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The Effect of Varying Pouring Temperatures on Fluidity and Microstructure in The Re-Melting of Used Motorcycle Wheels Through Sand Casting

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ABSTRACT

Reutilization of renewable components, such as motorcycle wheels, helps reduce environmental impact and production costs. Used alloy wheels can be recycled by remelting through metal casting. However, problems arise when the castings to be made are relatively thin. This requires a liquid met-al with good castability to minimize production defects, especially in thin and complex products. Factors affecting product quality include fluidity and microstructure, which are influenced by variations in casting temperature. This study aims to determine the fluidity value and microstructure of the specimens. The method used is experimental. The material used consists of used motorcycle wheels. The casting method employed is sand casting, using a spiral-shaped mold with a thickness of 4 mm. The pouring tempera-ture variations used were 730°C, 750°C, and 770°C. The results showed that a pouring temperature of 730°C resulted in a fluidity value of 514 mm, while a pouring temperature of 750°C resulted in a fluidity value of 663 mm. At a pouring temperature of 770°C, the fluidity value increased to 714 mm. Increasing the casting temperature causes an increase in fluidity value. At low temperatures, the microstructure exhibits larger dendrites, whereas at high temperatures, the dendrite structure becomes finer. The silicon eu-tectic between the Dendrite Arm Spacing (DAS) becomes narrower at lower temperatures and wider at higher temperatures.

Keywords: Alloy recycling, sand casting, fluidity, microstructure

Introduction

Many automotive industries, including motorcycles, experience rapid development in today's era. The presence of used or damaged motorcycles is one of the problems that must be faced. Reusing renewable components like motorcycle rims is an attractive alternative for reducing environmental impacts and production costs. The casting technique forms raw materials/workpiece materials by melting or liquefying metal in a melting furnace. The melted results are then inserted into a mold or pattern (Dwisetiono, 2019). Casting techniques are very broad in use, especially in engine parts, because they can also be used to form complex engine parts.

One of the processes for making engine parts uses the sand-casting method. The sand-casting method is the most common production method used in the industrial world. This method allows the manufacture of products at low cost and fast time with a capacity of tons (Bhirawa, 2013).

In addition, the microstructure is also an essential factor in showing the results of castings at various pouring temperatures in the form of dendrite structures. This dendrite structure is a characteristic of aluminum-silicon (Al-Si) alloys. The difference in the microstructure of castings

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with various pouring temperatures lies in the dendrites' size and arrangement. The size of the dendrites will decrease as the pouring temperature increases (Daely, 2016).

Pour temperature is an essential factor in the metal casting process because it can affect the physical and mechanical properties of the final product, including strength, hardness, ductility, and wear. Pour temperature can also affect fluidity in the mold. Therefore, pouring temperature is crucial in ensuring the quality and reliability of the cast metal products produced. (Li et al. 2021), with the research title "Fluidity of Adc12 + xLa Aluminium Alloys," explains the effect of rare earth lanthanum and casting temperature on the fluidity of ADC12 aluminium alloy studied through spiral fluidity specimens with an optical microscope and differential thermal analyzer. The least squares regression method provided the best fit between the function and experimental data. The experimental results showed that the fluidity length of the ADC12 alloy increased rapidly with increasing La addition, which resulted from a decrease in the crystallization temperature range, a sizeable exothermic reaction, and a finer a-Al primary phase. When La was added 0.6 wt%, the crystallization temperature range decreased by 32.66%, and the fluidity length was 1,321 mm (an increase of 38.91%) compared to the base alloy. With increasing casting temperature, the fluidity length increased. When the pouring temperature is 760oC, the fluidity length increases to 1,321 mm, 114.1% compared to the alloy at 670 °C (Li et al., 2021).

Wijoyo et al. (2017), in a study entitled "The Effect of Adding 12% Mg to the Results of Remelting Used Aluminum Rims on Fluidity and Hardness with Variations in Pouring Temperature," explained that recycling is a process of turning used materials into new materials to prevent waste that can be helpful something, reducing the use of new raw materials, reducing energy use, reducing pollution, land damage, and greenhouse gas emissions when compared to the process of making new goods. This study aims to investigate the effect of adding 12% Mg to the results of remelting used aluminum rims on fluidity and hardness with variations in pouring temperature. The research materials are aluminum alloys from used car rims and magnesium, then melted and poured into molds with variations in pouring temperatures of 670°C, 720°C, and 770°C. Casting is done using the evaporative method using a polystyrene foam pattern. The study showed that variations in pouring temperature on the fluidity of the results of remelting used rims with the addition of 12% Mg generally increased the flowability properties. At the same time, the hardness was optimum at a pouring temperature in the range of 700°C (Wijoyo & Pratama, 2017).

