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# Analysis of Fluidity and Flow Characteristics of A356 Aluminum in Sand Casting Using Numerical Simulation Method

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**ABSTRACT**

Aluminum silicon alloy is an aluminum alloy that is widely used in engineering. This alloy has good strength and is widely produced into components through the casting process. Silicon content can lead to a decrease in the fluidity of aluminum castings which in turn will reduce the quality of castings, this fluidity is also influenced by the temperature at which molten aluminum is poured. This study aims to determine the effect of pouring temperature on fluidity, flow characteristics and casting defects in aluminum silicon alloy casting using sand molds. Casting is done by gravity casting, simulation flow analysis includes the distribution of flow velocity, temperature, pressure, surface defects and fluidity that occur during the process of filling the mold cavity and the comparison of the fluidity of castings and surface defects in the experimental. Pouring temperatures of 685, 710, 735, 760 and 785°C with 1, 3, 5, 7, 9, and 12 mm pattern mold thicknesses. The simulation process uses computational fluid dynamic based software. The results obtained that the pouring temperature of 785oC has the highest flow velocity of ±0.145 m/s in a 12mm cavity and a high temperature distribution of ±759oC in a 3mm cavity, while the pouring temperature of 685oC has a high pressure distribution of ±107287 Pa in the cavity. 6mm. Surface defects that occur at least at a temperature of 685oC. The best casting fluidity is at a temperature of 785oC where the cavities of 12, 9, 7, 5 and 3 mm are fully filled and 1mm reaches 181.4 mm.

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## 1. INTRODUCTION

The metal casting industry grows along with the development of casting techniques and methods as well as various models of cast products that flood the domestic market (Setiawan, 2014). We find many cast products ranging from household furniture, automotive components, water pumps to ship propellers (Slamet & Hidayat, 2010). The market demand for this prospective and broad cast metal product is not matched by an increase in the quality of the resulting product so that we encounter many products with (Sudibyo et al., 2013) low quality, namely the number of defects that arise in cast products, especially in casting using sand molds, one of which is surface defects (Kusharjanta & Ariawan, 2011). The quality of the sand mold casting is influenced by the mold, the nature of the molten metal, the design of the channel system, and the pouring temperature

(Rahangmetan et al., 2018). These factors are interconnected with each other so to optimize it is very difficult (Hardianto, 2017). Of the many defects that often occur in casting using sand molds are shrinkage defects (Tjitro & Hartanto, 2002). This defect arises due to the failure of compensation for liquid shrinkage and solidification (Sayuti, 2019). This case is usually caused by inaccurate riser size, channel system and pouring temperature (Sari, 2015). Shrinkage defects can be laminated with one of them by optimizing the pouring temperature. In general, shrinkage defects are eliminated by trial and error, this method takes a lot of time and costs so that it can result in large costs and production time. Numerical simulation is an option to reduce trial and error, usually to overcome the pouring temperature error, CFD (Computational Fluid Dynamic) based software is used (Country & Jamari, 2012). This program is able to display a product or final result like a real object before the process of making the workpiece is carried out so that a product can be identified and its characteristics can be analyzed before being produced (Ramli, 2012).

S.Tjitro et al modeled the riser variation on the distribution of the freezing process using numerical simulation analysis using Ansys software with the aim of predicting shrinkage defects in cast products. The results show that the temperature distribution using a riser of about 125 seconds is faster than without a riser of 310 seconds (Halim et al., 2022). Sulatin et al analyzed the use of two variations of cooling on shrinkage, filling temperature, and prosity using a numerical method simulation using magma sortware. The results showed that the percentage of shrinkage porosity in the second cooling using spot cooling coupled with line cooling was about 3.78% better when compared to using only spot cooling which was around 3.8%. Hafid et al conducted research in the form of simulations of inlet manifold casting products made of AC2B aluminum material with the permanent mold gravity casting method with variations in the addition of a riser using Adstefan simulation software (Ramadan, 2021). Based on the above studies, there are several studies and simulations on the effect of casting temperature on the aluminum casting results, but it is still rare to use simulation methods to analyze how defects occur and fluid flow characteristics when the liquid fills the mold (Tarkono & Ali, 2016). Therefore, this study will discuss this phenomenon and compare it with the results of experimental experiments (Ardiana et al., 2021). Taking into account the things above, it is hoped that the quality of cast products in aluminum casting using sand molds will improve (Syaputra, 2020).

