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The Effect of Heating and Cooling Media Temperature on Injection Molding Products Shrinkage

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Abstract

Injection molding is the process of molding products with various shapes and sizes from plastic materials. The problem that often arises is the presence of product defects due to shrinkage. In this regard, the effect of water cooling on product size shrinkage in the injection molding process of making acetabular cups with polypropylene plastic and metal steel mold materials will be investigated through experimental investigations. The test begins with the manufacture of molds and injection machines, then the PP liquid plastic is injected twice into the mold, the first with cooling and the second without cooling. Both products are compared for depreciation by measurement. Shrinkage analysis is done by measuring the height and diameter of the product which is then compared with the size of the mold, so that final conclusions can be drawn. Measurement of shrinkage on the outside of the product is taken from three directions, namely the height of the X-axis product (dx), the outside diameter of the Y-axis product (dy), and the outside diameter of the Z-axis product (hz). For the inside of the product with a hemispherical shape, the shrinkage measurement is calculated by calculating the volume which can then be found the average radius. The results showed that the average shrinkage of the cooling test on the X axis = 1.224 %, on the Y axis = 1.857 %, on the Z axis = 1.83%, and on the radius r = 0.825 %. The average shrinkage of the test without cooling on the X axis = 1,591 %, on the Y axis = 2,32%, on the Z axis = 2,369 %, and on the radius r = 1,267 %.

Keywords: Injection Molding, Shrinkage, Heating Cooling Temperature

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INTRODUCTION

For this plastic injection tool, it functions as a tool for printing plastic waste into raw material for semi-finished products, which can later be melted down again and can be used in producing other types of plastic products. The injection process itself is carried out by entering raw materials in the form of chopped plastic through a hopper and the plastic will be heated in a pipe tube. After the plastic melts at a certain temperature, the plastic is pushed out of the tube through a notepad to be injected into the mold [1]. Next, the printed object is allowed to freeze and cool for a while in the mold before the mold is removed and opened to remove the printed object.

The molding process of plastic products requires various parameters from the injection molding machine, including melting temperature, cooling and injection speed. This parameter affects the product yield, so must find the appropriate variant based on the product. The hope of this research is to determine the effect of heating temperature on the quality of goods on injection molding machines. Thus, the temperature change of the injection molding machine can be predicted, and good semi-finished raw materials can be produced. Therefore, observing the heating temperature setting and holding time in order to know the effect on product quality. By analyzing the effect of heating temperature on the injection molding machine on product quality, it can predict the best parameters of the injection molding process.

However, several researchers have conducted research, including: [2] in the journal Media Machines, reported that plastic injection is a manufacturing process to make products with plastic base materials or in this occasion polypropylene. This process often results in product defects such as shrinkage, cracks, inappropriate dimensions, and damage when the product comes out of the mold, so a lot of material is wasted. Although the product defect is influenced by many factors, the most important is the shrinkage problem, or material shrinkage. [3]in the journal Mechanical Engineering, states that shrinkage defects can arise, among others, if the melting temperature is too high. This defect can be reduced by designing process parameters appropriately and correctly. [4] in his research states that in every mold making, it must always take into account the occurrence of shrinkage after cooling and exiting the mold cavity. This happens because of the phase change from liquid to solid material, there will definitely be a change in volume. However, some researchers have not investigated the effect of changes in heating temperature and cooling media on the shrinkage rate of polypropylene plastic.

Literature Review

Plastic Molding Plastic molding is the process of forming workpieces with the desired shape from compound materials using tools in the form of molds or molds which in the manufacturing process use heat treatment and pressure application. Selection of the molding process is generally determined by the selection of materials to obtain the desired properties of the workpiece to be made. In addition to this, the choice of molding process is also influenced by the shape of the product design[]. Based on the plastic material being made, product shape, and factors affecting the molding process, the basic molding methods can be divided into several types, namely: 1. Compression Molding In this compression molding process, plastic material is placed in a heated mold. After the plastic compound becomes soft and plastic, the top of the die/mold will move down and press the material into the desired shape according to the shape of the mold. If the existing heat and pressure is continued, it will produce a chemical reaction that can harden the thermosetting material. A mold for thermosetting materials is subjected to heat between 3000 – 3590 F (1490 – 1820 C) and a molding pressure between 11 bar [5].

