ACTA TEHNICA CORVINIENSIS – Bulletin of Engineering
Tome VIII [2015] Fascicule 4 [October – December]
ISSN: 2067 – 3809

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EFFECTS OF SPIN AND DIE CASTING ON MICROSTRUCTURE AND CORROSION BEHAVIOUR OF Al-Mg-Si ALLOY

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Abstract: The microstructure and corrosion behavior of Al-Mg-Si alloy using spin, die and sand casting was investigated. The materials used were aluminium scrap, magnesium and silicon, they were all subjected to chemical analysis using spectrometric analyser. Charge calculation to determine the amount needed to be charged into the furnace was properly worked out and charged into the crucible furnace from which as-cast aluminium was obtained. Density measurements were used as a basis of evaluating the percentage porosity of the cast products; the corrosion behavior of the cast produced in acid 0.1M, 0.3M and 0.5M H_2SO_4 and saline 0.1M, 0.3 and 0.5M NaCl environment were investigated using corrosion rate, mass loss. From the results it was observed that magnesium and silicon were better dispersed in aluminium matrix of the spin casting. However, during the corrosion test in H_2SO_4, die casting exhibited best corrosion resistance followed by spin and sand casting. The spin, sand and die casting all exhibited good corrosion resistance in NaCl.
Keywords: Al-Mg-Si alloy, spin casting, sand casting, corrosion, spectrometric analyser

INTRODUCTION

Casting is one of the oldest manufacturing process, it is a fabrication process whereby a totally molten metal is poured into a mould cavity having the desired shape; upon solidification, the metal assumes the shape of the mould but experience some shrinkage [1]. Casting is the most economical.

A number of different casting techniques are commonly employed, including sand, die, investment, continuous and spin casting. Sand Casting probably the most common method, ordinary sand is used as the mould material [1]. A two-piece mould is formed by packing sand around a pattern that has the shape of the intended casting. A gating system is usually incorporated into the mould to expedite the flow of molten metal into the cavity and to minimize internal casting defects. It has been stated that when pouring temperature is lower than optimum, the mould cavity will not fill the gate or riser will solidify too rapidly and intercept directional solidification.

Die casting is a versatile process capable of being used in mass production of alloys having properties unobtainable by other manufacturing method [2].

Spin casting is both gravity and pressure independent since it creates its own force feed using a temporary sand mould held in a spinning chamber at up to 300-3000rpm as the molten metal is poured. The molten metal is centrifugally thrown towards the inside mould wall, where it solidifies after cooling. The casting is usually a fine-grained outer diameter, owing to chilling against the mould surface. Impurities and inclusion are thrown to the surface of the inside diameter which can be machined away [3].

Aluminium alloys have great use potential in the structural components in the aerospace and automobile industries mainly because of their low density and high specific strength [4], also aluminium alloys have a wide diversity of industrial applications because of their high specific strength, light weight and corrosion resistance. Therefore these alloys motivate considerable interest to the aviation industries [5, 6]. Aluminium alloy for a cast component is based upon mechanical and corrosion properties it can achieve. Aluminium alloy casting properties result from three primary factors: casting alloy, melting and casting methods. The properties obtained from one particular combination of these factors may not be identical to those achieved with the same alloy in a different casting facility.

EXPERIMENTAL MATERIAL AND METHODS

The materials used for the work were scraps of Aluminium purchased from Northern Nigeria Cable Processing Company Limited (NOCACO), Kaduna also Magnesium used. The silicon used was obtained from Engineering Materials Development Institute (EMDI), Akure, Nigeria.

Table 1. Chemical composition of basic materials (after casting)

Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
0.40	0.24	0.03	0.04	0.55	0.03	0.01	0.02	98.68

The three casting methods were carried out for the work, they are:

(i) Spin casting
(ii) Sand
(iii) Die casting.

