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

METAL: Jurnal Sistem Mekanik dan Termal

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

Research article

The manufacture and distribution temperature of aluminum molding for plastic beam from waste PP

Hendra[a], Yoga Rahmadi Putra[a], Reski Septiana[a], Hernadewita[b], Harly Demustila[c], Rispandi[d], Hermiyetti[e], Rahmayetty[c].

[a]Department of Mechanical Engineering, Sultan Ageng Tirtayasa University, Jl. Jendral Sudirman KM 3 Cilegon Banten, 42435, Indonesia
[b]Master of Industrial Engineering, Mercubuana University, Jl. South Meruya, Jakarta, 10650, Indonesia
[c]Department of Chemical Engineering, Sultan Ageng Tirtayasa University, Jl. Jendral Sudirman KM 3 Cilegon Banten, 42435, Indonesia
[d]Department of Mechanical Engineering, Faculty of Engineering, Universitas Andalas, Limau Manis, Padang, West Sumatra, 25163, Indonesia
[e]Faculty of Economics, Bakrie University, Jl. H.R. Rasuna Said Kuningan, Jakarta, 12920, Indonesia

ARTICLE INFORMATION

Article History:
Received: 10 January 2025
Revised: 15 April 2025
Accepted: 30 April 2025

KEYWORDS

Injection Molding
Mold
Plastic Beam
Temperature Distribution
Quality of Product

CORRESPONDENCE

E-mail: hendra@untirta.ac.id

ABSTRACT

One method utilized in the production of plastic goods is injection molding. An essential part of the injection molding process is a mold, which is used to create different types of plastic goods in accordance with a preset design. The goal of this study is to create plastic beam molding molds using the EDM and milling production methods and evaluate the molds' form geometry and resilience to temperature. The material's thermal conductivity is 200 W/m.k. due to the properties of the 1060 aluminum alloy. It can be determined that the low mold temperature during the injection process causes plastic products to distort and swell. The results show that the electrical discharge machine (EDM) machining technique achieved a frequency of 142.8% and a duty cycle value of 57%. Using barrel temperatures of 160°C and 250°C for temperature resistance tests, the mold was determined to be in rather good condition when exposed to high temperatures. This is demonstrated by the results of testing the shape's geometry, which showed similar in the product's dimensions with the mold and an increase in the product's dimensions.

1. INTRODUCTION

The people cannot live today without the many technical devices that have benefited humanity over the years. The ease of use of modern technology is a concept that humanity first developed. There is one made of plastic. Due to its ability to facilitate a wide range of human activities, plastic is one of the most significant human innovations of our time.

The components of plastic are often referred to as monomers. If the monomers are identical, the mixture can be referred to as a homopolymer. However, if the materials are combined or not similar, polymers will be produced. Natural polymers include cellulose, protein, and natural rubber. And initially, people discovered that this polymer was utilized in everyday objects like tools and weapons.

https://doi.org/ 10.25077/metal.9.1.46-53.2025

Molding is the method by which plastic is formed to each desired shape during the production process. Injection molding, crushing machine, blow molding, cutting plastic machine, shorter of plastic machine, extrusion molding, and transfer molding are some of the different varieties of this plastic manufacturing process [1-8]. Injection molding is used in this study and manufacturing sector frequently use this methodology.

In order to inject the plastic material into the mold [9], pressure is applied to the cylinder after the plastic has melted to its melting point. This is the fundamental idea behind this technique. After cooling, the material inside the mold will be taken out of the mold. Because it is more cost-effective and lessens waste, which is growing daily. In this paper was investigate the production of plastic beam molds utilizing waste plastic materials [10].

The aim of this research is to create innovations for plastic beams since they are an attempt to reduce the amount of plastic garbage that is dispersed. Because its strength value is not lower than that of other beam wood, this plastic beam can generally be utilized as a replacement or substitute for beam wood in general. In addition, this plastic beam has aesthetic value that may be used to the interior requirements of chairs, tables, paving block, fuel, and other items to increase their market worth [1, 9, 10-12].

2. METHOD

This research used finite element method to simulate temperature distributions of the materials (aluminum). Experimental methods are used by manufacturing process and testing on the molds that have been made. In this paper are used several variables such as independent variables, dependent variables, control variables.

