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EFFECT OF POURING TEMPERATURE ON THE PROPERTIES OF Al-8% Si ALLOY SAND CAST COMPONENTS

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ABSTRACT

This study was conducted to produce sand castings and determine the effect of pouring temperature on the properties of sand cast products from Al-8%Si alloy. Molten alloy was poured into prepared sand moulds at pouring temperatures of 650, 700, 750, 800 and 850°C. The density of each casting was determined based on their mass and displaced volume of water. Test samples were cut from the castings for metallographic, tensile and hardness tests. It was found that the density and mechanical properties of the sand castings decrease with increase in pouring temperature, particularly at 800-850°C, although the fluidity of the molten alloy increases with increase with temperature. The study, therefore, recommended pouring temperatures of 650-700°C in order to obtain sound Al-8%Si alloy sand castings.

KEYWORDS: Sand casting; Pouring temperature; Alloy.

INTRODUCTION

Aluminium is a light white (or silvery), ductile, malleable and light metal which, although has high affinity for oxygen, does not corrode easily due to the presence of thin adherent film of alumina (Al_2O_3) on its surface. It is a good conductor of heat and electricity and it is non-toxic in nature. These attributes of aluminium make it useful for the manufacture of current bearing elements, kitchen utensils and food vessels in food and chemical industries, among others. All these combined with good surface appearance and recycleability make aluminium a desired material for use in modern society. However, pure aluminium is relatively soft and weak so that for most engineering purposes it is used in alloyed forms, in both wrought and cast conditions.

Aluminium and its alloys have made serious impact in every facet of our lives due to wide availability of aluminium ore and the useful physical, chemical and engineering properties of aluminium. They have replaced iron and steel and many other ferrous alloys in many applications and are used for household items, in transportation, energy and power sectors, among others (Zimmermann and Günther, 1982; Voskoboinikov *et al*, 1985; Higgins, 1991; Abubakre and Raji, 1999). Indeed, the world rise in usage of aluminium alloys has been phenomenal in the last century rising from zero in 1900 to about 15 million tonnes at the turn of the century (Hauck, 1990).

A large part of produced aluminium alloys is made into engineering and consumer goods by casting due to the relatively low melting temperature of aluminium and its alloys. Lynch *et al* (1975) observed that although sand cast parts are characterised by rough surface finishes, sand casting as a process offers a cheap means of fabrication which also allows undercuts and channels to be cast into the part. Sand casting allows the casting of many small-sized parts simultaneously in the same mould, increasing productivity. However, compared with many special casting methods such as die, squeeze, ...stings among others, sand casting, particularly ...y sand casting process is characterised by low repeatability in casting dimensions (Campbell, 2000) and sand cast products are inferior in mechanical properties, which to a large extent depend on the casting parameters (Lynch *et al*, 1975; Cerri *et al*, 2000 and Raji, 2004). Molten aluminium alloys are susceptible to oxidation and hydrogen absorption which leads to degradation of mechanical properties due to oxide inclusion and/ or gas porosity particularly at high temperatures and hence the need for careful control of melt temperature (Clegg, 1991). This study was, therefore, carried out to determine the effect of pouring temperature on some physical and mechanical properties of Al-8%Si alloy sand castings.

MATERIALS AND METHODS

Al-Si alloy scrap, proprietary "Foseco" flux and hexachlorethane tablets were used in this study. The composition of the Al-Si alloy scrap is as follows: Si=8.081%, Sn<1.980%, V<0.182%, Cr<0.110%, Mn=0.173%, Fe=0.686%, Co<0.027%, Ni=0.001%, Cu=1.920%, Zn=0.511%, As<0.007%, Pb=0.073%, Zr=0.004%, Nb<0.001%, Mo<0.001% and Al $\approx$ 86.243%.

Sand castings of the shape shown in Fig. 1 were made from Aluminium-Silicon alloy. Specimens were then prepared from the castings to determine the mechanical properties of the castings poured at various temperatures and the results compared with each other.