The aims of this research are: (1) To know the phenomenon of flow velocity simulation in the sand mold (Yamin, 2020). (2) Knowing the temperature distribution of the metal liquid in the mold cavity using simulation (Anwar et al., 2021). (3) Knowing the pressure distribution of the liquid in the mold cavity using simulation (Permadi, 2020). (4) Predicting surface defects in castings using simulation(Al Wafa, 2020). (5) Predicting the fluidity that occurs in castings using simulation (Primary, 2016). (6) Analyze and compare the simulation results of casting defects and fluidity with experimental results.

The benefits of this research are as follows: (1) Researchers can add insight and knowledge and experience in aluminum alloy casting. (2) For academics, this research can be used as an additional reference for research on CFD in aluminum alloy casting (Yustisiabellah & Indra Sidharta, nd). (3) For industry, it can be used as a reference or guide in casting Aluminum alloys (Purnawan et al., 2016).

## 2. RESEARCH METHOD

### 2.1 Research Flowchart

Broadly speaking, the implementation of this research will be carried out sequentially and systematically as shown in Figure 3.3

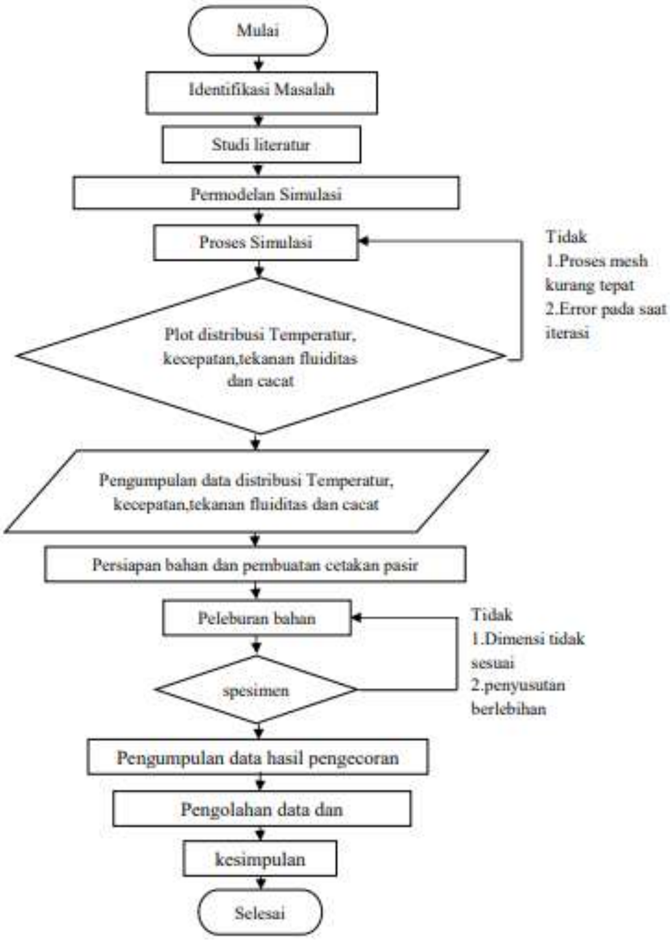


**Figure 1.** Research Flowchart

## 2.2 Method of Research

To analyze the characteristics of this sand mold, a sequence of processes is needed so that the work on this final project can run well which includes: (1) Preliminary Data Collection. This stage is the stage of collecting data about information on the development of traditional casting using sand molds and the development of research on problems and constraints that often arise in the foundry as well as the specifications and dimensions of the data needed during research (Harefa, 2022). (2) Literature Study. This research must be carried out based on theoretical principles recognized in the world of science so that it can be used as a reference for completing this research. This literature study is carried out by obtaining it from reference books, scientific journals, symposium collections, personal discussions, or even via the internet (Risparyanto, 2013). (3) Calculation and Analysis of Computed Data Data calculation in this study was carried out through software simulation. The data needed during the work process is inputted into the data computing process. Next, a discussion of the data generated from the simulation will