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# Design and Performance Testing of a Keychain Product Mold for a Learning Module in the Metrology and Plastic Moulding Laboratory at XYZ

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***Abstract***

*In the current technological era, plastic assumes a crucial role in daily life. This is substantiated by the continuously escalating demand for plastic-based products. Manufacturing items by reshaping plastic raw materials necessitates the use of plastic forming tools or machinery. A prevalently utilized apparatus is the injection molding machine, which employs a specialized mold. The mold design process mandates rigorous calculations and planning to ensure the production of dimensionally identical and uniform parts, thereby facilitating mass production. The primary objective of this research was to design, implement, and validate a mold for plastic injection molding, specifically intended for the mass production of keychains. The methodology employed was the Sighley's Mechanical Engineering Design approach, which encompasses the following sequential procedures: Problem Identification, Problem Definition, Synthesis, Analysis and Optimization, Evaluation, and Presentation. The fabricated keychain mold yielded two products per injection cycle, with mold dimensions (L×W×H) measuring 110 mm×100 mm×160 mm. The mold was mounted on the injection molding machine, requiring a clamping force of 46710 N, with system control provided by an Arduino and cooling facilitated by an external fan. The test results identified the optimal operating parameters for a single molding process, comprising a heating temperature of 210°C, an injection time of 17 seconds, and a cooling time of 12 seconds.*

***Keywords:*** *Injection;Molding; Mold; Plastic*

**Abstrak**

Pada masa modern seperti sekarang ini plastik mempunyai peran yang penting dalam kehidupan sehari – hari manusia. Hal ini bisa diperhatikan dari terjadinya peningkatan kebutuhan produk berbahan dasar plastik setiap tahunnya. Membuat produk dengan membentuk ulang bahan baku plastik diperlukan alat atau mesin pembentuk plastik. Salah satu alat yang biasa digunakan adalah mesin injection molding dengan menggunakan mold sebagai cetakannya. Proses rancang bangun mold diperlukan perhitungan dan perencanaan agar dapat menghasilkan produk dengan ukuran dan bentuk yang identik sehingga proses pembuatanya dilakukan secara masal. Tujuan dari penelitian ini adalah Merancang dan merealisasikan mold untuk injection molding plastik dengan produk masal gantungan kunci. Metode yang digunakan adalah Sighley's Mechanical Engineering Design yang terdiri dari prosedur-prosedur : Identifikasi Masalah, Pendefinisian Masalah, Sintesis, Analisis & Optimasi, Evaluasi, serta Presentasi. Mold cetakan gantungan kunci yang telah dibuat menghasilkan 2 produk sekali inject, dimensi mold (PxLxT) yaitu 110 mm x 100 mm x 160 mm. Mold dipasang pada mesin injection molding dengan clamping force sebesar 46710 N dengan sistem control menggunakan Arduino dan pendingin menggunakan kipas. Hasil pengujian didapatkan parameter hasil pengujian terbaik dengan parameter Suhu pemanasan 210 °C, lama waktu injeksi 17 detik, dan lama waktu pendinginan 12 detik dalam satu kali proses cetak.

**Keywords:** Injection Molding; Mold; Plastik

## 1. Introduction

Creating a machine or tool to reshape plastic is one way to address the plastic recycling process, which is currently a problem facing Indonesia regarding the accumulation of plastic waste [1][2][3]. According to data from Making Oceans

Plastic Free in 2017 [4], the population in Indonesia uses an average of 182.7 billion plastic bags per year. This number results in a total of 1,278,900 tons of plastic bag waste in Indonesia per year. To create a product by reshaping plastic raw materials, a plastic forming tool or machine is required. One commonly used tool is an injection molding machine using a mold as a mold [5][6][7]. Injection molding is a technique for molding a product using plastic pellets or recycled plastic that is then heated in a barrel according to the material's melting point. The heated material is then inserted into a chamber, called a mold, according to the desired product. One product that can be made with injection molding is a keychain [8][9].