Plastic is a polymer that has extraordinary properties. Plastics used for packaging have various advantages, including flexibility, laminated form and transparency [6]. Plastic materials used in the manufacture of plastic products include polypropylene, polyethylene, polystyrene, and others [7]. Polypropylene is used in various applications, such as automotive components, laboratory equipment, food or beverage containers. Polyethylene is commonly used for packaging milk bottles, detergent bottles and water pipes [8]. Polystyrene is used for making TV casings, lenses made of plastic and many others [9]. The injection molding process is a complex process because it involves several process steps that begin with the material filling step, namely the melted plastic material will flow from the injection unit through the sprue, runner, gate and into the cavity. The plastic material contained in the cavity is then held in the mold under a certain pressure to maintain shrinkage while the product is cooling [10]. A common problem that often occurs in the plastic injection industry is the shrinkage of the products resulting from the injection process. In the injection molding process there are many parameters that can affect the injection results [11]. The parameters are holding time, injection time, cooling time, mold temperature and others. If one of the parameters of the injection process is ignored, the results of the molded object will not be good, among other things, shrinkage defects will arise in the printed object [12]. Shrinkage is a defect in the form of a change in product dimensions resulting from the injection molding process. Mold cooling is one of the factors that affect shrinkage product defects. The use of media for mold cooling at PT XYZ is by using a cooling tower and water chiller. However, if there are unfavorable mold conditions such as a leaky mold or cracks in the insert cavity or insert core area and the output for delivery is urgent, then cooling must use air temporarily until the mold is scheduled to be repaired after production is complete. Seeing incidents like this, trying to analyze the shrinkage of plastic products that occur between cooling using air and cooling towers with polypropylene material. Research on the analysis of shrinkage of plastic products in the injection molding process using cooling towers and air cooling media to find out the description of the amount of shrinkage between cooling towers and air. The aim of this research is to find out the value of shrinkage or shrinkage between cooling tower cooling media and air in the injection molding process [13].

Making plastic products is done using the Plastic Injection Molding (PIM) method. Plastic injection is the process of forming products from plastic materials with a variety of different shapes and sizes. The Injection Molding method is the process of forming workpieces from compound material in the form of granules which are placed into a hopper and entered into an injection cylinder which is then pushed through a nozzle and sprue bushing into the cavity of a closed mold. After a while it is cooled, the mold will be opened and the finished object will be removed with the help of an ejector. The most suitable material is a thermoplastic material. This material will soften due to heating and vice versa will heat up again when cooled. These material changes are only physical, not chemical changes, making it possible to recycle materials as needed. The plastic material that is transferred from the heating cylinder, the temperature ranges from 117^0C to 274^0C or according to recommendations from the manufacturer of the plastic material []. The hotter the temperature, the thinner the material (lower viscosity) so that it is easier to inject into the mold. Each material has a molding temperature character (mold flow index). The softer the formulation, the higher the plastic content, which requires a low temperature, and the harder the formulation, the higher the temperature [14]. The influencing factors in Injection Molding are the plastic material used, the injection machine and the Injection Molding process. Quantitatively, the injection molding process is greatly influenced by material temperature, pressure, material flow rate in the molding cylinder, molding temperature, resin viscosity, cooling rate. However, not all of these factors can be measured in an isolated Injection Molding room. The production process using an Injection Molding machine is inseparable from product defects. Some problems that are often found in injection molding products include [15]:

- Short molding is a product defect due to imperfect filling.
- Sink marks are product defects in the form of convex shapes on the surface of the product
- Air bubble found air bubbles in the product.
- Warpage is a condition of product defects that are visible on the curved or bent surface of the product
- Weldmarks or flow marks, are product defects in the form of lines on the surface of the product,
- Discolored molding is a defect in the form of color fading on the product/opaque.
- Black spot, Product defects which are found such as black spots on the product, which occur in certain parts of the product
- Hole/gap, is a loose product defect in the part that is printed due to the influence of less hot temperatures.
- Over molding, defective cable products are pushed due to too high pressure.

This can result in delays in delivery to consumers and can result in big losses for the company because a lot of material is wasted and product quality is low due to product defects. Production machines play an important role in determining the quality and quantity of production results. To understand this problem, a study was carried out on the effect of temperature and pressure on injection molding machines on product defects [16].