be carried out (Lubis, 2012). (4) Casting Process, At this stage casting is carried out which starts from melting the material, pouring liquid metal into the mold until drying the castings. (5) Data Collection and Drawing Conclusions (Rahmanto, 2019). After getting all the data needed, conclusions are drawn (Sri & Indriati, 2019). This conclusion is based on the correlation with the research objectives that have been previously set. Thus, it is hoped that there will be no deviation from the research objectives (Tersiana, 2018).

## 3. RESULTS AND DISCUSSIONS

### 3.1. Simulation Analysis of Speed Distribution Results

A numerical simulation has been carried out to see the aluminum flow velocity contour which is shown in the form of a 3-dimensional contour to the xyz plane. Analysis of the simulation results is carried out when the metal liquid fills the mold for 1 second, the results are as follows: - Aluminum flow rate at 1 second. The results obtained are in the form of fluid contours indicated by colors that indicate the magnitude of the resulting velocity at the time of casting. red color indicates that the maximum speed area occurs in this area. While the blue contour shows the smallest speed. The maximum speed for each casting thickness at the inlet is shown in table 4.1 below:

**Table 1.** Distribution of Aluminum Flow Velocity on Casting Thickness

| Tebal Coran | Kecepatan Pada Tempratur Tuang (m/s) | | | | |
|---|---|---|---|---|---|
| (mm) | 685 | 710 | 735 | 760 | 785 |
| 1 | | | | | |
| 3 | | | | | |
| 5 | | | | | |
| 7 | 0.13 | 0.154 | 0.199 | 0.209 | |
| 9 | | 0.154 | 0.231 | 0.233 | 0.248 |
| 12 | | | 0.199 | 0.233 | 0.303 |

**Table 2.** Showing Simulation Results in the form of Velocity Distribution of Each Casting Thickness. The Flow Velocity Graph Is Shown By Figure 4.2.

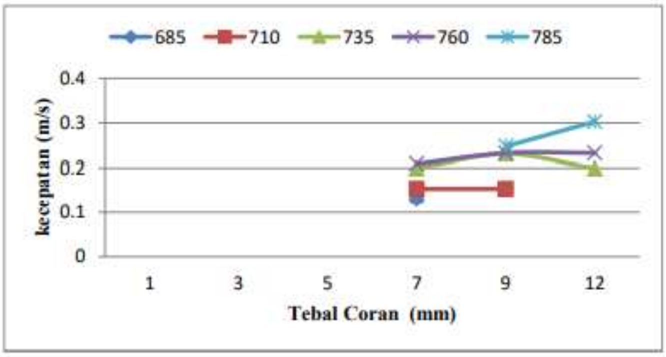


**Figure 2.** Graph of Flow Velocity Vs Cast Thickness

From the graph above, we can see that the highest flow velocity is found at the pouring temperature of 7850C in the 12mm cavity, which is ± 0.303 m/s as shown by the light blue contour in Figure 4.1 (a) This is because the flow is focused on the 12mm cavity. While the lowest fluid velocity is indicated by the pouring temperature of 685oC with the maximum speed in cavity 7 only reaching ± 0.13 m/s. This is due to the low pouring temperature which results in high flow viscosity. Aluminum flow rate at 2 seconds.