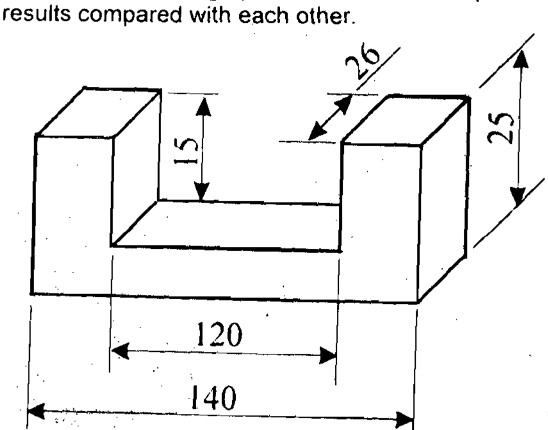

Fig. 1: Dimensions of Produced Castings
Dimensions are in mm.

MELTING OF ALLOY

Melting of scrap was done in a 0.3kg capacity crucible placed inside a 2kW electric resistance furnace. Fluxing was done at about 650°C by covering the surface of the already molten alloy with about 2% by weight of charge of proprietary covering flux "Foseco". The flux was then worked into the surface of the alloy to remove aluminium dross and other impurities. The resultant dross was removed leaving a very clean surface. Smaller quantity (about 1% by weight of charge) of the flux was then added for the purpose of

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protecting the molten alloy from the effect of the atmosphere. Hexachloroethane tablets amounting to about 0.5% by weight of charge were used to remove dissolved hydrogen gas. The alloy was then heated to the required pouring temperatures of 650, 700, 750, 800 and 850°C and the alloy poured into already prepared sand mould.

CASTING

Sand Mix Preparation

Natural moulding silica sand with 18.64% of clay and 5.76% moisture content was obtained, dried and screened with a sieve of 1.18mm aperture size. Having liberated the sand of large and foreign particles, a sand mix containing 98% of the sand and 2% of water by mass was prepared and thoroughly mixed. Mixing was done manually by the up and down shovelling of the sand heap.

In addition to the above, fine clay-free silica sand was also obtained to serve as parting sand. This type of sand was used to separate the contents of the drag from the cope and to ease the removal of pattern from the mould.

Sand Moulding and Casting

A two-part flask floor moulding was adopted to obtain green sand moulds. A prepared wooden pattern was placed on the floor and a drag flask having a cross section of 250mm x 150mm and a height of 100mm was placed upside down around the pattern. Parting sand was sprinkled on the pattern and the exposed surface of the floor within the drag. The moulding sand was then shovelled into the drag and rammed properly using suitable rammers until the drag was completely filled up. Excess moulding sand was then removed by drawing a straight edge over the completed drag. The completed drag was turned over.

The cope flask was placed over the completed drag and parting sand was sprinkled on the exposed surfaces of the drag and the pattern. Two sprue pins for a sprue and a riser were positioned appropriately, one close to the pattern and the other on top of the pattern. Moulding sand was then shovelled into the cope and rammed until it was full. Thereafter, excess moulding sand was removed by drawing a straight edge across the cope. Circular basins were cut around the two sprue pins, one to form the pouring basin and the other the feeder. Markings were made across the parting lines on all the four sides of the assembly for easy reassembly after dismantling it. The pins were rapped and removed. The completed cope was then removed from the top of the drag and placed upside down.

From the impression left on the drag by one of the sprue pins, a gate was cut towards the pattern. The pattern was then rapped and removed with the help of spikes. Necessary repairs were made and the moulds were then reassembled as shown in Fig. 2 and placed close to the furnace awaiting pouring of molten aluminium-silicon alloy.

Upon attaining the appropriate pouring temperatures of 650, 700, 750, 800 and 850°C, the molten alloy was poured from the crucible into the mould cavity through the pouring basin and it rose up through the riser to the top of the cope. The poured alloy was left to stand for solidification to take place. After 15mins of standing, the moulds were separated and the casting was knocked out of the sand mould. Three sets of five castings each were made with the alloy poured at 650, 700, 750, 800 and 850°C.