Injection molding is a technique of injecting plastic into a mould. The material used in injection molding is plastic pellets. Before the material is processed, the material must be heated first in a container called a hopper or dehumidifier. Heating the material is done to dry the material from the absorbed water vapor. A significant parameter in the injection molding process is the ideal barrel temperature setting to increase gradually from low at the back to higher at the front, especially at the nozzle [17]. In this barrel, the dye and polymer material are mixed. Setting a temperature that is too hot can also result in silver or the product becomes very shiny. Injection pressure is the pressure exerted when injecting material into the mold. Adjust the pressure at each injection stage. The first pressure should not be too large, ranging from 30 to 100Mpa depending on the tonnage of the machine used. The second injection pressure is between 40 - 60% of the first pressure. High pressure will cause overpacking or flashing, and can even damage the mold. Conversely, if it is too low, it will result in a short shot product / product not being full. Holding press is pressure that is held so that the material that has been injected into the mold does not change its shape. It is in this stage that product quality is very influential. Setting the holding press for the initial stage is recommended at 50% of the Injection press [18].

Plastics are generally classified into 3 types, namely: thermoplastics, thermo-setting and elastomers. Thermoplastic is a type of plastic that softens when heated and hardens when cooled. Examples of thermoplastic materials include: polyethylene, polypropylene, and PVC (polyvinyl chloride). Thermosetting plastics harden when heated and cannot be recycled. Examples of thermo-setting plastics are: bakelite, silicone, epoxy and others, while elastic is a very elastic material. An example of an elastic material is synthetic rubber. The third type of plastic material is the elastomer. Elastomer comes from the words elastic and mer. This type of plastic has rubber-like properties. [19] conducted research using polypropylene and polystyrene plastics. The aim of the researchers was to determine the effect of injection parameters on shrinkage in the material. The research method uses Taguchi. From the experiment, the influence of the parameters of melting temperature, injection pressure, holding pressure, and holding time can affect the determination of shrinkage results. Melting temperature is the main factor in its effect on shrinkage compared to other parameters [20]. pressure parameters and pressure time have a significant influence on the occurrence of shrinkage [21].

METHOD

In this study, experiments will be conducted to determine the effect of heating and cooling temperatures on the amount of dimensional shrinkage in the plastic injection process. Shrinkage analysis is done by measuring the height and diameter of the product which is then compared with the size of the mold, so that final conclusions can be drawn. In this study, the heating temperature varied: 2500 C, 275°C and 300°C with cooling media and without cooling. The plastic material used is Polypropylene (PP) produced by P.T. Sidobangun Malang, East Java, Indonesia. Polypropylene plastic granules.

The planned product is an acetabular cup model as shown in Figure 1, a 2-dimensional acetabular cup model complete with sizes. Mold cavity design, cooling channel and plastic material inlet.

Figure 1 Mold Model

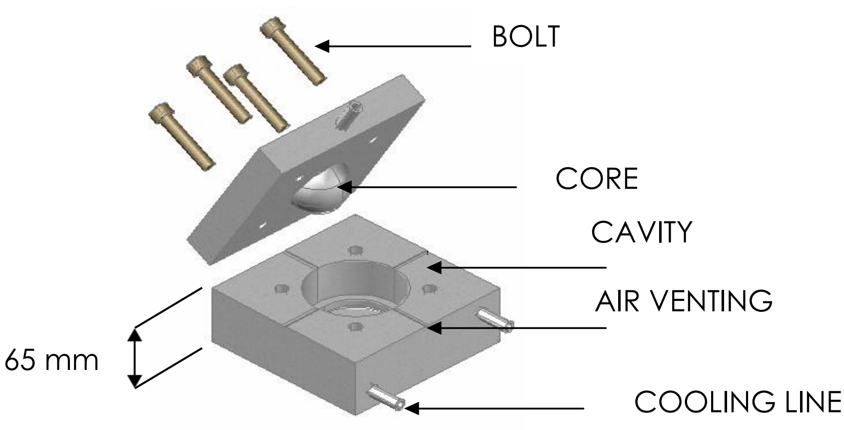
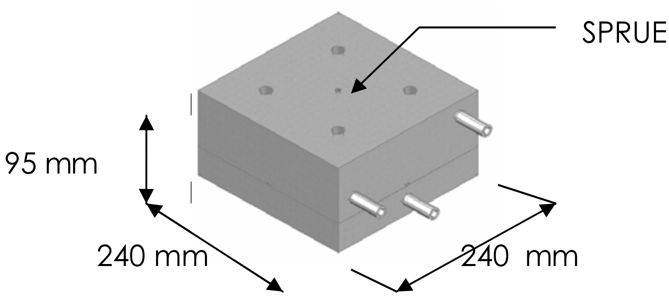


Figure 2 Mold parts



RESULT AND DISCUSSION

A. Comparison of Shrinkage (Shrinkage) of Product Height in the X-Axis Direction In Injection Molding With Cooling and Without Cooling.