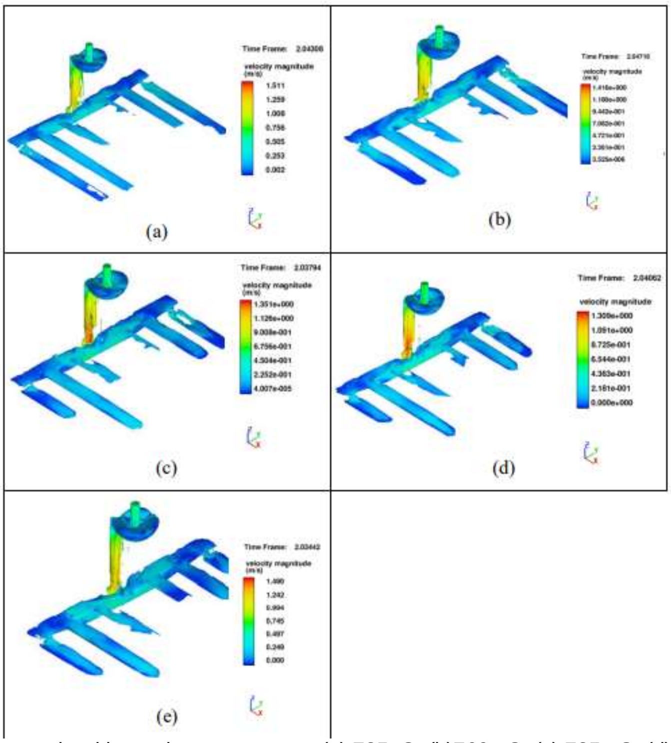

**Figure 3.** flow rate at 2 seconds with pouring temperature (a) 785oC, (b)760 oC, (c) 735 oC, (d) 710 oC and (e) 685 oC.

The results obtained are in the form of fluid contours indicated by colors that indicate the magnitude of the resulting velocity at the time of casting. The red color indicates that the maximum speed area occurs in this area. While the blue contour shows the smallest speed. The maximum speed for each casting thickness at the inlet is shown in table 4.2 below:

**Table 3.** shows the simulation results in the form of velocity distribution of each casting thickness. The flow velocity graph is shown in Figure 4.

| Tebal Rongga (mm) | Kecepatan Pada Tempratur Tuang (m/s) | | | | |
|---|---|---|---|---|---|
| | 685 | 710 | 735 | 760 | 785 |
| 1 | 0.356 | 0.276 | 0.249 | 0.18 | 0.227 |
| 3 | 0.268 | 0.193 | 0.249 | 0.18 | 0.227 |
| 5 | 0.268 | 0.193 | 0.174 | 0.18 | 0.227 |
| 7 | 0.268 | 0.193 | 0.174 | 0.18 | 0.227 |
| 9 | 0.268 | 0.276 | 0.249 | 0.26 | 0.3 |
| 12 | 0.268 | 0.359 | 0.325 | 0.341 | 0.373 |

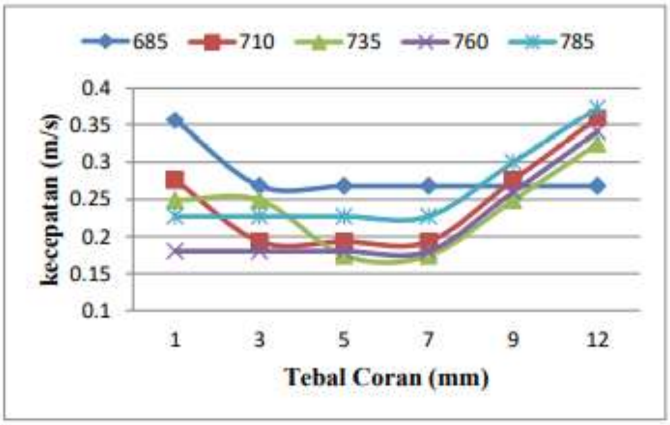


**Figure 4.** Graph of Flow Velocity Vs Cast Thickness

From the graph above, we can see that the highest flow velocity is found at the pouring temperature of 7850C in a 12mm cavity, which is ± 0.373 m/s as shown by the light blue contour in Figure 4.1 (a) This is due to the high pouring temperature which results in low flow viscosity. . While the lowest fluid velocity is indicated by the pouring temperature of 735oC with the maximum speed in the 5mm and 7mm cavities only reaching ± 0.174 m/s. This is due to the low pouring temperature which results in high flow viscosity.