According to Bambang Tjiroso et al. (2010) The Effect of Chemical Composition and Tilt Casting Mold Inclination Speed on the Microstructure of Al-Si-Cu Alloys, four variations of the alloy were obtained, namely 1.17% Cu, 1.65% Cu, 2.14% Cu, and 2.76% Cu. Microstructure observations were carried out on all cast products with mold inclination speeds of 9, 12, and 15°/second. The accumulation of silicon alloy segregation is seen in a blackish color. The structure consists of an Al matrix (white), an interdendritic network of eutectic silicon (dark gray, sharp), Cu; Mg-Si-Al, and Fe; Si-Al (Tjiroso et. al., 2010).

Casting is a process in which raw metal materials are melted in a furnace and then poured into molds to form objects (Surdia & Chijiwa, 2009). This technique is widely used, especially for creating complex machine parts. One method used to produce machine parts is sand casting. Sand casting is one of the most commonly used production methods in the industry. This method allows for low-cost and quick production of products with a capacity of tons (Markum, 2009).

One important factor affecting the quality of products made using the sand-casting method is fluidity during casting. Fluidity refers to the ability of molten metal to flow into the mold before solidifying. Good fluidity is generally intended to prevent defects in the cast product (Daely, 2016).

Additionally, the pouring temperature is an important factor in the metal casting process because it can affect the physical and mechanical properties of the final product, such as strength, hardness, ductility, and wear resistance. The pouring temperature also influences the fluidity of the metal in the mold. Therefore, maintaining the correct pouring temperature is crucial for ensuring the quality and reliability of the cast metal products (Suherman, 2019).

Aluminum casting is a manufacturing process that has been around for some time. This method has been used in making many aluminum products used as parts of aircraft, automobiles, turbines, and structures like bridges (Alare & Adeloya, 2023). Ishfaq et al. (2022) formulate empirical relations for the contradictory responses, i.e., hardness, ultimate tensile strength and surface roughness, using the response surface methodology. The experimental results were comprehensively analyzed using statistical and scanning electron microscopic analyses.

Olaiya et al. (2019) the mechanical properties of scraped and recycled Aluminium cooking utensils were examined to assess their suitability for engineering applications. The scraps collected from dump sites and other places were melted and cast into sample rods using sand casting and die-casting methods. Cast components were then machined into standard dimensions to suit available machines for testing. The tests carried out include composition before and after melting, tensile testing, and hardness testing as well as metallographic test. Universal testing machine was used for tensile test while Rockwell B scale testing machine was used for hardness test. Ultimate tensile test value of 161.34N/mm2 and 172.25N/mm2 were obtained for sand-cast and die-cast specimens respectively, Hardness result value of 23.3 HRB was obtained for sand-cast sample while die-cast sample had a result of 26.7HRB. Metallographic investigation reveal that die-cast samples have better mechanical properties with closely packed grain size and surface finish compared to sand cast samples. It was then concluded that aluminium cooking utensils can be recycled and reused for other useful engineering applications where less strength and hardness are required (Olaiya et. al., 2019).

The objective of this research is to determine how variations in pouring temperature affect the fluidity and microstructure of aluminium from used motorcycle rims using the sand-casting method.

Material and Methods

The method used in this research is experimental, utilizing aluminium from motorcycle rims as the material. The sand-casting method is employed, and fluidity is measured using a spiral-shaped mold with dimensions of 4 mm thickness, 10 mm width, and 1005 mm length. The pouring temperatures are varied at 730°C, 750°C, and 770°C. Tests are conducted to determine the fluidity values, and microstructure observations are made on the specimens. Preparation of tools and materials includes preparation of melting furnace, ladle, blower, and other supporting tools. The materials prepared are used motorcycle rims.

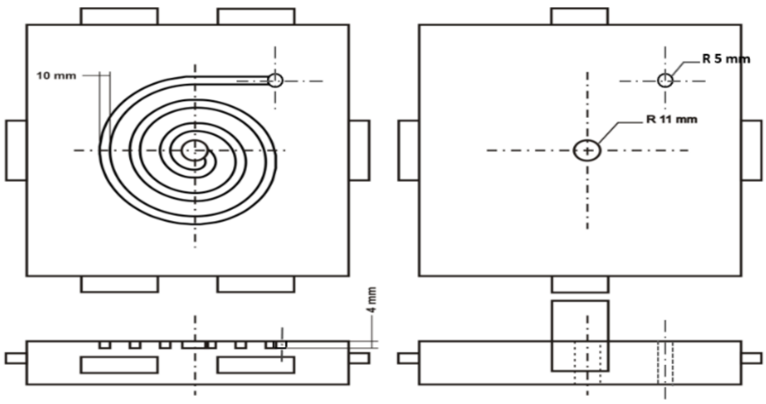

Figure 1. Fluidity mold

Fluidity value analysis.

