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Modification of the Indonesian Growing Bucket Cover Design on the Thickness of the Pipe Place to Reduce Warpage using Solidworks Plastics Software

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ABSTRACT

Cover Indonesian Growing Bucket has a product defect problem in the form of a warpage caused by a design considered good. There was a discrepancy in the parameter settings with the initial analysis results, resulting in a difference in cooling time of 2.3 s from the original 3.9 s. This happened because parameter changes aimed to reduce warpage cycle time from the original 25.4 s to 23.8 s. Based on the problems, design modifications and analysis were carried out using Solidworks Plastics software. The design modification and analysis process was carried out using the Experiment of Analysis method, which was carried out by modifying the thickness of the part, which resulted in a warpage. The analysis was carried out to obtain optimal thickness results with the smallest cooling time gap. Modifications and design analysis are done by making three (3) alternative thicknesses for the pipe clamp section. The best modification of the three (3) alternatives made will be used as a reference basis for making material cost calculation data. From the results of design modifications and analysis, it was found that the design thickness changed to 1.5 mm. Based on the results of this analysis, alternative options are produced, which are then used as a reference in design modifications so that the resulting fill time and cycle time are more optimal.

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INTRODUCTION

PT. ATMI IGI CENTER is a manufacturing company engaged in mold & dies and also plastic injection. Products produced at PT. ATMI IGI CENTER such as plastic products and molds from customers, one of the products being worked on is the Cover Indonesian Growing Bucket product. The Indonesian Growing Bucket Cover production process is carried out by PT. ATMI IGI CENTER experienced several problems, including poor product design caused by product defects in the form of warpage, resulting in the production target not being achieved.

The results of discussions with the production department and product development department from PT. ATMI IGI CENTER produced an initial hypothesis in the form of a statement that the design of the product at the end is not good if using normal injection machine settings, where there is a temperature difference at the end of the product which is where the pipe is clamped, so that the injection machine operator changes the parameter settings to be very slow. This change resulted in the production speed of the Cover Indonesian Growing Bucket slowing down and requiring a cycle time of 25.4 s for one cycle.

Figure 1. Cover Indonesian Growing Bucket

The Indonesian Growing Bucket is a product whose initial idea was to use references from the Dutch Bucket System. The Dutch Bucket System is a hydroponic system that emphasizes circulation and efficient use of water (Nandar, et al., 2020). The material used in making the Indonesian Growing Bucket is Polypropylene (PP) with general characteristics, namely elastic, chemical resistant, electrically resistant, etc. (Malpass & Band, 2012). Polypropylene also resistant to chemicals (Sahwan, et al., 2005). Polypropylene waste is easy to use for making plastic products, even when calcium has to be added (Hutama, et al., 2022).

Making Indonesian Growing Buckets from plastic material is carried out using the injection molding process, which is the process most used in producing plastic pellets into a product for production. The working principle of injection molding according to Bruce (1998) is like a syringe, where the plastic melt is injected into a mold which is tightly closed and inside the machine, so that the melt fills the space in the mold according to the desired product shape. The advantage of the injection molding method compared to other methods is that there is no limit to the complexity of product design, so that the variety of products produced is quite wide, with product sizes that can be printed ranging from small products to large products, and the products produced have good tolerance and precision.

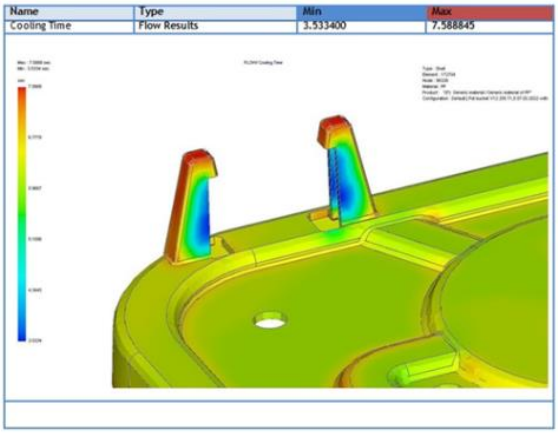


Figure 2. The location where the temperature difference occurs

The production process in injection molding can be influenced by several factors, including the plastic material, the injection machine, and the injection process parameters used. According to Purnomo, et al (2017) the production process carried out using injection molding needs to pay attention to several settings of the injection machine such as temperature, filling phase, holding phase, and plasticizing. Parameters that are not set properly have an impact on poor results or do not comply with product specifications, including the weight of the product produced. Research conducted by Purnomo, et al (2017) obtained results namely that the settings of the injection machine which have an influence on product weight are injection speed, holding time, cooling time, and melt temperature.

