FUTAJEET 8 (2) (2014) (69-73)

Journal of Engineering and Engineering Technology

# Effect of Mill Scale Particulate in Sand Mould on the Microstructure and Mechanical Properties of Cast 6063 Aluminium Alloys

**Oloruntoba, D.T. and Seidu, S. O.**
Department of Metallurgical and Materials Engineering Federal University of Technology, Akure, Ondo State, Nigeria.

**Keywords:**
Sand-mould,
Mill-scale,
Aluminium,
Mechanical properties,
Cooling-rate,
Microstructure

**A B S T R A C T**

*The effect of the use of mill scale admixtures in sand mould on the mechanical properties of cast aluminium was investigated. The sand mould contains varying proportions of the mill scale such as 0 %, 10 %, 15 %, 20 %, 25 % and 30 % volume/weight. The cooling rate of the mould was considered while the mechanical properties and the microstructure analysis of the cast metal were carried out. It was observed that percentage increase in mill scale promotes rapid cooling which enhances grain refinement. The tensile strength was found to increase from 143.42 N/mm2 to 191.69 N/mm2 while the hardness properties were found to increase from 42.9 BHN to 61.5 BHN. The microstructural examination of the specimens were observed and revealed more fine grains as the percentage of mill scale increases from 0 % to 30 % in the sand mould. Mill scales from steel rolling mills could find application as additives to moulding sands for the production of cast aluminium in foundry industries in Nigeria.*

## 1. Introduction

Moulding materials are those materials which possess the necessary structural strength and have interfacial properties that enable them to withstand the several thermo-chemical and hydrostatic forces accompanying melt lodgement into a mould. Such compositions embody what are known as moulding sand, binder and auxiliary materials, (Asuquo and Bobo-Jama 1985). The high usage of natural sand in mould casting is predicated on its cheapness as a result of its relative abundance and other intricate qualities such as ease of dressing.

Mill scale is an oxide of iron which is formed as a result of decarburization process taking place on the preheated billet in the reheating furnace at the rolling mill, Lawal and Sekunowo (2000). Mill Scale formed as result of hot rolling of steel billets constitute disposal problem to rolling mill industries, as low strength is one of the challenges in the use of aluminium alloy for construction and manufacturing purposes. The mill scale occurs when billet or ingot is subjected to high temperature which leads to heavy coatings of oxide on the heated metal, which spalls off and is eventually collected as a steel-mill by-product. Oxidation of the billets in the reheating furnace is usually substantial resulting in a lot of scale formation. The scales are discharged beneath the roll-stands during rolling operations. Aluminium alloys are cast by three main processes; sand casting, permanent mould and die casting. Sand casting is the simplest and most versatile of the aluminium casting processes (William, 1990). Jere et al., (1964), examined the structure and properties of materials and stated that low temperature solidification will lead to fine grain size as the growth rate is relatively slow compared to the nucleation rate. Therefore a large number of slowly growing nuclei result from large super cooling or rapid solidification rates. Conversely higher temperature means higher growth rate and lower nucleation rate, and subsequently the formation of coarse grain size. Large ingots which must cool slowly require additives to induce increased (heterogeneous) nucleation if fine grained structure is desired.

Grain refining additives control the primary grain sizes in castings. For the majority of casting processes, to control the aluminium grain size and optimise the properties, grain refiners must be added. In aluminium-silicon alloys grain refiners are based on aluminium-titanium alloy containing TiAl3 nucleants, or preferably the more potent aluminium-titanium-boron alloys which contain both TiAl3 and TiB2 Ray (1998). However, addition of nucleants to the melt for grain refinement will be additional cost of production; therefore the alternative means of grain refinement by the addition of mill scale to the sand mould will be cost effective in improvement of mechanical properties of cast aluminium which calls for a research.