### 3.2. A356 . Aluminum Fluidity Simulation Results

The following is a comparison between the casting temperature and the fluidity of the A356 aluminum silicon alloy castings.

**Table 4.** Fluidity simulation result data

| Tebal coran (mm) | Fluiditas pada variasi temp tuang (mm) | | | | |
|---|---|---|---|---|---|
| | 685 | 710 | 735 | 760 | 785 |
| 12 | 375 | 375 | 375 | 375 | 375 |
| 9 | 375 | 375 | 375 | 375 | 375 |
| 7 | 335 | 335 | 335 | 335 | 335 |
| 5 | 281.22 | 335 | 335 | 335 | 335 |
| 3 | 201.88 | 185 | 242.73 | 251.2 | 295 |
| 1 | 95.9 | 108 | 118 | 131.8 | 181.4 |

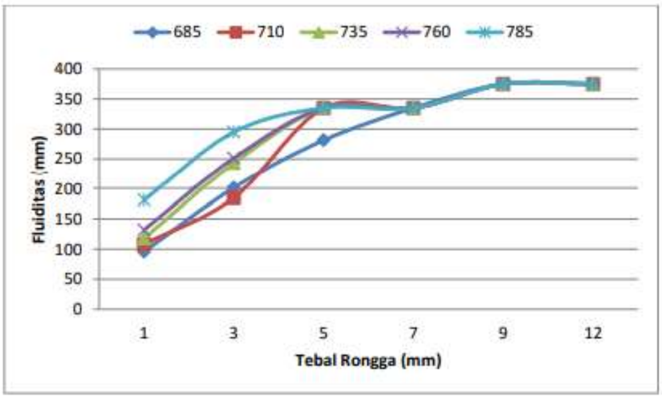


**Figure 5.** Fluidity vs casting thickness simulation graph

From the graph above, we can see that the lowest fluidity is at the pouring temperature of 685oC this is because the pouring temperature is close to the solid temperature of aluminum a356 liquid, which is 552.4oC. and we can also see in the graph above that the lowest fluidity at each pouring temperature is in the cavity the smallest is the 1mm cavity. This is due to the small channel cavity resulting in an increase in surface tension. Factors that affect the value of fluidity are temperature (degree of superheat), chemical composition, surface tension, conductivity of the mold material, inclusions and viscosity.

### 3.2.1. Comparison between Simulation Fluidity Results and Experimental Casting Results

The following is a comparison of the fluidity of the A356 aluminum silicon alloy castings by simulation and experimental.

