ARCN International Journal of Sustainable Development
ISSN: 2384-5341. Volume 14, Issue 1, (March, 2024) pages 121 – 124
DOI: 2726-4-573-1-1422
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https://arcnjournals.org

Assessment of Different Materials for Casting Operations: Comparing the Performance of Locally Available Clays and Aluminum Alloys as Casting Media

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Abstract: *This study assessed the efficacy of various materials, including locally available clays and aluminum alloys, as casting media for sand casting operations. Four plates measuring 165mm x 80mm x10mm were cast within sand molds, with steel, copper, and brass chills in the form of cylindrical bars (7mm in diameter, 50mm long) inserted at regular 30mm intervals within each mold, while one sample remained unchilled. Mechanical property tests and metallographic analyses were conducted on the cast samples. The findings indicated that the sample chilled with copper exhibited the highest mechanical properties, suggesting its superiority as a chill material in sand casting of aluminum alloy.*

Keywords: *casting; chills, aluminum alloy, impact strength test, mould.*

INTRODUCTION

Metal casting, a fundamental shaping process, involves pouring molten metal into a prepared mold, where it solidifies to take the shape of the mold cavity (Ibhadode, 2001). Sand casting, a prevalent method in metal casting, utilizes sand as the mold material (Ibhadode, 2001). Casting is broadly categorized into expendable and nonexpendable mold casting and can also be classified based on mold materials such as sand, ceramic, or metal, as well as pouring methods like gravity, low pressure die casting, and high pressure die casting (Navaneeth, 2009).

Sand casting's mechanical properties benefit from metallic inserts known as chills (Mehr, 2012). For intricate aluminum alloy parts, achieving strong directional solidification without chills can be challenging due to premature solidification throughout the metal, hindering proper feeding (Chi-Yuan et al., 2006). Chills, metallic inserts placed strategically in the sand mold, promote rapid solidification in metal casting. They come in two types: internal and external, and are typically made from iron, aluminum, or copper, either machined or cast, depending on manufacturing ease and desired thermal effects (Chi-Yuan et al., 2006).

Chill effectiveness hinges on various factors including size, conductivity, thermal capacity, and thermal transfer across the alloy/chill interface (David, 2011). Chilling enhances casting soundness, as observed through nondestructive testing methods like radiography or dye penetration inspection, although its impact on microstructure and mechanical properties is considerable (David, 2011). Research focusing on evaluating different materials as chills in sand casting aims to boost solidification rates and enhance mechanical and microstructural properties.

MATERIALS AND METHODS

In this research, various materials were utilized, sourced from different locations. Aluminium alloy scrap was acquired from Pantaker, a spare part market in Kaduna metropolis, Nigeria. Chills made of mild steel, brass, and copper were employed, while foundry sand and additives essential for the investigation were obtained from the metallurgical and Materials engineering foundry workshop of Ahmadu Bello University, Zaria.

Equipment

Various equipment was utilized for the experimentation and analysis conducted in the metallurgical and materials engineering workshop. The melting process of the alloy was executed using a charcoal-fired furnace. To assess the hardness of the samples, a Vicker Hardness Tester with a capacity of 10 kg was employed. Impact testing was facilitated by a Charpy Impact Testing Machine capable of handling 25J. The microstructural examination was carried out using an optical metallurgical microscope housed within the workshop. Tensile tests were conducted using a Hounsfield Tensometer located in the Mechanical Engineering workshop. Additionally, thermocouples were integrated into the casting operation to measure the temperature gradient of the solidifying metal.

Experimental Procedures

The experimental procedures of this study involved the casting of four samples of aluminium silicon alloy through the melting of spare part scrap on a charcoal-fired furnace, utilizing four distinct sand moulds. These moulds varied with the insertion of steel, brass, and copper chills, alongside a control mould without chill, labeled as samples A, B, C, and D respectively. Each sample exhibited a geometric dimension of 165mm x 80mm x 10mm, with cylindrical chills measuring 7mm in diameter and 50mm in length, arranged in each mould at regular intervals of 30mm. Prior to pouring the molten metal, fluxing and degassing processes were conducted, and the rates of cooling were monitored using thermocouples attached to the sand moulds. The arrangement of chills within the moulds is illustrated in Figure 1, contrasting with the sand mould without chill depicted in Figure 2, while the chemical composition of the samples is outlined in Table 1.

Figure.1: Sand mould with chills

The chemical analysis of the cast samples was conducted in the Tower Aluminium Rolling Mills Industry, Ogun State using Optical Emission Spectrometer.

Tensile Strength Test

The tensile test specimens were machined from the cast samples. The test piece was locked securely within the grips of the Tensometer machine. The test piece was stretch with force generated from manually operating the screw attached to the Tensometer until the test piece broke apart. The load and extension data available from the graph sheet attached to the machine were converted to specific values of stress and strain.

RESULTS AND DISCUSSION

The results demonstrate the critical role of cooling rate in shaping the microstructure of castings, particularly in aluminum alloy solidification. Higher cooling rates are shown to significantly reduce solidification time and grain size, attributed to a process where a substantial portion of solids forms early on, followed by a pasty mode of solidification with non-equilibrium eutectic solidification towards the end. Nucleation at various sites, such as the mould wall or dispersoids, leads to rapid spread into the liquid metal, resulting in crystallization at multiple centers. The use of different chill materials influences solidification rates, with copper chill exhibiting the fastest solidification, followed by brass, while steel shows a slower heat extraction rate. This differential heat extraction is attributed to the superior thermal conductivity and volumetric heat capacity of copper and brass compared to steel. These findings underscore the profound impact of solidification gradients on the resulting structure and mechanical properties of aluminum alloys.

CONCLUSIONS

Based on the results and discussion of the study, it is evident that the cast aluminium alloy sample with copper chill exhibited superior mechanical properties, including an ultimate tensile strength of 126.13mPa, hardness value of 6.87Hv0.05, and impact strength of 23.5j, alongside a finer grain structure compared to other samples investigated. Moreover, the cast sample with brass chill displayed higher mechanical property values than those with steel chill or no chill, while solidifying faster than the samples with different chill materials. Additionally, the microstructure analysis revealed a trend of increasing grain coarseness from samples chilled with brass, followed by steel, and those without any chill.

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