Learning about injection molding is currently very important in higher education, especially for XYZ mechanical engineering students. Learning that approaches the latest technology in the industrial world and developing technology can maximize learning. Figure 1 shows an image of a plastic injection machine, the position of the plastic mold on the plastic injection machine, and a construction drawing of the plastic mold. Figure 2 shows a pipe clamp product on the market, for which students from the Mechanical Engineering Department conducted reverse engineering, including analysis results and construction drawings of the plastic injection mold assembly.

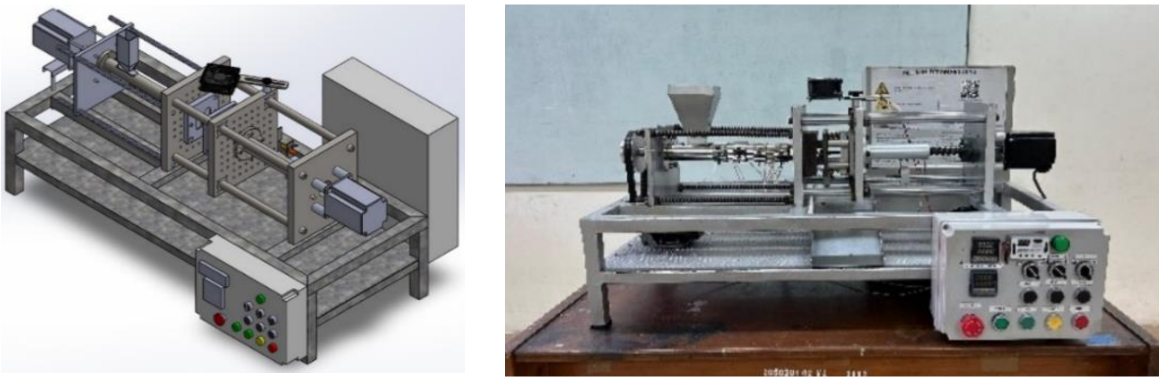

**Figure 1.** XYZ Laboratory Plastic Injection Machine

One product that can be made using injection molding is a keychain. A keychain is a small product generally used to store keys or as an accessory that can be attached to keys, bags, or clothing. A keychain is a small accessory designed to carry and organize keys, making them easier and helping to keep them safe, providing a combination of practicality and durability. Making keychains as a mass product using an injection molding machine can be used as a learning tool for students in the materials laboratory of the mechanical engineering department. Precise parameters are needed to obtain good molding results. The testing process to obtain injection molding parameters can be used by students as learning practice materials.

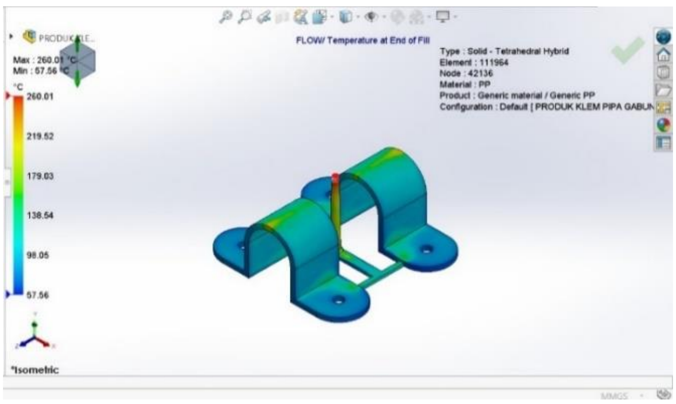


**Figure 2** Product, Analysis, and Construction of XYZ Student Design Results

## 2. Materials and Methodology

This research was conducted at the Metrology and Plastic Molding Laboratory, Department of Mechanical Engineering XYZ. The design and experimental testing approach to obtain the appropriate parameters followed the flow diagram as shown in Figure 3.