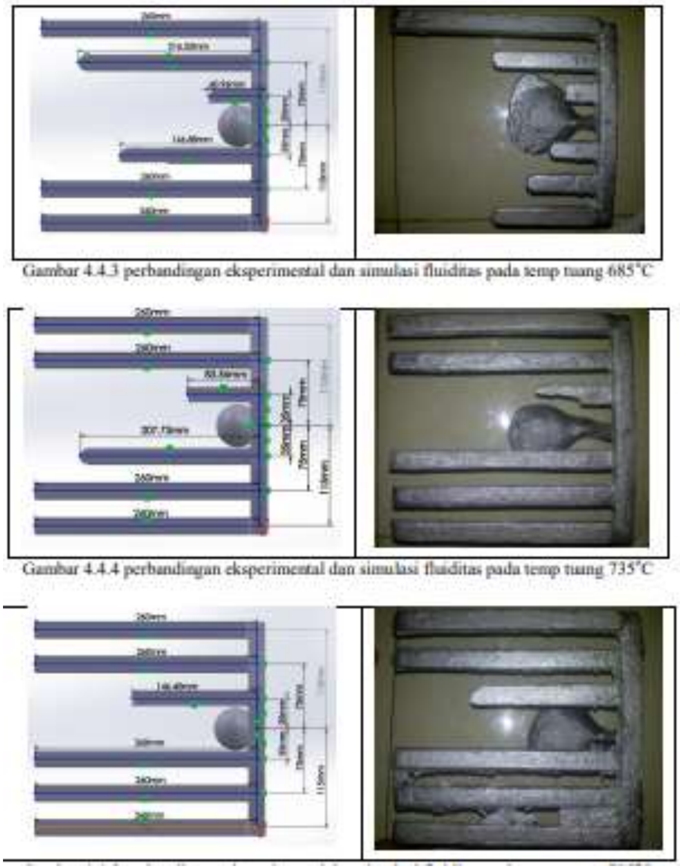


**Figure 6.** experimental comparison and fluidity simulation at pour temp 785oC

**Table 5.** Experimental and simulation fluidity results data

| Rongga Cetakan | Fluiditas pada variasi temp tuang (mm) | | | | | |
|---|---|---|---|---|---|---|
| | Eksperimental | | | Simulasi | | |
| | 685 | 735 | 785 | 685 | 735 | 785 |
| 12 | 375 | 375 | 375 | 375 | 375 | 375 |
| 9 | 252 | 375 | 375 | 375 | 375 | 375 |
| 7 | 171 | 335 | 335 | 335 | 335 | 335 |
| 5 | 215 | 335 | 335 | 281.22 | 335 | 335 |
| 3 | 103 | 295 | 295 | 201.88 | 250.92 | 295 |
| 1 | 83 | 130 | 210 | 95.9 | 131 | 181.4 |

**Table 4.4.2**shows experimental and simulated values of fluidity for A356 aluminum material. The fluidity graph of A356 Aluminum material can be seen in Figure 4.4.6