The continuing high demand for high quality castings and improved strength for aluminium as well as solving environmental problems of waste disposal from rolling mills lead to the investigation of the properties and the effect of mill scale as an auxiliary material (additive) to sand mould for casting of aluminum. This research work investigates the effect of mill scale admixture in sand mould on cooling rate and microstructure; it's subsequent effect on the hardness and tensile properties of cast aluminium. The work aims at establishing modalities for its direct utilization for moulding in

Correspondence:
E-mail address:dtoloruntoba@futa.edu.ng, seidu2@yahoo.co.uk

| | | |
|---|---|---|
| 1200 | 0 | 0 |
| 1100 | 100 | 10 |
| 1050 | 150 | 15 |
| 1000 | 200 | 20 |
| 950 | 250 | 25 |
| 900 | 300 | 30 |

Table 2: Chemical composition of the cast 6063 aluminum alloy

| Element | Al | Mg | Si | Fe | Cu | Mn | Zn | Cr | Ti |
|---|---|---|---|---|---|---|---|---|---|
| Composition % | 98.49 | 0.52 | 0.47 | 0.35 | 0.32 | 0.06 | 0.06 | 0.02 | 0.01 |

foundry shops.

## 2. Methods

Different sand moulds were prepared with varying percentages of mill scale obtained from Oshogbo Still Rolling Mill Oshogbo Osun State, Nigeria. The mill scale was crushed and milled to desired size of 425 micron. Amount of mill scale per volume/weight of sand: 0 %, 10 %, 15 %, 20 %, 25 % and 30 % with bentonite as an additive and were thoroughly mixed. Mould for casting the aluminium ingot was prepared from the mixture. The percentage addition of the mill scale to the moulding sand is shown in Table1 while the chemical composition of the cast aluminium is presented in Table 2

Aluminum scraps were melted in a lift out crucible furnace of 10kg capacity until the desire temperature was obtained. The molten metal was tapped into the ladle and poured to the already prepared moulds. .

After pouring, the temperature of the melt in the mould was measured at the interval of 2 minutes till it cooled to room temperature. Aluminium cast of 20 mm diameter by 150 mm length each was obtained. The cast samples were prepared for hardness and tensile testing. A sample from each percentage mill scale was polished, etched and viewed by optical metallurgical microscope.

## 3. Results and discussions

### *3.1 Effect of mill scale admixture in sand mould on the microstructure* of cast aluminum.

The results of the microstructure test are shown in Fig.1. The properties of aluminum magnesium-silicon alloys are controlled by the solid solution strengthening of the alfa-Al and solidification, which controls the primary grains size or shape as well as the nature of the eutectic microconstituent (Honeycombe and Hancock, 1989).

The results as shown in Figure 1 revealed that the increase in the proportion of mill scale leads to rapid cooling and promotes the refinement of the microstructure. It was shown that percentage increase in mill scale promotes rapid cooling which enhances grain growth refinement. The microstructure examination of the specimens were observed and revealed more fine grains as the percentage of mill scale increases from 0 % to 30 % mill scale in the sand mould. Figure 1 (F), shows the microstructure of 0 % mill scale admixture in the sand mould with larger grain size while Figure 1 (E), with 10 % mill scale admixture in sand mould shows a more fine grain structure compared to the later with 0 % mill scale in sand mould. Fig. 1 (D), (C), (B) and (A) revealed more fine grain structures as there is no heterogeneous nucleation as the aluminum cools to room temperature. This account for the increase in hardness value obtained for the cast aluminum from 10 % to 30 % mill scale admixtures in the sand mould.

### *3.2 Effect of mill scale admixture on the cooling rate of the melt*

Figure 2 shows the cooling of cast aluminium when varying percentages of mill scale was added into the sand mould. The cooling rate of the cast aluminium increases with increase in the percentages of the mill scale in the sand mould that is, fast cooling in a short time was observed for the mould of highest percentage (30 %) of mill scale. It is worth noting that, the rate of cooling and solidification plays a critical role in the materials properties, since the rate of cooling controls the degree of coarseness or degree of fineness of the grain structure of the cast material (Trivedi et al., (1989)

Also, the 30 % mill scale having the highest percentage of mill scale possessed the lowest temperature signifying the fastest cooling rate. Fig. 2 shows the depression that as the percentages of mill scale increases, the cooling rate decreases. This result contributed to its increase in tensile strength and hardness value. Hence, rapid cooling obtained in 25 % and 30 % mill scales admixture improved the mechanical properties of the cast materials.