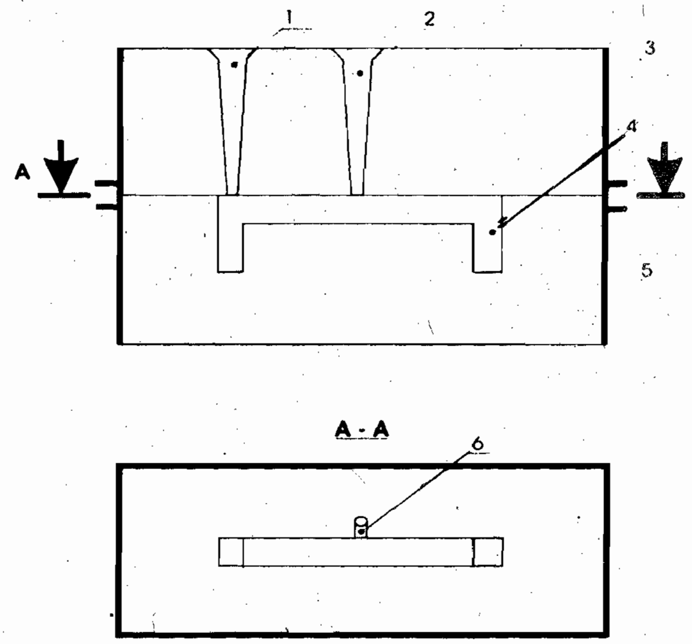

Fig. 2: Sectional Views of Assembled Sand Mould
1- Feeder, 2- Vertical Sprue 3- Moulding Box (Cope), 4- Mould Cavity, 5- Moulding Box (Drag), 6- In-Gate.

METALLOGRAPHIC STUDIES

Preparation of Al-Si samples for micro-examination involved mainly sampling, grinding, polishing and etching. Samples measuring 26mm x 15mm x 10mm were cut from the castings with the help of hacksaw. The samples were filed and ground. Grinding was done in succession on a Roll grinder using silicon carbide abrasive papers of 220-, 320-, 400-, and 600-grits. Rough polishing and final polishing were done using a paste made from silicon carbide powder (1000 grit) and a paste made from pure heavy grade of magnesium oxide (MgO) respectively on a billiard cloth on the circular disc machine polisher. The speed of the wheel was maintained at 600rpm and 350rpm for rough and final polishing respectively. Final rinsing was done with warm water and the specimens were blown dry with a hand dryer and then kept in a desiccator.

Etching of the specimens was done using approximately 0.24% Hydrofluoric acid (HF) made from 1ml HF (48%) and 199ml water. The specimens were etched for a period of 60s each in a porcelain dish and then rinsed in running water, immersed in a boiling ethanol for 60s and then blown dry with the dryer. Each specimen was then mounted on an optical microscope and the microstructure observed and photographed at a magnification of x125.

DETERMINATION OF DENSITY AND MECHANICAL PROPERTIES

To determine the density of the castings, castings were weighed using weighing balance. The volume of water displaced by each casting was determined with the help of a displacement can. The density of each casting was then found by dividing the mass of the casting by the volume of water displaced by it.

Tensile test was conducted on a Tinius Oslen 290 model Universal tensile testing machine with a digital 300KN capacity. The tensile specimen, made according to American Society for Testing and Materials (ASTM) standard E8M-1990 for sub-size specimen (6mm) was held in the machine using wedge grips with liners for flat specimens. The specimen was gradually loaded until it fractured. Hardness test was carried out on a "Micromet" Rockwell type hardness-tester using an F scale. Measurements at three different locations were made and the average value of Rockwell number was noted.