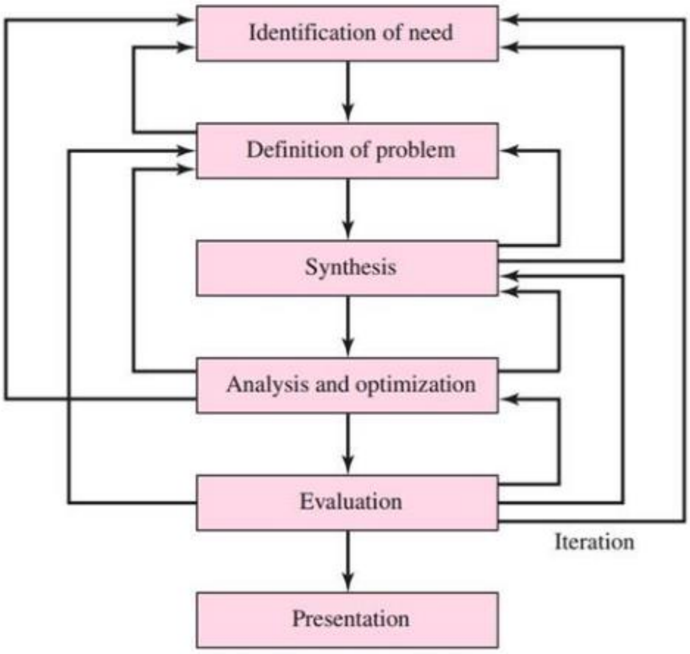


**Figure 3** Research Flow

The stages in the Shigley-Mitchell Model design process above can be explained as follows [9]

a. Need Recognition

The design and performance testing process begins with identifying the need for a keychain mold, recognizing a problem that would be solved by creating a new product or modifying an existing one.

b. Problem Definition

This stage involves formulating the problem regarding the need for a keychain mold, which will result in design guidelines and performance testing. It also determines the specifications of the keychain mold to be designed and tested, such as capacity, design, and dimensions.

c. Synthesis

This stage serves as an alternative solution to the problem underlying this design. The injection mold design, presented in the form of engineering drawings, is carried out using SolidWorks 2023 [10]. This stage consists of functional planning, including the mold components and the injection machine. In addition, this stage also includes structural design, including material selection, mold dimensions, and injection machine [11][12][13][14]. After the design, the mold manufacturing process begins.

d. Analysis

In the keychain mold design, after the prototype was created, a performance analysis was conducted using several working parameters to produce a mold that could perform optimally. The parameters analyzed were heating temperature, injection time, and cooling time.

e. Evaluation

Mold performance testing was carried out using the following parameters for molding plastic keychains using polypropylene (PP) material: heating temperature (°C) ranging from 190°C to 220°C, injection time (seconds), and cooling time (seconds). Observations were made on the resulting keychain molds, including air bubbles, uniform mold fill, product separation during injection, burnt product, and stains.

f. Presentation

The final step in the mold design process is the presentation stage, which involves compiling the mold design documents in the form of complete drawings or working drawings, component lists, material specifications, and other information required for the keychain mold manufacturing process and unit.

## 3. Result and Discussion

### 3.1. Keychain Product Design

The product to be created is a keychain with dimensions of 50 mm x 20 mm x 5 mm in length, width, and height. The product design is planned to produce two keychains in one print run. The product design can be seen in Figure 4 below.

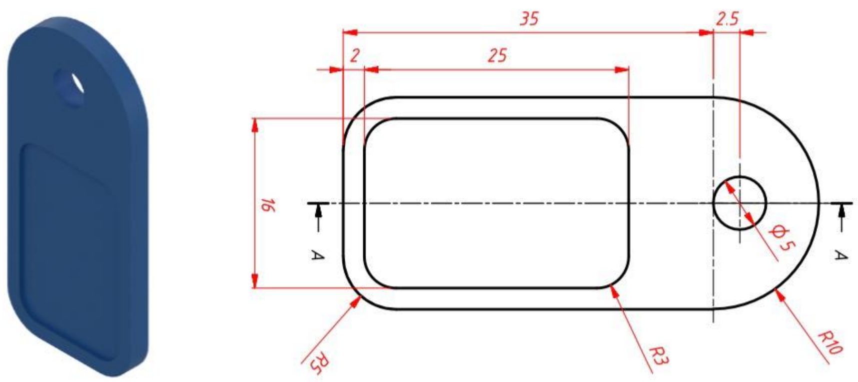


**Figure 4** Keychain product design

### 3.2. Molding Design

The design of the keychain mold produces 2 products in one injection as shown in the following figure 5.