### *3.3 The effect of mill scale admixture in sand mould on hardness properties of cast aluminum.*

Hardness is the measure of the degree of deformation in material Higgins (1988). Fig.3 shows that hardness of the cast aluminum increases with increase in mill scale percentage composition. The maximum hardness values of 61.5 BHN were obtained at 30 % mill scale admixture. The decrease in the hardness at 15% mill scale admixture may be due to section thickness. It is worth noting that, the rate of cooling and solidification plays a critical role in the material properties (Trivedi et al., 1989) because the rate of cooling controls the degree of grain structure of the cast materials as shown in Fig. 1. According to Ray (1998), optimum properties are usually achieved when the aluminium grains are small and uniform in size. To achieve this, nucleation must occur as close

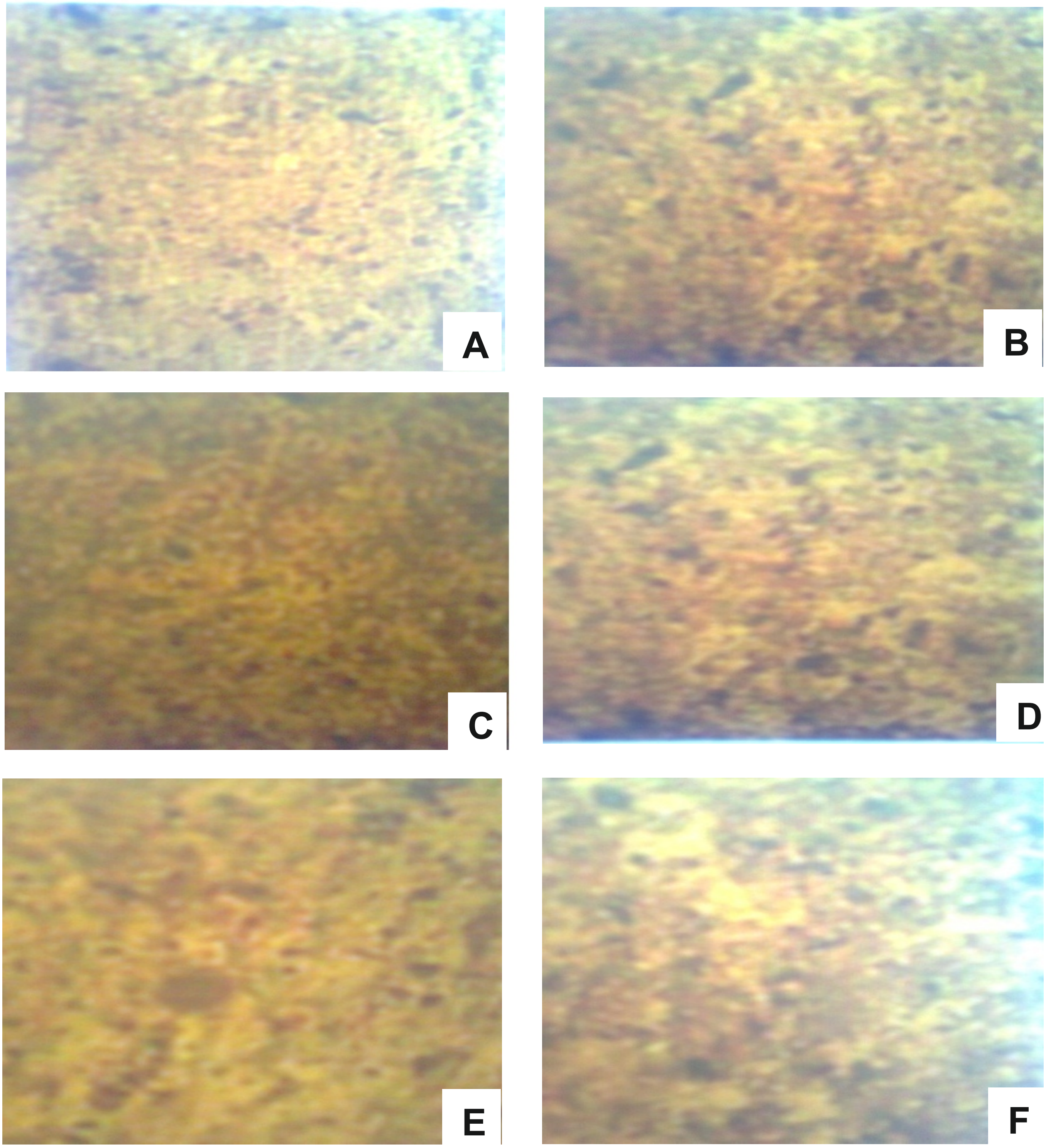