RESULTS AND DISCUSSION

The results of metallographic study, density, hardness and strength characteristics of the castings are shown in Figs.3-7. The results of metallographic study of the cast samples showed that in all cases, the microstructure of the cast samples were of hypoeutectic structure consisting of primary alpha solid solution of silicon in aluminium (α) in a matrix of eutectic (α +Si). However, the grain sizes differed for various castings and increased with increase in pouring temperature. The obtained ASTM grain size numbers were 4.58, 4.31, 4.15, 4.06 and 3.87 for pouring temperatures of 650, 700, 750, 800 and 850°C respectively (large value indicates fine grain size). The presence of moisture in sand moulds leads to gas porosity which tends to reduce the densities of the sand castings. For the sand castings, the densities of castings made at pouring temperatures of 650, 700 and 750°C were higher than those made at 800 and 850°C (Fig. 5). This is because molten metal at high temperatures tends to dissolve in more gases than that at low temperatures, which could lead to increase in gas trapped in the casting and hence reduced density (Voskoboinikov, 1985 and Clegg, 1991).

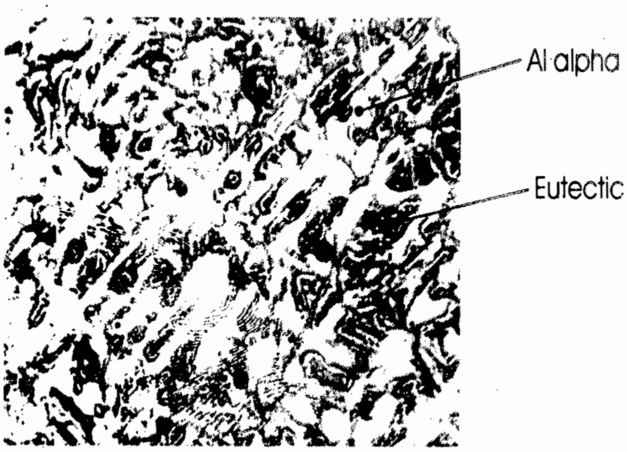

Fig. 3: Micrograph of Al-8%Si Alloy Sand Cast at a Pouring Temperature of 700°C (x125).

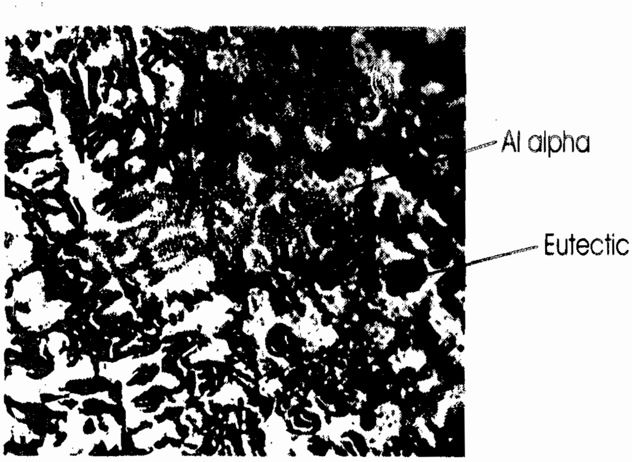

Fig. 4: Micrograph of Al-8%Si Alloy Sand Cast at a Pouring Temperature of 800°C (x125).