The patterns used were made of wood with diameters of 20 mm by 150 mm long. The patterns were made larger than the original dimension to *compensate for shrinkage during solidification and machining operation. Natural sand was used to prepare the sand mould, a mixture of silica sand with considerable amount of bentonite. The addition of bentonite improved the bonding strength. The moulding of the pattern was carried out using a moulding box comprising of cope and drag that gave rigidity and strength to the sand. Parting sand was properly applied for the easy removal of the mould from the pattern. The gating system was properly designed for smooth channeling of the molten metal into the mould cavities through the sprue, runner, in-gates and riser that were perfectly placed in position. The die mould was prepared with cast iron.*

The cast aluminium scraps, magnesium and silicon were carefully worked out and charged into the furnace.

Crucible furnace was used for the melting of the charges. Prior to charging, the crucible furnace was checked to prevent leak of molten metal and also to guide against moisture, which can generate vapour during melting. Metallurgical factors in the choice of melting facilities related to the tendency of the charge to react with its surrounding, affecting composition control, impurity level and metallic yield were considered. The charged materials in the furnace were allowed to melt down (at 700°C) and then the furnace was switched off. The molten metal was tapped from the furnace, poured into the spin casting machine mould and sand mould, both were allowed to air cool.

The removal of the sand which stuck on the surface of the sand cast was carried out with the aid of sand blasting bar, sprue and ingates were also removed using hacksaw. Cleaning operation was also performed by grinding to smoothen the surface and unnecessary attachment on the surface of the metal to improve the appearance.

The determination of the experimental densities of the various casting products were carried out by measuring the weight of the test samples using a high precision electronic weighing balance with a tolerance of 0.1mg. The weights of the measured samples were divided by their respective volume.

$$\text{Experimental density, } \rho = \frac{mass\ of\ the\ sample}{volume\ of\ the\ sample} \qquad (1)$$

The percentage porosity of the cast aluminium was determined by use of equation

$$\%\ \text{volume porosity} = \frac{(\rho cal - \rho exp)}{\rho cal} \qquad (2)$$

where ρ_{cal} = Theoretical Density (g/cm^3), ρ_{exp} = Experimental Density (g/cm^3) [7, 8]

The environments for the study were acidic and marine environments of different concentrations made from tetraoxosulphate (vi) acid and sodium chloride following standard procedure. The concentrations were 0.1 M, 0.3M and 0.5M respectively made from the stock solutions of H2SO4 (98% purity assay) for the acid. The concentrations for the sodium chloride were 0.1M, 0.3M and 0.5M respectively.

The dimensions of the various samples were carefully calculated, which in turns were used to calculate the surface area with the empirical formular:

$$\text{Surface area (mm}^2) = 2\pi r(r + h)$$

Each of the specimens were carefully washed with distilled water after the specific surface area has been calculated, followed by carefully weighing to ascertain their initial weights, using the digital analytical weighing machine prior to immersion.

The corrosion tests were carried out in H_2SO_4 and NaCl of different concentrations which were 0.1M, 0.3M and 0.5M respectively. The specimen was earlier polished with emery papers starting from 120 grit to 640 grit sizes. The samples were degreased with acetone and rinsed in distilled water before immersion in the prepared solutions of H_2SO_4 and NaCl with different concentrations; which were all exposed to atmospheric air. The results of the corrosion rate, mass loss, electrode potential measurements; the electrochemical experiments were monitored on two day intervals. The samples were exposed in the H_2SO_4 and NaCl solutions for 60 days respectively. Mass loss (mg/cm^2) for each sample was evaluated by dividing the weight loss (measured by digital analytical weighing machine) by its total surface area which is in accordance ASTM standard practice. Corrosion rate for each sample was evaluated from the weight loss measurement following standard procedures.