Fluidity testing is a crucial process in metallurgy and foundry industries, where molten metal's ability to flow into a mold before solidifying is analyzed. One common method to assess fluidity is through sand-casting, a process where molten metal is poured into a sand mold to create a desired shape. Fluidity testing using the sand-casting method helps engineers understand the behavior of molten metal as it flows through intricate mold cavities and solidifies, enabling them to optimize casting parameters, minimize defects, and produce high-quality castings.

Fluidity testing using the sand-casting method with varying pouring temperatures is conducted by measuring the end point of solidification in a spiral-shaped mold, with the aim of obtaining fluidity values in the casting. The data collected will later form a graph comparing the length of aluminium that can enter the mold with the number of samples taken. Fluidity testing is a crucial process in metallurgy and foundry industries, where molten metal's ability to flow into a mold before solidifying is analyzed. One common method to assess fluidity is through **sand-casting**, a process where molten metal is poured into a sand mold to create a desired shape. Fluidity testing using the sand-casting method helps engineers understand the behavior of molten metal as it flows through intricate mold cavities and solidifies, enabling them to optimize casting parameters, minimize defects, and produce high-quality castings.

Microstructure Observation

Microstructure observation is conducted on each casting specimen to determine the microstructure visible in the cast products. Microstructure observation is a fundamental technique used in materials science and engineering to analyze the internal structure of materials at the microscopic level. It involves examining the arrangement, size, shape, and distribution of phases and grains within a material to understand its mechanical, physical, and chemical properties. By observing microstructures, researchers can deduce important information about a material's behavior, including its strength, toughness, ductility, and susceptibility to failure. The process of microstructure observation involves several critical steps, from sample preparation to imaging and analysis, each of which is essential to obtaining accurate and meaningful results. This guide will provide a detailed overview of the various stages involved in microstructure observation, including:

1. Sample Selection
2. Sample Preparation
3. Microscopy Techniques
4. Imaging and Data Analysis

In this research, the Optical microscopy was used. This is one of the most commonly used techniques for microstructure observation. It involves using light to examine the surface of the sample at magnifications typically ranging from 50x to 1000x. Optical microscopes are equipped with polarized light, dark field, and bright field capabilities to enhance contrast and highlight specific features such as grain boundaries, inclusions, and phases.

Steps for preparing a sample for microstructure observation

Sectioning

The material (Al or Al-Si) is cut into a small sample using abrasive saws or other precision cutting tools. Care must be taken to avoid introducing excessive heat, which can alter the microstructure.

Mounting

The cut sample is mounted in a resin block to provide a stable base for subsequent polishing steps. Cold or hot mounting techniques are used depending on the material's sensitivity to heat.

Grinding

The mounted sample is ground using a series of progressively finer abrasive papers (starting at 240 grit and progressing to 1200 grit or higher). This step removes the rough surface layer and smooths the sample.

Polishing

After grinding, the sample is polished. This step removes surface scratches and prepares the sample for fine microstructure observation. Polishing is critical as it reveals fine details like grain boundaries and second phases in the microstructure.

Etching

The polished sample is etched using chemical solutions that reveal the grain boundaries, phases, or inclusions.

Results and Discussion

The Effect of Pouring Temperature Variations on Fluidity

The results of the analysis of the effect of casting temperature variations on fluidity in motorcycle alloy wheel materials can be seen in Table 1.

Table 1. Fluidity test results

specimen	Thickness (mm)	Temperature (°C)	Fluidity Value (mm)
1		730	514
2	4	750	663
3		770	714

Table 1. shows the results of variations in pouring temperature on fluidity values. The test results were obtained at a pouring temperature of 730°C with a thickness of 4 mm. A fluidity value of 514 mm was obtained when applied to a spiral mold. Meanwhile, for a pouring temperature of 750°C with the same thickness (4 mm), there was a pretty good increase in fluidity from the casting with a pouring temperature of 730°C. Where at a pouring temperature of 750°C, the fluidity value obtained was 663 mm, and the test results at a pouring temperature of 770°C with the same thickness (4 mm) had better fluidity properties than at a pouring temperature of 730°C and 750°C. Where at a pouring temperature of 770 °C, it produced a fluidity value of 714 mm.