2.1. Dependent Variable

The dependent variable is used in this study to make a difference to get optimal result data in the manufacturing process and its function.

2.1.1. Manufacturing Process

Several manufacturing processes are carried out to manufacture molds for plastic beam molding, such as electrical discharge machines (EDM) and CNC milling machines, as shown in Figures 1 and 2.

Figure 1. Electrical Discharge Machine (EDM)

Figure 2. CNC Milling Machine

2.1.2. Barrel Temperature

Barrel temperature variations for heating of material PP are set up on 160 °C, and 250 °C. Table 1 shows the properties of PP plastic. Table 2 shows the mold material specification, aluminum alloy 1060.

Table 1. Properties of PP (Polypropylene) Plastic

Properties of PP (Polypropylene) Plastic	
Melting Point	130 – 171°C
Tensile Strength	25-50 MPa
Elongation	100 – 600 %

Table 2. Mold Material Specification Aluminium Alloy 1060.

Designation	**Value**
Density (ρ)	2700 kg/m^3
Shear strength (τ)	48,3x10^6 N/m^2
Young's modulus (E)	69x10^9 N/m^2
Poisson's ratio (ν)	0,33
Yield strength (σ)	27,6 x10^6 N/m^2
Melting point	900°C

2.2. *Control Variable*

The control variables in this study are room temperature and the type of mold material, which is aluminum alloy 1060 or polypropylene (PP) plastic material, as shown in Tables 1 and 2.

2.3. *Bound Variable*

The study's bound factors are the molding shape's geometry and temperature resistance, which are known to be influenced by the independent variables-barrel temperature and manufacturing method.

2.4. *Tools and Materials*

The tools and materials used in this paper are:

1. Injection Moulding Machine
2. EDM Machine (Electrical Discharge Machine)
3. Conventional milling machine
4. Clamps
5. Thermocouple k-type
6. Vernier Caliver
7. Chisels (carbide and HSS)
8. PP (Polypropylene) Plastic Waste

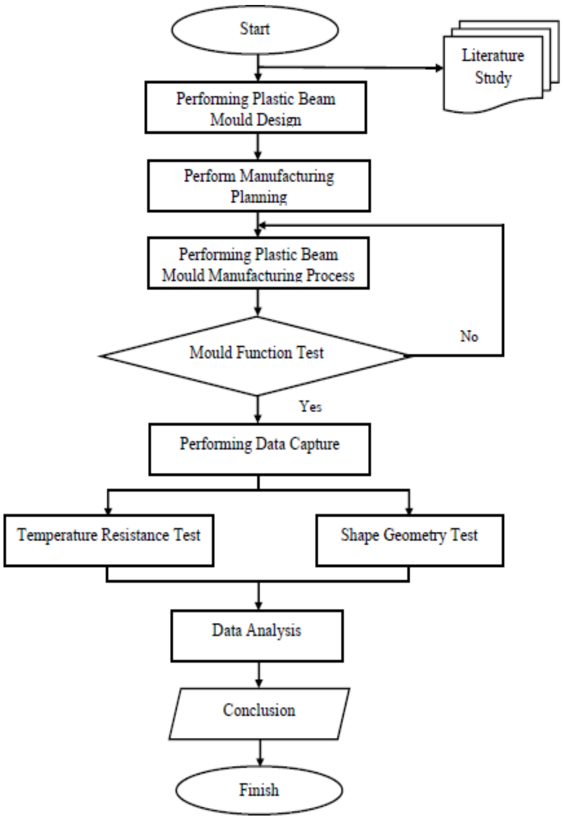

Figure 3. Research Flowchart

2.5. *Flowchart*

Fig. 3 show the research flowchart breaks down the steps involved in conducting a literature study, designing and simulating a mold, producing the mold, testing its shape geometry and temperature resistance, and more. Analyse the data collected after testing and draw conclusions from the conducted research.

2.6. *Data Analysis Technique*

This research was conducted with a experimental and simulation method. Experimental methods by testing the molds that have been made, namely temperature resistance testing, and testing the geometry of the mould shape. Fig. 4 show the plastic beam mold design.