***Figure 1**. Micrograph of Spin Casting (x400)*

***Figure 2**. Micrograph of Sand Casting (x400)*

***Figure 3**. Micrograph of Die Casting (x400)*

***Table 1**. Experimental Results – Density Measurement*

Type of casting	Theoretical density (g/cm^3)	Experimental density (g/cm)	Porosity (%)
Spin casting	2.70	2.69	0.37
Sand casting	2.70	2.67	1.11
Die casting	2.70	2.67	1.11

EXPERIMENTAL RESULTS – CORROSION PROPERTIES

Effect of tetraoxosulphate (VI) acid on the corrosion rate

Figure 4.1 and 4.2 presents the corrosion rate and mass loss plot for Al-Mg-Si alloy which were cast with spin, sand, and die casting and their *coupons immersed in 0.1M H_2SO_4. It was observed that the corrosion rate was at the peak for die and sand casting at day two with die castinghigher than sand casting, spin casting reached its peak at day 23 which was far below the peak reached by sand and die casting. The corrosion rate curve reveal that the passive film formed on the specimens were not stable as there were repeated film formation and breakdown which was reflected by an increase in corrosion rate. In Figure 4.10, there is dissolution of the samples in 0.1M H_2SO_4. The anomalous weight loss for 60 days was reasonable due to the localized corrosion of Al-Mg-Si alloy in 0.1M H_2SO_4 which showed discrete in different periods. Similar results have been reported in atmospheric corrosion of stainless steel [9,10,11].*

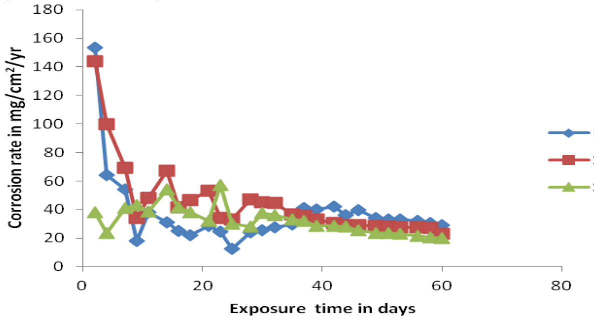

Figure 4.1. *Variation of corrosion rate of cast products in 0.1M H_2SO_4*

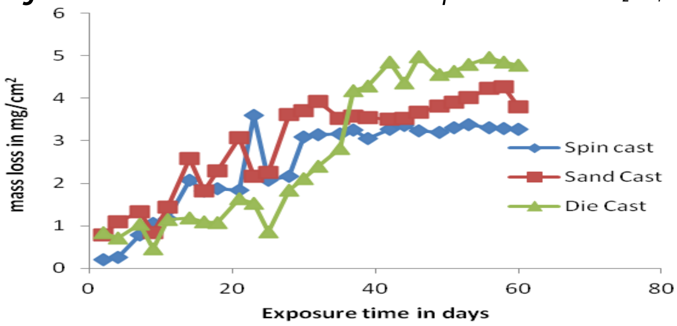

Figure 4.2 *- Variation of mass loss against exposure time of cast products in 0.1M H_2SO_4*

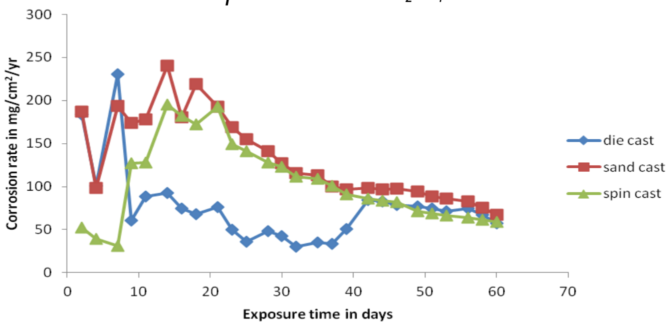

Figure 4.3*. Variation of corrosion rate of cast products in 0.3M H_2SO_4*

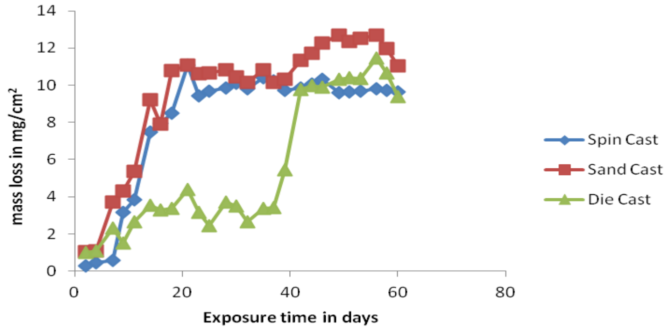

Figure 4.4*. Variation of mass loss against exposure time of cast products in 0.3M H_2SO_4*