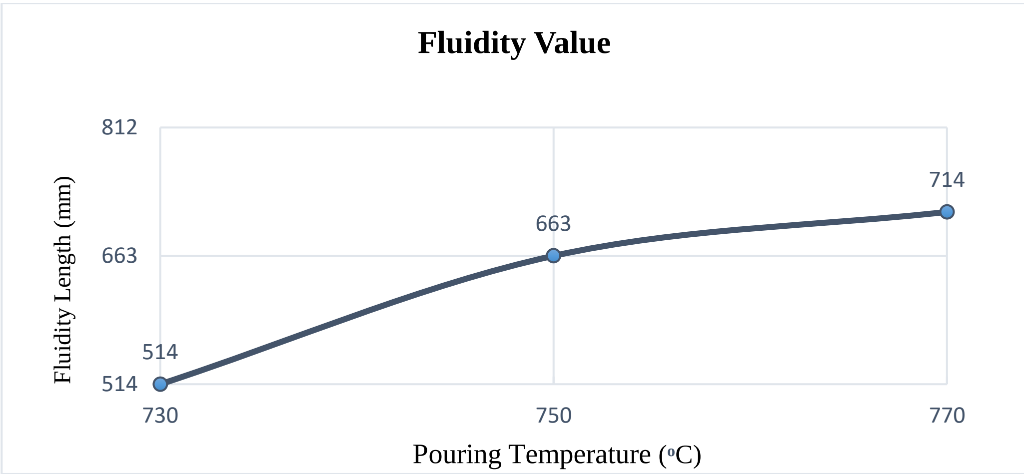

Figure 2. Relationship graph between pouring temperature variation and fluidity value

The effect of pouring temperature variation can affect the fluidity value. As the casting temperature increases, the fluidity value will also increase. The tendency of increasing fluidity is especially noticeable at higher casting temperatures, namely 770˚C and 750˚C. The increase in fluidity is not significant at lower casting temperatures (730˚C). This result is in line which states that increasing the pouring temperature greatly affects fluidity where increasing the pouring temperature will extend the time to remain liquid and reduce the cooling rate of the melt, which helps increase the flow length (Zou et al., 2021). In line with the fluidity of liquid metal will increase as the pouring temperature is increased, the fluidity properties are always getting better with increasing pouring temperature (Wijaya et al., 2017).

The effect of pouring temperature variation on microstructure

The Effect of pouring temperature variation on microstructure was show figures 3, 4, and 5 e. The Microstructure Photographs show castings of used motorcycle wheels in sand casting mold patterns with variations in casting temperatures of 730˚C, 750˚C, and 770˚.