**Fig.1. Microstructure of cast aluminum alloy from sand mould with varying percentages (A 30 %, B 25 %, C 20 %, D 15 %, E 10 %, F 0 %) of mill scale admixtures**

to the liquidus temperature as possible, that is undercooling must be minimised.

*3.4 The effect of mill scale admixture in sand mould on tensile properties of cast aluminum alloy.*

Figure 2 shows that tensile stress increases with increase in percentage mill scale admixture in the sand .mould. It increases progressively from 0 %, 10 %, 15 %, 20 %, 25 % and 30 % mill scale admixture in sand mould respectively Also, elongation and reduction in area increases as the tensile properties increases but the yield strength increase and later decreases, these may be due to the rate of cooling of the cast samples. One of the most frequently specified properties of aluminum is that, the thickness of aluminum will greatly influence both tensile and hardness properties

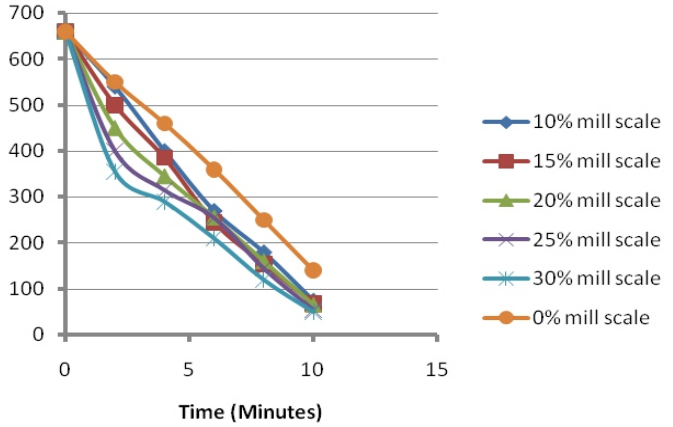


**Figure 2: Graph of cooling rate for cast aluminum alloy from sand mould with varying percentage mill scale admixtures.**