Figure 3. Shrinkage of Product Height in the X-Axis Direction

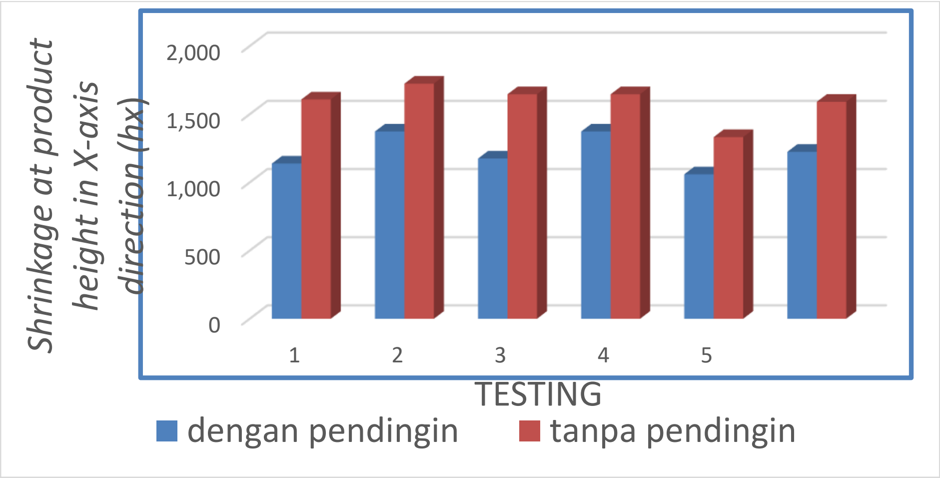
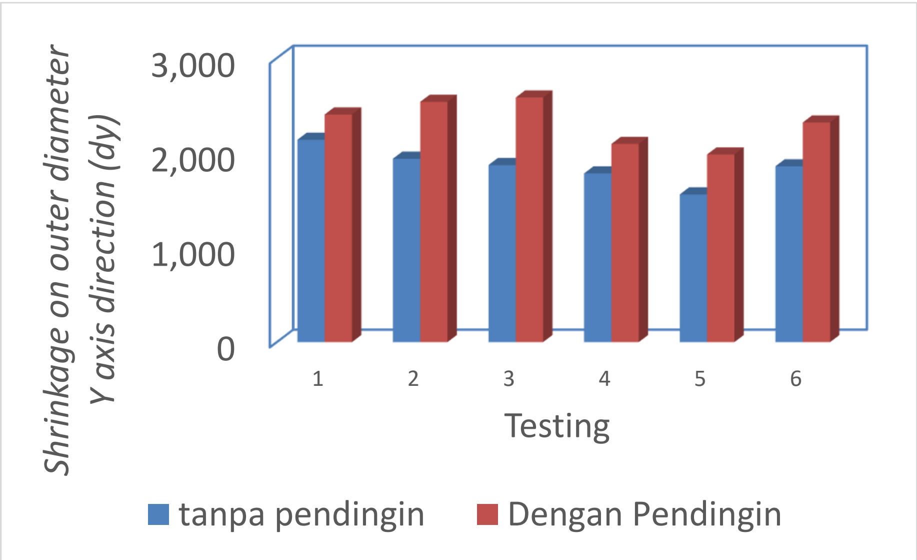


Figure 3 shows that from 5 injection molding tests with coolant, the product's high shrinkage in the X-axis direction is above 1% below 1.5% with very variable heights.

B. Comparison of Shrinkage Outer Diameter of Product in Y . Direction

Figure 4 shows the histogram of the average shrinkage from the injection molding test with cooling 1.224 % while for the injection molding test without cooling it is 1.591 %.

Figure 4. Shrinkage on the outer diameter of the Y axis direction (dy)



Figures 4 show that the shrinkage in the injection molding test with cooling is smaller than in the injection molding test without cooling. This is because in the cooling process there is an even distribution of heat transfer in the product.

