., & Rudi, A, "The effect of the temperature of the iron on plastic products made from polypropylene (PP) in injection molding," *Jurnal Rekayasa Material, Manufaktur dan Energi*. Vol. 5, No.1, 2022.

[8] Kholidah, N, "The Effect of Temperature on Yield Percentage in the Catalytic Cracking Process of Plastic Waste into Liquid Fuel". *Jurnal Ilmu Kimia dan Terapan*, Vol. 2, No. 1, 30-31, 2018.

[9] Mawardi, I, Hasrin, H, Hanif, H, "Product Quality Analysis by Setting Injection Temperature Parameters of Polypropylene (PP) Plastic Material in the Injection Process," *Industrial Engineering Jourbal*, Vol. 4 No. 2, 2015.

[10] Maulana, A., Yusup, I. M., Syafrizal, F., K, R. A., & Satria, D, "Ngoper Termals (Pengoptimalan Temperarur Terhadap Material Barrel dan Screw) Plasctic Processing Machineri As The Utilizaton Of Plastic Waste," *EPrints Respository UNTIRTA*, 2017.

[11] Gadelmawla ES, Koura MM, Maksoud TMA, Elewa IM, Soliman HH, "Roughness parameters," *J. Mater Process Technol*. Apr;123(1) [11]:133–45, 2002.