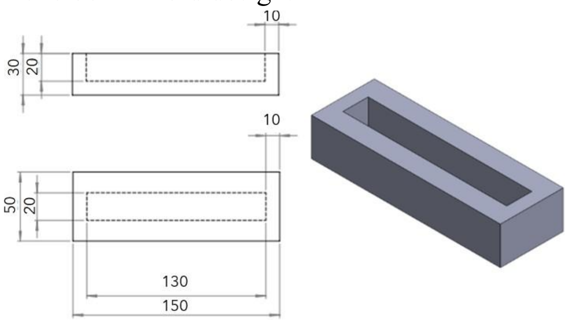

Figure 4. Plastic beam mold design

3. RESULTS AND ANALYSIS

3.1. Manufacturing Process

Electrical Discharge Machine (EDM) and a milling machine are used in the process of creating this mold. The manufactured molding workpiece's results are in accordance with ASTM D3641, which specifies a minimum mold wall thickness of 2-4 mm.

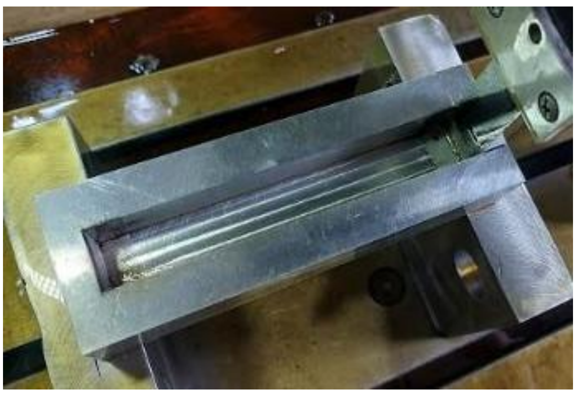

Figure 5. Mold of plastic beam

 https://doi.org/ 10.25077/metal.9.1.46-53.2025

3.2. Milling Process Machining

A milling machine is used for the facing process in the first stage, and a 20 mm deep feed is achieved in the second stage by counter-milling [13]. The following step is to create a 4 mm diameter hole with a milling drill, and lastly, form a copper electrode for an electrical discharge machine (EDM) as shown in Fig. 6. And electrical discharge machine (EDM) process in Fig. 7.

Figure 6. Machining process of molding

Figure 7. Mould electrical discharge machine (EDM) process

Table 3. Properties of work piece and electrical discharge machine (EDM)

No	Component	Materials	Size
1	Workpiece	Aluminum Alloy 1060	150 x 50 x 30 (mm)
2	Electrode	Copper	100 x 20 x 10 (mm)
3	Bolt		M6 x 20 (mm)
4	*Dielectric Fluid*	EDM *Oil*	20 liters

Table 4. Electrical discharge machine (EDM) machine parameters

Machine parameters	
Ampere	2,3A
Jog time	0,4 m
Work time	0,8 second
T_{on}	4 μs
T_{of}	3 μs

The duty cycle value and frequency in the EDM machining process are derived from the machine parameters mentioned above as shown in Table 4. The percentage of Ton's relative time to cycle time is known as the duty cycle. The workpiece cutting efficiency increases with the duty cycle value.

- *Duty Cycle*:

$$Duty\ Cycle = \frac{On - time\ (\mu s)}{Total\ Cycle\ Time\ (\mu s)} x100\ \%$$

$$Duty\ Cycle = \frac{4}{4\ \mu s + 3\ \mu s} x100\ \% = 57\%$$

- *Frequency:*

$$Frequency\ (kHz) = \frac{1000}{Total\ Cycle\ Time\ (\mu s)}$$

$$Frequency\ (kHz) = \frac{1000}{4\ \mu s + 3\ \mu s} = 142{,}8\ kHz$$

3.3. Temperature Resistance Testing

Three temperature variables such as variable 1 (160^{o}C), and variable 2 (250^{o}C), are utilized in the beam plastic injection molding process in this temperature resistance test. and polypropylene (PP) plastic waste, which has a melting point between 130^{o}C - 171^{o}C., is the type of plastic waste material utilized.