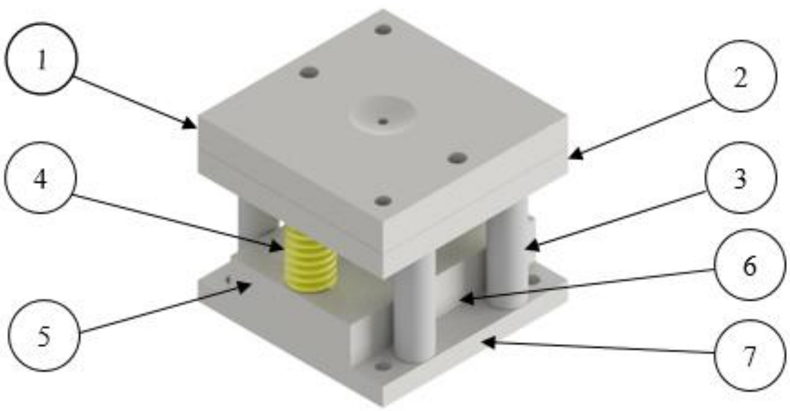


**Figure 5.** Mold Design

The parts of the mold are as follows [15][16].

1. Cavity
2. Core
3. Stripper
4. Spring
5. Ejector
6. Ejector retainer plate
7. Base mold

### 3.3. Mold Design and Construction

The mold design results were based on learning needs in the Materials Laboratory of the XYZ Mechanical Engineering Department, with detailed specifications outlined in Table 1. The keychain molding is shown in Figure 6, while the design and finished results of the engineering design are shown in Figure 7.