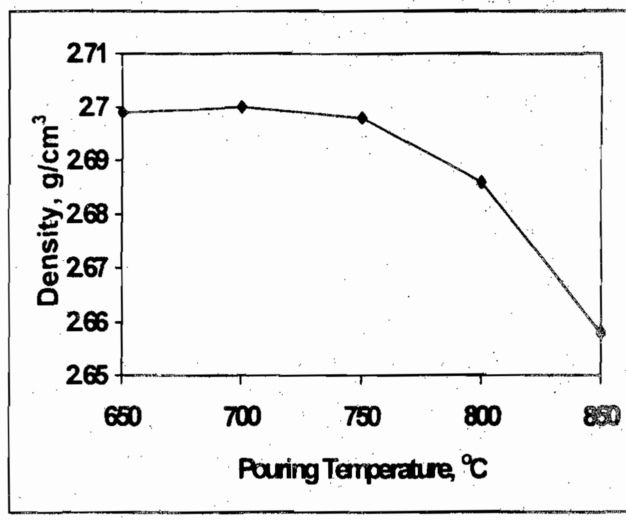

Fig. 5: The Effect of Pouring Temperature on Density of Sand Cast Al-8%Si Alloy

The hardness of the sand castings ranged from HRF35.5 down to HRF31.5 with increase in pouring temperature (Fig. 6). The UTS of sand castings varied from 102 to 57MPa with increase in pouring temperature from 650 to 850°C (Fig. 6). The proof stresses of sand castings made at various pouring temperatures were almost the same. They ranged from 35 to 40MPa as shown in Fig. 7. The percentage elongation of Al-8%Si alloy sand castings was found to be between 1.8 and 2.3% (Fig. 7). The reduction in hardness, UTS, proof stress and elongation of sand castings with increase in pouring temperature is due to grain growth as a result of over heating of the alloy. This agrees with Voskoboinikov (1985) who stated that very high pouring temperature leads to decrease in the quality of ingot as over heated metal cools longer in ingot moulds resulting in strong chemical segregation of the ingot and Askeland (1985) who observed that a shorter solidification time produces a finer grain size and a stronger casting. It was however, observed that sand casting of Al-8%Si alloy at 650°C was difficult due to its high viscosity at low temperatures.

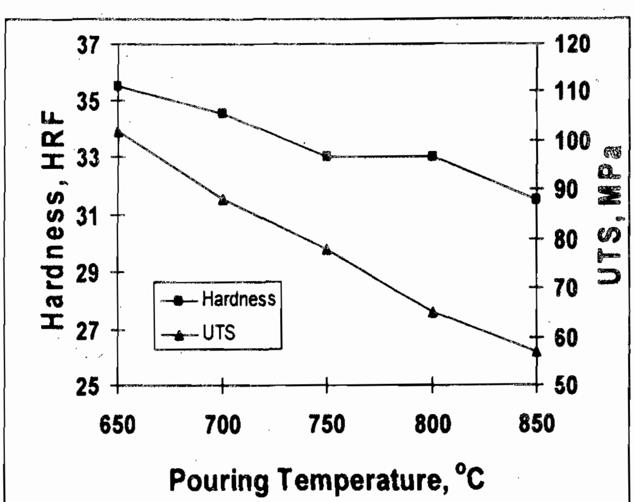

Fig. 6: Variations in Hardness and Ultimate Tensile Strength of Sand Cast Al-8%Si Alloy versus Pouring Temperature

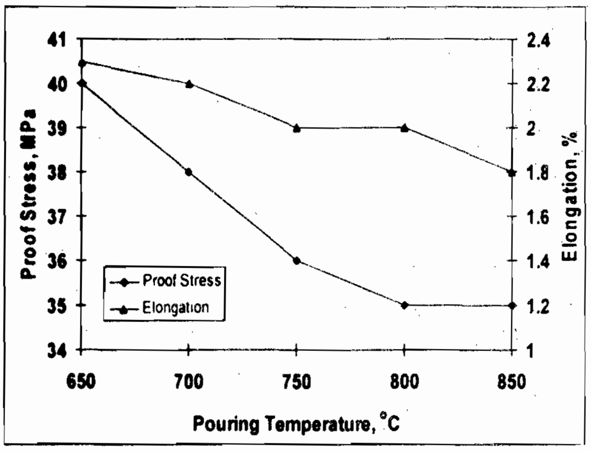

Fig. 7: The Effect of Pouring Temperature on Proof Stress and Elongation of Sand Cast Al-8%Si Alloy

CONCLUSIONS AND RECOMMENDATIONS

The study concluded that pouring temperature of sand cast Al-8%Si alloy affects the microstructure, density and gas porosity and mechanical properties of the castings. The grain sizes and gas entrapment increased with increase in pouring temperature while density and mechanical properties such as UTS, proof stress, hardness and elongation decrease with increase in pouring temperature. The study, therefore, recommended pouring temperatures of 650-700°C for sand cast Al-8%Si alloy.

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