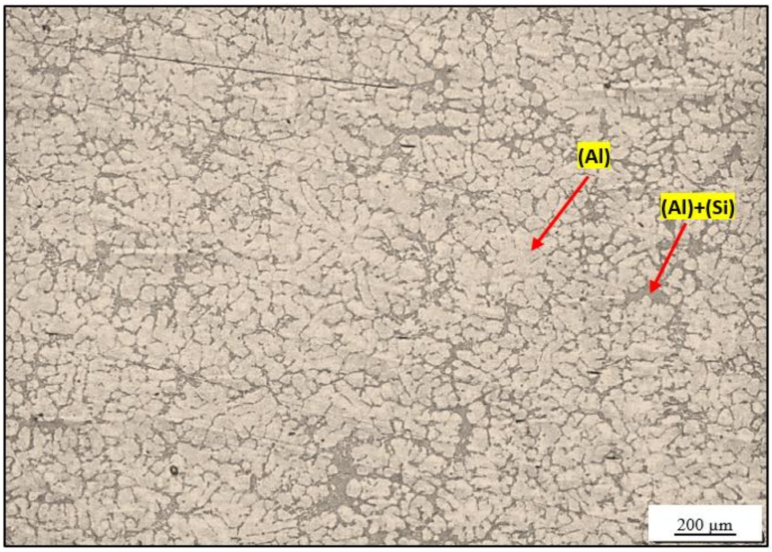

Figure 3. Microstructure remelting results of cast temperature variation 730 ˚C

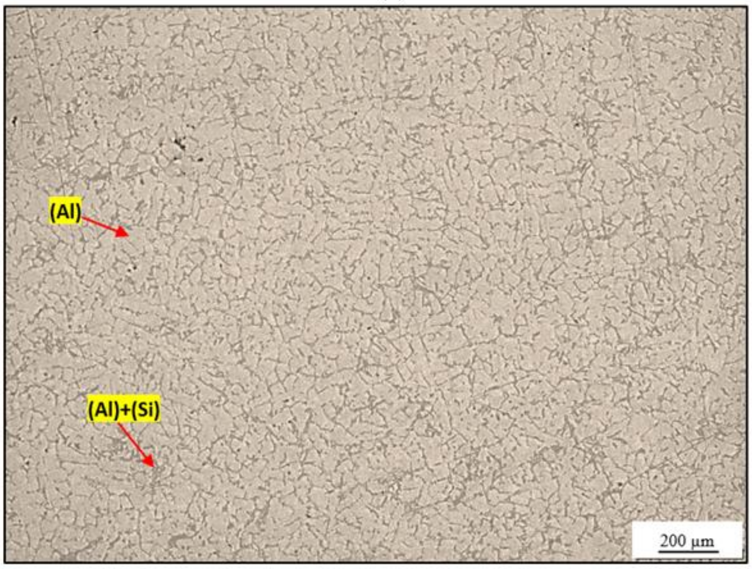

Figure 4. Microstructure remelting results of cast temperature variation 750 ˚C

The results show that at three different casting temperature variations, the overall microstructure of the castings is a dendrite structure. The main difference in the microstructure of the castings lies in the size and arrangement of the dendrite structure. In the microstructure of castings with a cast temperature variation of 730 ° C, the dendrite formed has a large size, this is because at this temperature (730 ° C) has a relatively faster cooling speed, so the dendrite structure has less time to grow and develop. Whereas in the 750°C pouring temperature variation, the dendrite structure formed is smaller than the lower temperature (730°C). In the 770°C pouring temperature variation where the dendrite formed has almost the same size as the 750°C pouring temperature variation, but the dendrite structure is smaller than the previous temperature variation, this is because the 750°C and 770°C pouring temperatures have a slower cooling speed than the 730°C temperature so that the dendrite structure grows longer and forms a smaller dendrite structure.

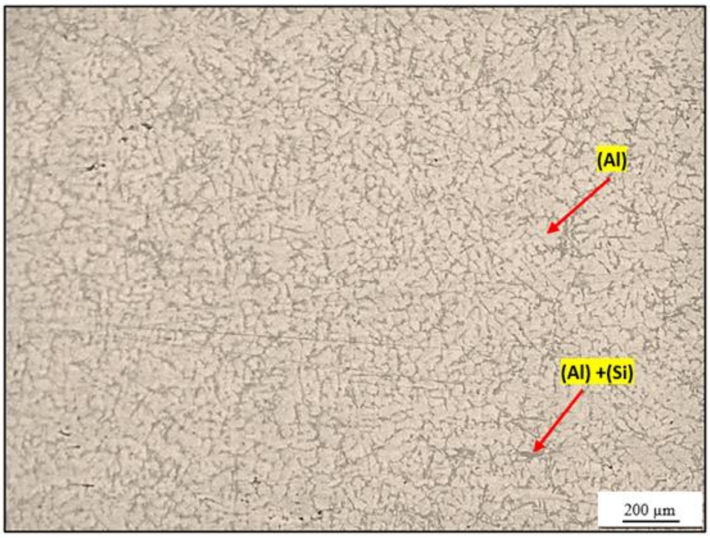

Figure 5. Microstructure remelting results of cast temperature variation 770 ˚C

The microstructure of castings of used motorcycle wheels in sand casting mold patterns with variations in casting temperature (730°C, 750°C, and 770°C) changes as the casting temperature increases. At low casting temperatures, the silicon eutectic found between the Dendrite Arm Spacing (DAS) becomes narrower. Conversely, at high pouring temperatures, the silicon eutectic contained between the Dendrite Arm Spacing (DAS) has a longer freezing time. As a result, the eutectic silicon contained between the Dendrite Arm Spacing (DAS) will decompose longer to form a wider microstructure.

Conclusion

At a temperature of 730 ° C, a fluidity value of 514 mm is obtained, at a temperature of 750 ° C, a fluidity value of 663 mm is obtained and at a temperature of 770 ° C, the fluidity value increases to 714 mm. Increasing the pouring temperature the fluidity value will also increase. Lower casting temperatures result in larger dendrite structures, while higher casting temperatures result in smaller dendrite structures. The eutectic silicon present between the Dendrite Arm Spacing (DAS) becomes narrower at lower casting temperatures. Conversely, at higher casting temperatures, the eutectic silicon between the DAS forms a wider microstructure.

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