3.4. Mould Temperature Resistance Testing (barrel temperature 160^{o}C)

The variable barrel temperature utilized in the initial step of testing the mold's temperature resistance is 160°C. The starting temperature is determined by the melting point of the kind of plastic waste that will be utilized, specifically polypropylene (PP), which has a melting point of 130^{o}C - 171^{o}C. Fig. 8 show that injection of plastic liquid into the plastic beam mold at 160^{o}C.

Figure 8. Injection of plastic liquid into plastic beam mould (barrel temperature 160°C)

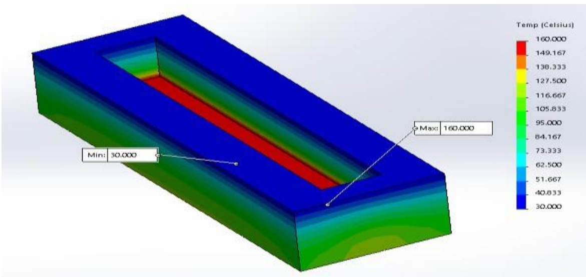

Figure 9. Mould heat transfer simulation (barrel temperature 160°C)

As observed in Fig. 9, there are certain color changes on the mold walls that show how much heat propagation takes place. This shows that when the plastic liquid initially enters and comes into contact with the bottom wall of the red mold, the bottom of the mold receives the maximum temperature.

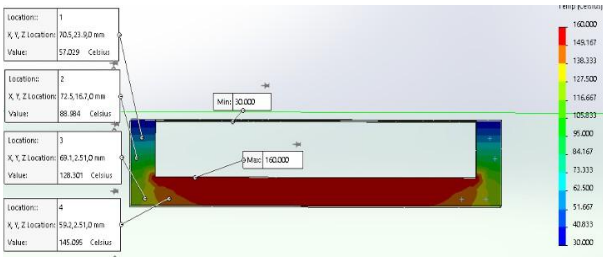

Figure 10. Section Clipping in plastic beam mould simulation (barrel temperature 160°C)

Figure 11. shows the graph of each curve location showing a decrease in temperature. For example, at location 1, the time required from a temperature of 95°C to a temperature of 57°C is 600 seconds (10 minutes). at location 2, the time required from a temperature of 132°C to a temperature of 80°C takes 100 seconds (1.6 minutes).

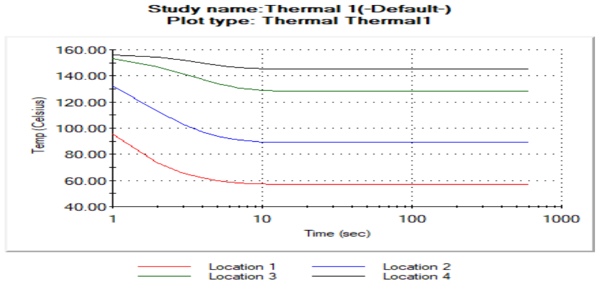

Figure 11. Heat Transfer Simulation Graph on plastic beam mould (barrel temperature 160°C)

The graph in Figure 11 illustrates the temperature increase that the mold experiences every 5 minutes. The graph below shows that the mold experiences the highest temperature at the first 5 minutes, with the first point showing an increase of 110°C, the second point showing 109.8°C, the third point showing 111.1°C, and the fourth point showing 108.9°C. As time passes, the mold cools and, at 90 minutes, it nearly reaches room temperature or normal temperature, with the first point measuring 37.3°C, the second being 36.5°C, the third being 38.9°C, and the fourth being 37.2°C (see Fig. 12).

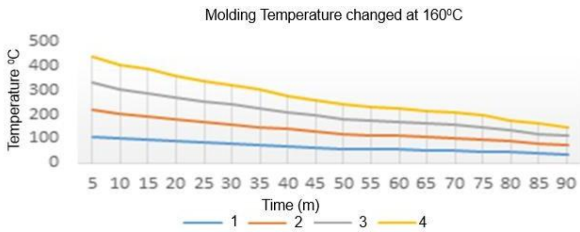

Figure 12. Result of Mold Temperature Changed at Barrel temperature 160°C

3.5. Mould Temperature Resistance Testing (barrel temperature 250°C)

Figure 13. Injection of plastic liquid into plastic beam mould (barrel temperature 250°C)

 https://doi.org/ 10.25077/metal.9.1.46-53.2025

Figure 13 depicts the plastic injection process with a barrel temperature of 250°C. The viscosity of the plastic liquid in the mold is shown in the picture. The shape of the plastic liquid flow is more liquid at a barrel temperature of 250°C than it is at a barrel temperature of 160°C, which makes it appear more viscous, like a paste. in order for the plastic liquid to more rapidly and uniformly fill the spaces in the plastic beam mold during the temperature resistance test at 250°C.