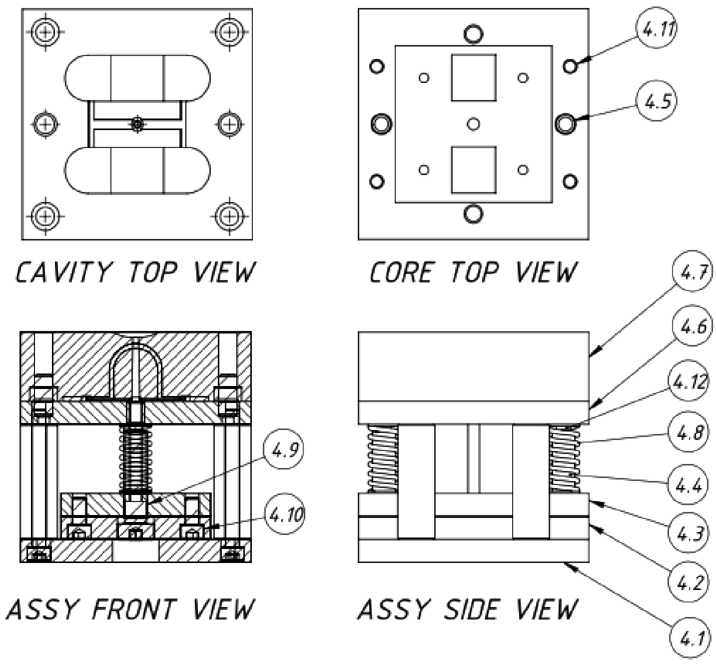


**Figure 6.** Keychain Molding

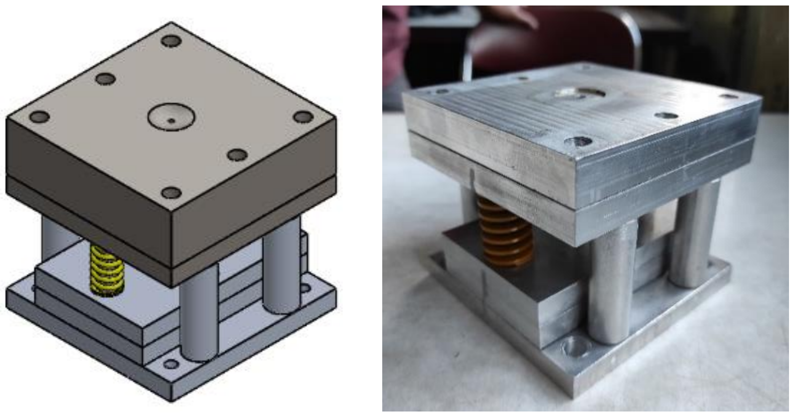

**Figure 7.** Design and Finished Product of Mold Keychain Product

It is these detailed specifications that make the molded keychain products sturdy.

**Table 1.** Mold specifications

| Jumlah | Nama Bagian | No Bag | Bahan | Ukuran |
|---|---|---|---|---|
| 1 | Adaptor Base | 4.1 | Al 6061 | 102x102x10 |
| 1 | Ejector Retainer Plate | 4.2 | Al 6061 | 102x67x10 |
| 1 | Ejector Plate | 4.3 | Al 6061 | 102x67x10 |
| 4 | Stripper | 4.4 | Al 6061 | Ø 16x52 |
| 1 | Guide Pin | 4.5 | Mild Steel | Ø 10x20 |
| 1 | Core | 4.6 | S60C | 102x102x40 |
| 1 | Cavity | 4.7 | S60C | 102x102x40 |
| 2 | Spring yellow | 4.8 | SAE9254 | 358-10-20 |
| 1 | Ejector Pin | 4.9 | SKH51 | Ø 5x44.5 |
| 2 | Baut L | 4.10 | Alloy Steel | M6x60 |
| 4 | Baut L | 4.11 | Alloy Steel | M6x10 |
| 2 | Shouder Bold | 4.12 | Alloy Steel | M8-10x40 |

### 3.4. Keychain Printing Testing

The results of testing keychains made of Polypropylene (P) at temperatures ranging from 190°C to 220°C, taking into account the injection time and cooling time. The tool test results are shown in Table 2, while the mold results from 10 experiments are shown in Figure 7. The results from 10 experiments are shown in Table 2 below.

**Table 2.** Product Testing Results

| **Operating Parameters** | **Experiment Number -** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| Heating temperature (°C) | 190 | 190 | 190 | 200 | 200 | 200 | 210 | 210 | 210 | 220 | 220 |
| Injection time (seconds) | 17 | 17 | 18 | 16 | 17 | 17 | 16 | 17 | 17 | 15 | 16 |
| Cooling time (seconds) | 10 | 10 | 10 | 10 | 11 | 11 | 12 | 12 | 14 | 14 | 14 |
| **Observation result** | | | | | | | | | | | |
| Air bubbles present | ✓ | ✓ | ✓ | ✓ | | | | | | | |
| All sections are filled | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Flash has occurred | | | | ✓ | | | | | | | ✓ |
| Product can be removed | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Product is burned | | | | | | | | | | ✓ | ✓ |
| Product is stained | ✓ | ✓ | | | ✓ | | | | | | ✓ |
| Surface is wavy | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | ✓ |

*The (✓) sign means "yes"

The mold has been tested 10 times and is capable of producing good key chains, the results of which are shown in Figure 4.


**Figure 7.** Products from the results of 10 tests

## 4. Conclusion

This research developed a keychain mold capable of producing two products per cycle. Test results indicate that the clamping force applied to the mold can withstand a load of 4671 N. The optimal processing parameters were achieved at a temperature of 210°C, an injection time of 17 s, and a cooling time of 12 s. These conditions yielded products with the appropriate dimensions, free from deformation, and devoid of defects such as air voids and bubbles or rough surface marks.

## Acknowledgements

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