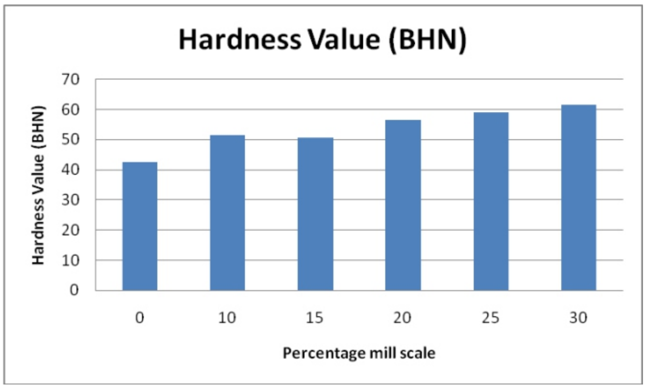


**Figure 3: Effects of varying percentages of mill scale on the hardness properties of the cast aluminium.**

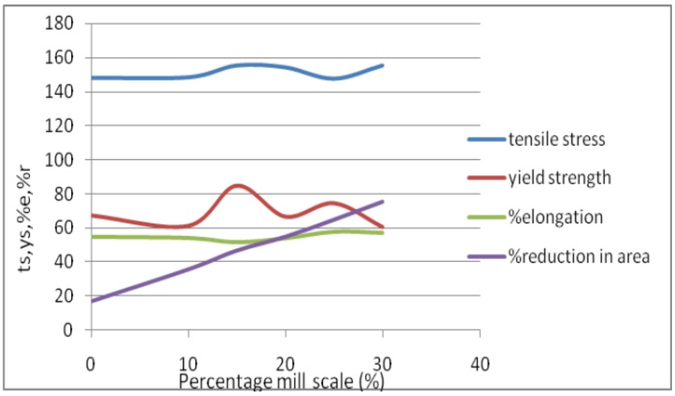


**Figure 4: Effect of varying percentages of mill scale admixture on tensile strength, yield strength, % elongation and % reduction on cast aluminium**

(Higgins, 1988)

It was observed that the mill scale in sand mould improves surface finishing, decreases metal penetration, reduces burn-on, and increases the chilling effect of the mould. It also increases glazing with enough iron oxide in combination with silica sand. Mould washes could also be avoided with the use of mill scale. Mill scale (iron oxide) decreases green strength and permeability while improving the hot strength Bindary (1982).

## 4. Conclusion.

The following conclusions were drawn from the investigation of strengthening mechanism of cast aluminium with mill scale admixture in sand mould:

1 Mill scale in sand mould improves surface finishing, decreases metal penetration, reduces burn-off and increases the chilling effect of the mould.

2 As the percentages of mill scale increases in the sand mould the cooling rate also increases.

3 Highest hardness value of 61 BHN was obtained at 30 % mill scale admixture in sand mould which gives the finest microstructure.

3 The use of mill scale in sand mould as additives have contributed positively to the mechanical properties of cast aluminum such as tensile property; hardness increases progressively as the percentage of mill scale increases.

5 Mill scale which constitute a disposal problem to rolling mill industries could find alternative use in foundry industries as sand mould admixture for improvement of mechanical properties of cast aluminium.

## References

Asuquo, L. and Bobo-Jama, L. (1985), Foundry Technology First Edition, Abil Publisher Enugu and Lagos Nigeria pp 9-50

Bhandary, V. S. (1982), Foundry technology directory. The institute of Indian foundrymen, Calcutta.

Higgins, R. A. (1988), Engineering Metallurgy Part II metallurgical process Technology, Second Edition, Suffolk and Haftnolls Limited, Cornwall, England pp 73-89

Jere, H. B., Robert, M. R. and John, W. (1964), Structure and Properties of Materials, Volume II. John Wiley & Sons Inc. Ney York. pp 113-114.

Lawal, G. I. and Sekunowo, O. I. (2000), Carbon reduction with the aid of granulated mill scale (FeO) during steel production via the electric arc furnace process, NSE Technical Transactions Vol.35, No. 2 pp 8-16

Ray, C. (1998), Grain refinement of aluminium-silicon foundry alloys, London & Scandinavian Metallurgical Co. Limited, South Yorkshire, England. http://www.lsm.co.uk

Honeycombe, R. W.K and Hancock, P. (1989), Metallurgy of the light metals second edition.

Trivedi R., Sekhar, J.A. and Mazumdar, J. (1989): Principles of Solidification and Materials Processing Oxford and IBH Publishing Co. PVT.

William, F. S. (1990): Principles of Materials Science and Engineering, Second Edition, Graw-Hill, Inc., London

.