Figure 14, show significant temperature transfer within the range of 30°C to 250°C. This temperature transfer spreads throughout the mould, reaching a maximum temperature of 250°C.

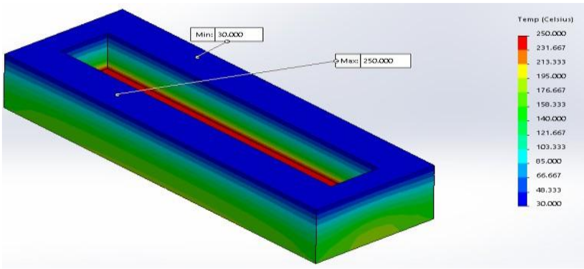

Figure 14. Mould heat transfer simulation (barrel temperature 250°C)

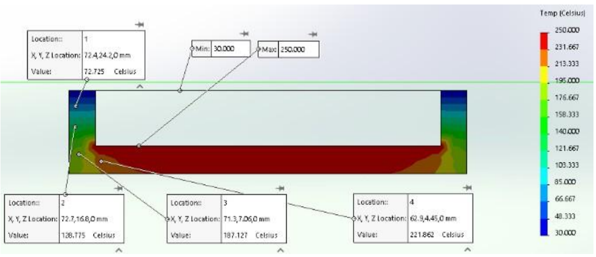

Figure 15. Section Clipping in plastic beam mould simulation (barrel temperature 250°C)

In Figure 15, each curve representing a specific location shows a decrease in temperature as well as an increase. For example, at location 1, the time required to reduce the temperature from 98°C to 72°C is 600 seconds (10 minutes). While within 600 seconds, at location 2 there was a decrease in temperature from 145°C to 128°C. at location 3 there was an increase in temperature from 180°C to 190°C within 3 seconds, then the temperature stabilised at 187°C for 600 seconds (10 minutes). in addition, at location 4, there was also an increase in temperature from 205°C to 221°C within 4 seconds, and the temperature stabilised for 600 seconds (10 minutes) (see Figs. 16-17).

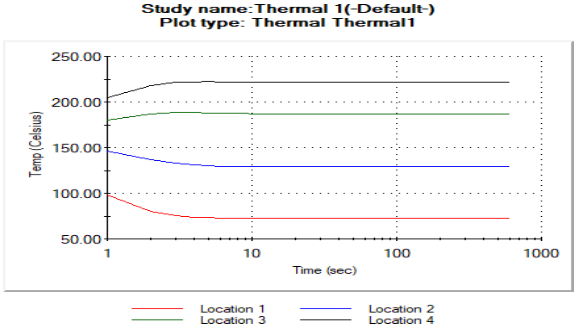

Figure 16. Heat Transfer Simulation Graph on plastic beam mold (barrel temperature 250°C)

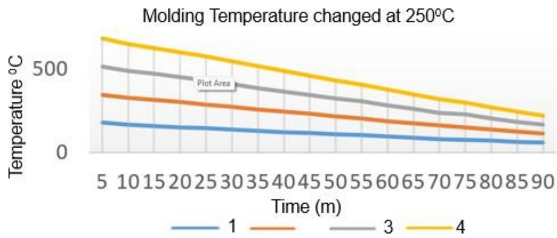

Figure 17. Result of Mold Temperature Changed at Barrel temperature 250°C)

3.6. *Shape Geometry Testing*

To obtain a reasonably precise measurement value when assessing the geometry of the mold's shape, a measuring tool is used as a reference. Using the ASTM E29 standard as a guide, the geometry test seeks to ascertain how the mold's shape changes as plastic temperature is transferred to it.

3.7. *Testing Results Shape geometry (barrel temperature 160°C)*

As a result of the shape geometry test conducted on a plastic beam mold at 160°C, the product results are shown in Figure 18, which indicates that the plastic beam product has larger dimensions upon being demolded.