The injection process parameters set in the production process can influence the production cycle time so that production can be increased. Cycle time in the injection molding process is the time required by the machine to carry out 1 product production cycle, where in 1 cycle it can produce several products depending on the number of cavities in 1 molding. Cycle time is an important factor for increasing production efficiency, production capacity and costs incurred for production.

The change in the Indonesian Growing Bucket cover design aims to increase production capacity by optimizing to reduce product defects and cycle time. Product weight is something that needs to be researched further to get an Indonesian Growing Bucket cover product that meets PT. ATMI IGI CENTER’s expectations. Optimizing product design is a solution to overcome problems that have occurred before.

This research focuses on modifying the Cover Indonesian Growing Bucket design using the Experiment of Analysis method using Solidworks Plastics software to analyze the results and effects of developing the Cover Indonesian Growing Bucket product design with the Cover Indonesian Growing Bucket product design which has not yet been developed. The development of the Cover Indonesian Growing Bucket product design aims to increase production speed, from initially having a defective product, then developing it by emphasizing changes to the product design, which is expected to get better results from design testing.

METHOD

The design process for the Indonesian Growing Bucket Cover was analyzed using the Experiment of Analysis method. This design method is an analytical method where many experiments are used. In this case, the experiment in question is a design experiment and in the process a lot of analytical data will be collected from each design experiment. So that from the results of the analysis of various experiments, the final result is obtained in the form of the expected design. The experiments refers to research by Hayu (2021), to obtain the appropriate time and product mass. The stages of the Experiment of Analysis can be seen in Figure 3.

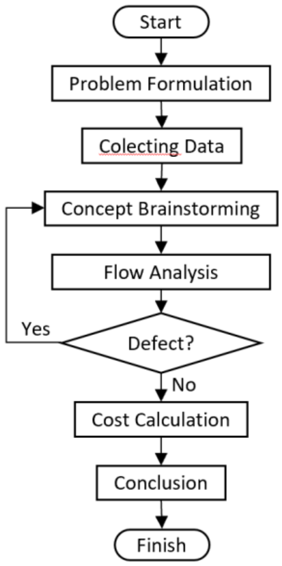


Figure 3. Research Flowchart

The tools and materials used in this research are:

1. Solidworks Plastics Software
2. Laptops & Computers.

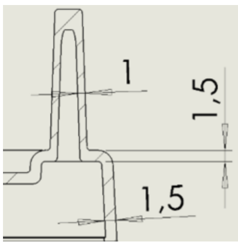


Figure 4. The Non-uniform Thickness

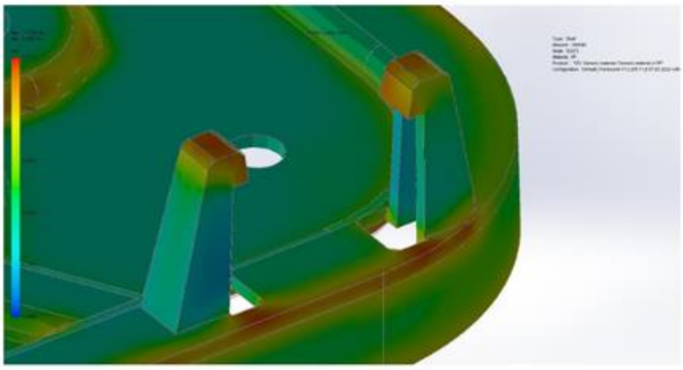
Design modifications are made to product parts with non-uniform cooling times. Three (3) alternative designs will be used with a focus on the non-uniform thickness of the product (1 mm thick) with a maximum thickness limit of 1.5 mm, this is because the overall thickness of the product is 1.5 mm. The thickness distribution of plastic products is not influenced by temperature (Budiyantoto, C., &

Kurniawan., P., 2022). Design alternatives are shown in the following table:Table 1 is the result of alternatives 1, 2, and 3 in terms of cooling time differences.