C. Comparison of Shrinkage (Shrinkage) Outer Diameter of the Product in the Z-Axis Direction

Figure 5. Shrinkage Outer Diameter of the Product in the Z-Axis Direction

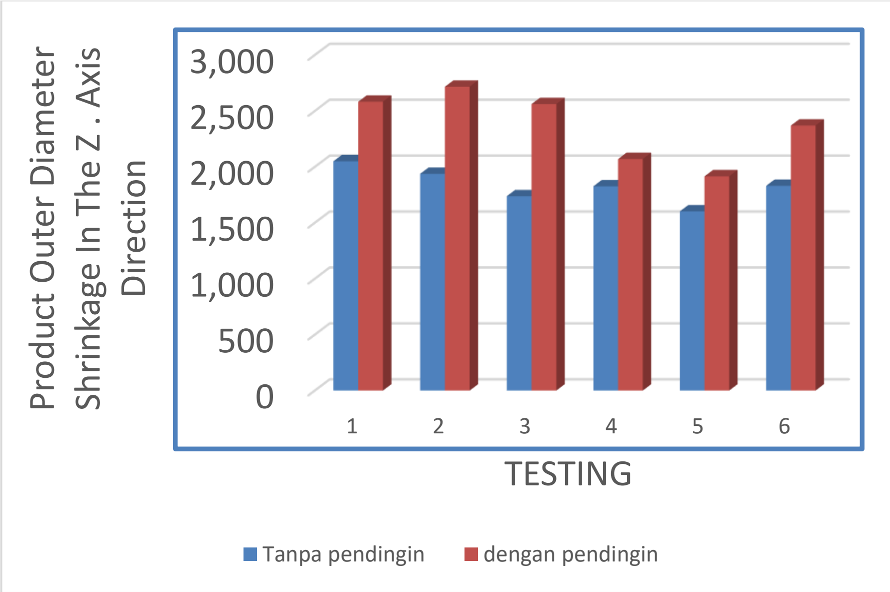
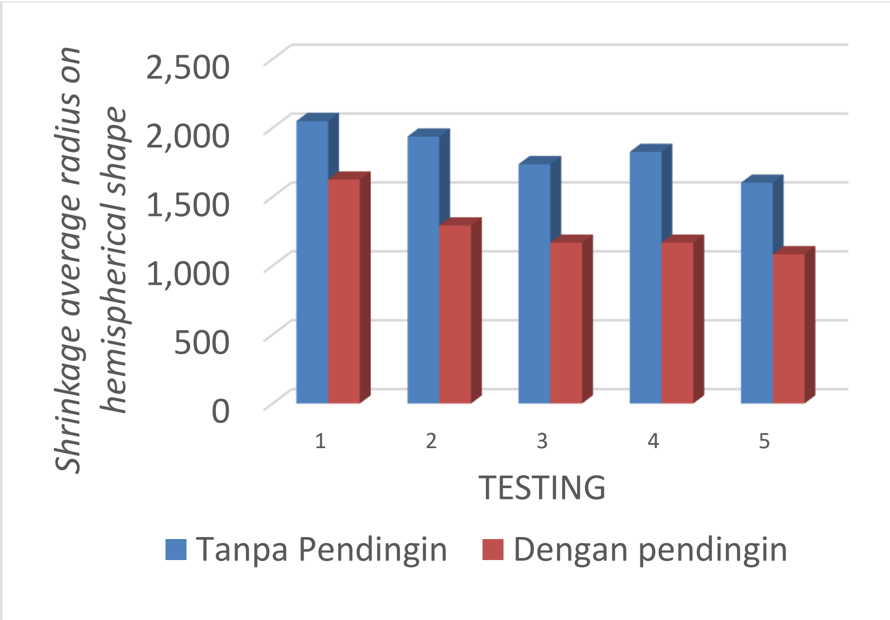


Figure 6. shrinkage of the outer diameter of the product in the Y .-axis direction



In Figure 6, it is shown that 4 out of 5 injection molding tests with the product diameter shrinkage cooler in the Y-axis direction are below 2% and 4 out of 5 times the injection molding test without the product diameter shrinkage cooler in the Y-axis direction is above 2%. Figure 7 shows the histogram of the average shrinkage from the injection molding test with coolant 1.827% while for the injection molding test without cooling it is 2.32%.

Figure 7 shows that the shrinkage in the injection molding test product with cooling is smaller than the shrinkage in the injection molding test product with the coolant. This is because in the cooling process there is an even distribution of heat transfer in the product.

CONCLUSSION

From the results of testing and analysis and discussion of the data obtained, it can be concluded that the cooling in the injection molding process greatly affects the shrinkage of the product. In the injection molding test product with cooling the shrinkage is smaller than the injection molding test without cooling. Measurements on the injection molding shrinkage product were tested with a coolant on the X axis = 1,224 %, on the Y axis = 1,857 %, on the Z axis = 1,83%, and on the radius r = 0,825%. The average shrinkage of the test without cooling on the X axis = 1,591 %, on the Y axis = 2,32%, on the Z axis = 2,369 %, and on the radius r = 1,267 %.

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