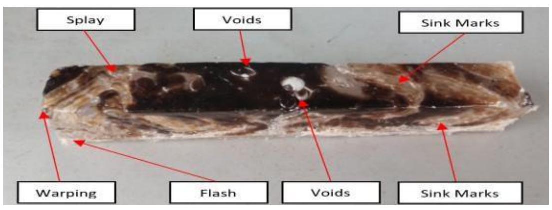

Figure 18. Mould product yield (barrel temperature 160°C)

The volume of the mould is 52 cm^2 (130 mm × 20 mm × 20 mm), while the dimensions of the resulting product are 58 cm^2 (126.48 mm × 19.42 mm × 23.74 mm). This is due to several factors, including low mould temperature as it can result in uneven cooling of parts of the product, causing some parts to cool and shrink faster than others. As a result, the final product may distort or swell.

3.8. Testing Results Shape geometry (barrel temperature 250^{o}C)

Figure 19 although the volume of the mould is 52 cm^2 (130 mm × 20 mm × 20 mm), the dimensions of the resulting product are 52.8 cm^2 (127.32 mm × 19.32 mm × 21.48 mm). In the long dimension part, the product has a dimension reduction of 2.68 mm. this is due to the low mould temperature factor during the injection process, causing shrinkage in the product.

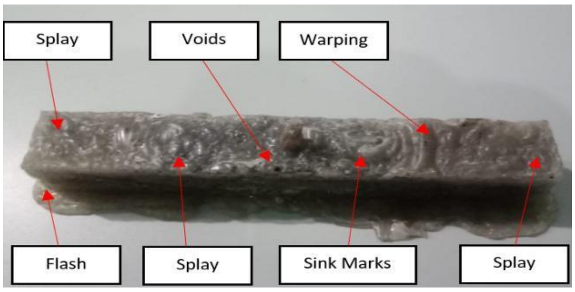

Figure 19. Mould product yield (barrel temperature 250^{o}C)

This is also seen in the product's width and thickness measurements, where there is dimensional shrinkage and swelling. The low mold temperature also contributes to this, allowing some parts to cool and shrink more quickly than others. Consequently, the finished product could become distorted or swollen.

It can be inferred from the analysis of the two-injection-molded plastic beam products that the faults that arise exhibit a variety of defects, both inside and on the product's exterior. One kind of defect that is observed is the Voids defect, which results from mistakes made during the plastic injection process when the material is placed into the mold. This flaw indicates that the molded object contains empty areas. It is advised to raise the plastic injection temperature in order to make the plastic more fluid and capable of adequately filling the mold space.

Apart from vacancies, the plastic material can also develop splay faults as a result of moisture. This issue can be resolved by drying the plastic material before putting it into the barrel. The product also exhibits flash flaws, which are brought on by leftover plastic that escapes the mold during the injection process. After cooling, the final product must be completed.

Unevenness in the cooling process and mold pressure cause warping flaws. A balance between temperature and pressure in the mold can be achieved with the aid of proper nozzle configuration during the injection process. Lastly, sink marks develop because the product cools more slowly than the mold, creating hollows in the final product. These flaws can be avoided and the intended product shape can be attained with a more uniform cooling procedure.

4. CONCLUSIONS

A work time value of 0.8 seconds is derived from the milling and EDM machining processes. On the other hand, the EDM machining technique achieved a frequency of 142.8% and a duty cycle value of 57%. The results of the shape geometry test showed that the dimensions of the plastic beam product and the mold differed. The mold's volume was 52 cm2 (130 × 20 × 20) mm at a barrel temperature of 290^{o}C, and the finished product's dimensions were 52.8 cm2 (127.78 × 19.42 × 22.12) mm. There was a 2.22 mm dimensional reduction in the product's length dimension. Analysis revealed that the product shrank as a result of the low mold temperature during the injection process. The product's width and thickness also shrink, in part because of the low mold temperature, which causes some components to cool and shrink more quickly than others. The end outcome could be distorted or swollen as a result. 290^{o}C is the ideal temperature to utilize for injection mold plastic on aluminum mold dies, according to the findings of the tests that have been conducted.

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