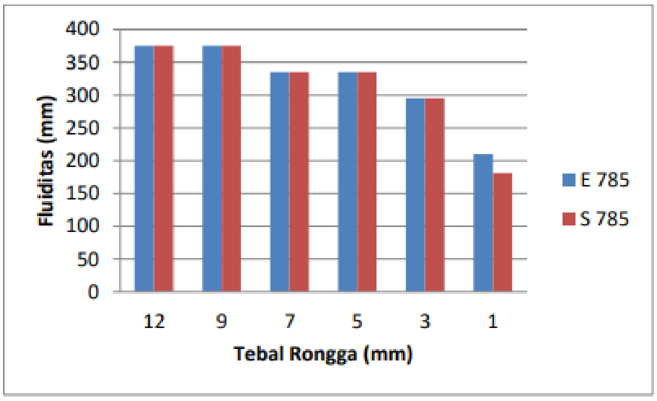


**Figure 7.** Experimental Fluidity Graph And Pour Temperature Simulation 785 Oc

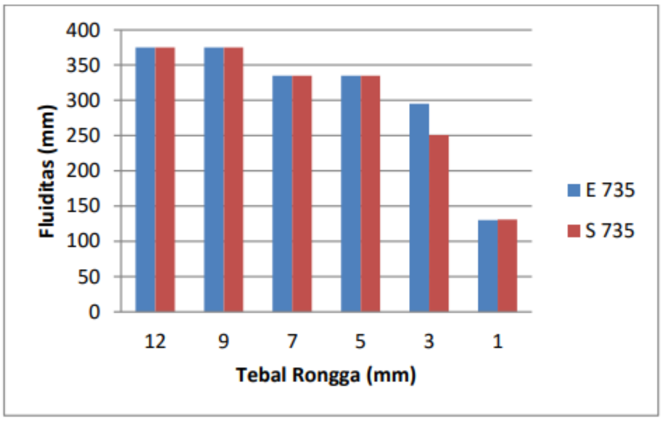


**Figure 8.** Experimental fluidity graph and pour temperature simulation 735 oC

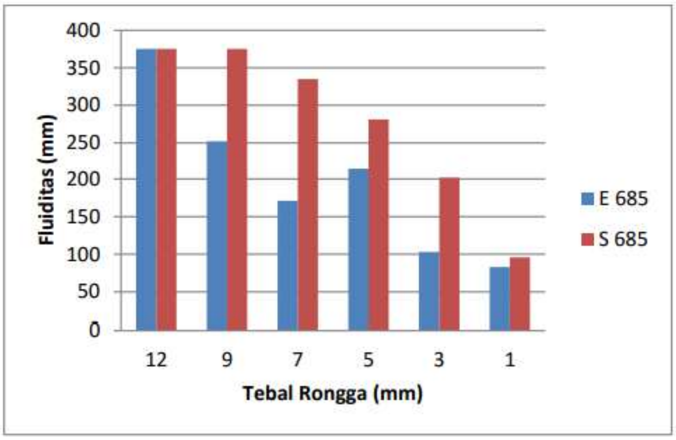


**Figure 9.** Experimental fluidity graph and pour temperature simulation 685 oC

From table 4.4.2 and the graph above, we can calculate the percent error between the simulation and experimental data using the percent error formula for each pouring temperature. The percent error value between experimental and simulation data at each pouring temperature can be seen in table 4.4.3

**Table 6.** Simulation and Experimental Error Percentage Table

| Rongga Cetakan (mm) | % Ralat | | |
|---|---|---|---|
| | 685 °C | 735 °C | 785 °C |
| 12 | 0% | 0% | 0% |
| 9 | 32.80% | 0% | 0% |
| 7 | 48,9% | 0% | 0% |
| 5 | 23,4% | 0% | 0% |
| 3 | 48,7% | 14,9% | 0% |
| 1 | 12,6% | 0,76% | 13,6% |

From the value of the percent error in table 4.4.7 above, we can see that the highest present error is at the pouring temperature of 685oC, which is in the 7mm cavity of 48.9% this is because experimentally at the time of casting there are many factors that affect the fluidity of the flow of aluminum A356 in the sand mold. such as water content in sand, bentonite content in sand and sand grain size which cannot be adjusted during simulation using software. This also happened in a study conducted by Sabatino et al where they performed an analysis of the fluidity of a356 using the spiral method using simulation and experimental and the simulation results showed far differences at the time of pouring with the lowest temperature. Increasing the pouring temperature increases the length of the fluidity. Increasing temperature increases fluidity linearly. The simulation results show that the increase in pouring temperature increases the length of the fluidity in the A356 alloy.

## 4. CONCLUSION

(3) The highest pressure occurs at a pouring temperature of 760oC in cavity 12, which is ±107287 Pa at the 6th second, while the lowest pressure occurs at a pouring temperature of 785oC, namely in the 7mm cavity in the 5th second, which is 99343 pa. (4) The highest concentration of surface defects was found at a casting temperature of 785 oC while the lowest was found at a casting temperature of 685 oC. (5) The best fluidity simulation results were obtained at a pouring temperature of 785oC. This is because the 12mm, 9mm, 7mm, 5mm and 3mm cavities are completely filled while in 1mm cavities the fluidity length reaches 181.4 mm. The worst fluidity is that at the pouring temperature of 685oC there are three unfilled cavities, namely the 5mm cavity 281mm long, 3mm 201mm and 1mm 95.

Suggestions in this study are: (1) Equipment or computers with adequate specifications so that experiments can be carried out with smaller mesh sizes so that more accurate results can be obtained. (2) To develop software that is suitable and easy to understand for students, as well as for beginners in learning to use flow simulation. (3) It is necessary to conduct further research on the uncontrolled variables in this study, such as pouring speed, water content in the sand mold, and pouring temperature, especially in casting using sand molds.

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