Table 1. Cooling Time Difference Table

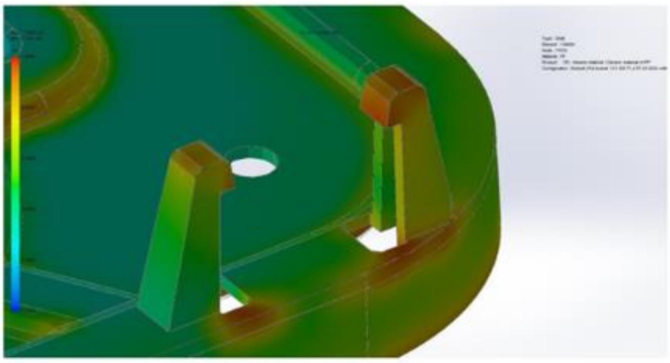
Alternative	Thickness Dimensions	Cooling Time (second)		∆ Cooling Time
		Min	Max	
1	1.4 mm	5.2	7.8	2.6
2	1.5 mm	5.4	7.4	2
3	1.6 mm	5.2	7.7	2.5

Plastic flow simulation results from alternatives 1, 2 and 3. Alternative 2 shows the best improvement in terms of product cooling time.



Name	Type	Min	Max
Cooling Time	Flow Results	5.219625	7.778892

Figure 4. Alternative 1



Name	Type	Min	Max
Cooling Time	Flow Results	5.134320	7.444519

Figure 5. Alternative 2

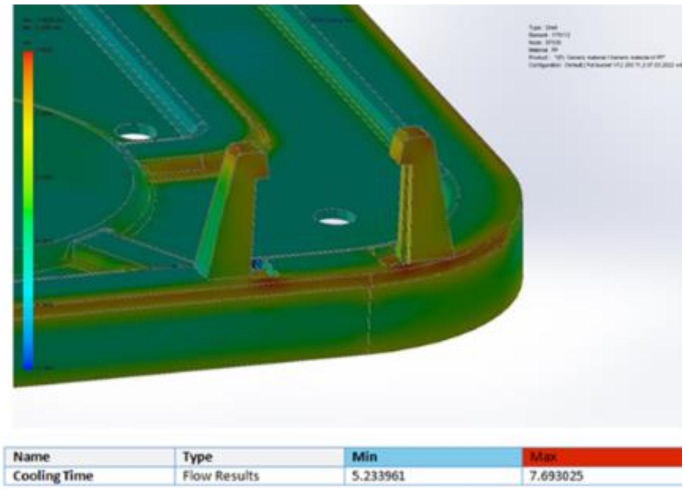


Figure 6. Alternative 3

These three (3) alternatives require different material requirements and material costs but require the same fill time. With a PP plastic material price of IDR.27,000.00/kg from supplier PT. Tunas Harapan, Surabaya, Table 2 shows that material costs have increased.

Table 2. Material Cost Table

Alternative	Thickness Dimensions (mm)	Weight (g)	Cost material (IDR)
1	1.4	112.69	3,042.63
2	1.5	112.74	3,043.98
3	1.6	112.80	3,044.25

Mold Tooling is one of the factors that must be considered because it will cost quite a lot. Mold tooling costs include:

1. EDM Cost
    a. Graphite Cost
        i. Material cost for graphite
            - Price of Graphite Block Tokai Carbon HK-15
                - 300mm x 150mm x 100mm (4,500,000 mm^3)
                  = IDR 2,700,000.00
            - Graphite Volume
                - 10mm x 19mm x 50mm
                  = 9,500 mm^3
            - Cost
                - IDR. 2,700,000.00 / 4,500,000 mm^3
                  = Rp 0.6 / mm^3
                - IDR. 0.6 / mm^3 x 9,500 mm^3
                  = IDR 5,700.00

ii. Machining cost for graphite
   - Machining cost Mill Hsiufong
     - IDR. 100,000/hrs
   - Time Required
     - 0.5 hrs
   - Cost
     - IDR. 180,000.00/hrs x 0.5hrs =
       = IDR. 90,000.00

iii. Total Graphite Cost
   - cost material graphite + cost machining graphite
     - IDR. 5,700.00 + IDR. 90,000.00
       = IDR. 95,700.00

b. Machining Cost

i. EDM Machine Cost
   - IDR180,000.00/hrs

ii. Time Required
   - 2 hrs

iii. Graphite Machining Cost
   - EDM Machine Cost x Time Required
     IDR. 180,000.00 x 2 hrs
     = IDR. 360,000.00

iv. EDM Cost
   - Total Graphite Cost + Graphite Machining Cost
     IDR. 5,700.00 + IDR. 90,000.00
     = IDR. 95,700.00

2. Polish Cost

a. Polishing Service Cost
   i. IDR. 50,000.00/hrs

b. Time Required
   i. 2 hrs

c. Total Polish Cost
   i. Polishing Service Cost x Time Required
      IDR. 50,000.00/hrs x 2 hrs
      = IDR. 100,000.00

3. Mold Assembly Cost

a. Assembly Service Cost
   i. IDR. 50,000.00/hrs
b. Time Required
   i. 1.5 hrs
c. Total Mold Assembly Cost
   i. Assembly Services Cost x Time Required
      IDR. 50,000.00 x 1.5 hrs
      = IDR. 75,000.00

4. Tooling Mold Cost
   a. EDM Cost + Polish Cost + Mold Assembly
      = IDR. 455,700.00 + IDR. 100,000.00 + IDR. 75,000.00
      = IDR. 630,700.00

Break Event Point (BEP) is a condition where the total amount of income is equal to the total amount of expenditure for production purposes in a certain period of time. In this case, what is calculated is the time needed for the accumulated profits from tooling mold production to be equal to the total tooling mold costs.

Volume produksi = 35,000 pcs / year
= 2,917 pcs / month
Profit = IDR. 5,649.00 / pcs
Cost tooling mold = IDR. 630,700.00

BEP (unit) $= \frac{cost\ tooling\ mold}{profit}$

$= \frac{IDR.630{,}700.00}{IDR.5{,}649.00/pcs}$

Cycle time = 25.4 second
Waktu BEP = BEP (unit) x cycle time
= 112 x 25.4 second
= 2,884.4 second
= 47.4 hours
= 1.97 days ≈ 2 days

RESULTS AND DISCUSSION

Based on the analysis results in Table 2, it appears that the fastest cooling time is 2 seconds. Of the three (3) alternatives that have been analyzed using Solidworks Plastics Software, it can be stated that alternative 2 is the most effective design for product cooling time uniformity. This result was obtained from the process of reducing the maximum time to the minimum time in program analysis. The faster the cooling time, the smaller the possibility of warpage occurring

After obtaining the best alternative, the process continues with calculating the manufacturing costs. The consequence of increasing thickness results in increasing the amount of material used. Even though alternative 1 has the cheapest costs, the second alternative has not much difference with alternative 1. With a weight of 112.74 grams and material price of IDR. 27,000.00/kg, alternative 2 has material costs of IDR. 3.043,98. The total cost to modify the mold using alternative design 2 is IDR.630,700.00. So, it requires production of 112 pcs with a time of 47.4 hours or 1.97 days or rounding up to 2 days to achieve the BEP target.

CONCLUSION

Based on the research that has been carried out, it can be concluded that modifying the product design in the thickness of the pipe housing by increasing the thickness from 1 mm to 1.5 mm is effective in overcoming the problem of product cooling time non-uniformity by improving the time difference from 3.9 seconds to 2.3 seconds.

If the mold tooling cost is IDR. 630,700.00, the BEP will be achieved by producing 112 pcs with an estimated time of 47.4 hours = 1.97 days ≈ 2 days.

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