Figure 4.3 and Figure 4.4 presents the corrosion rate versus exposure time and mass loss versus the exposure time plot. It was observed that the corrosion rate of the casting products in 0.3M H_2SO_4 shows that sand casting has the highest corrosion rate, while the die casting has the lowest corrosion rate, the corrosion rate for spin casting was low up to day 7 after which there was an increase in corrosion rate, at day 42, the corrosion rate for the three cast product were almost the same, this may be as a result of formation of films on the coupons surfaces.

Figure 4.5 and Figure 4.12 presents the corrosion rate versus exposure time and mass loss versus exposure time respectively in 0.5M H_2SO_4. It was observed that the die casting has the lowest corrosion rate while the sand casting has the highest corrosion rate. After the second day of the corrosion test, die casting corrosion rate drops, this was maintained throughout, this may be due to formation of passive films.

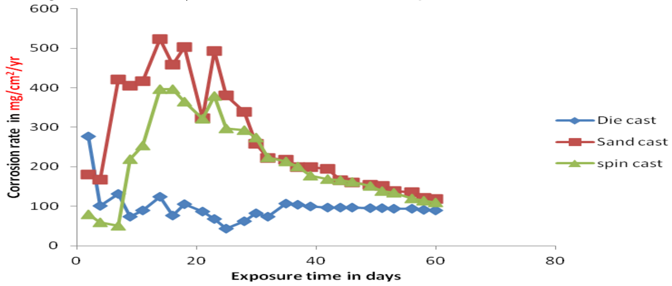

Figure 4.5. *Variation of corrosion rate of cast products in 0.5M H_2SO_4*

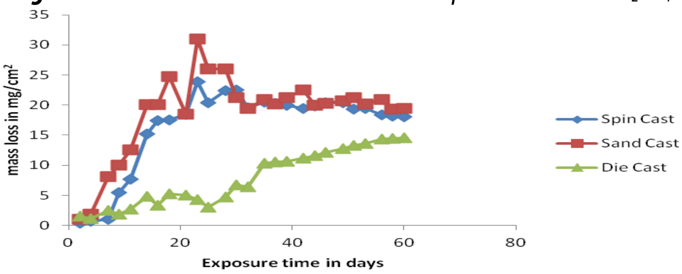

Figure 4.6*. Variation of mass loss against exposure time of cast products in 0.5 H_2SO_4*

EFFECT OF SODIUM CHLORIDE ON THE CORROSION RATE

Presented in Figure 4.6 are the results of corrosion rates versus the exposure time for the Al-Mg-Si alloys which were cast with three different methods namely; spin, sand, and die casting, their coupons were immersed in 0.1M NaCl. It was observed that the peak corrosion rate for each samples was observed at day four, after which there was no significant in the corrosion rate as the exposure time increases. The spin casting had the highest corrosion rate followed by die and sand casting.

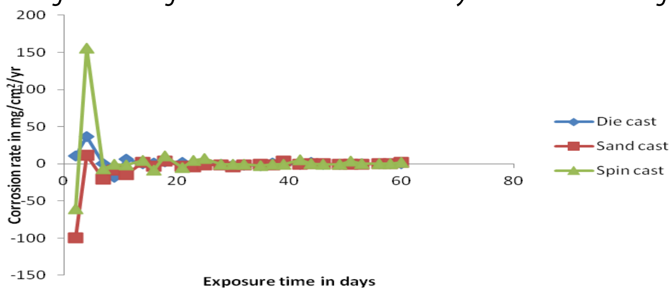

Figure 4.7*. Variation of corrosion rate of cast products in 0.1M NaCl*

The results shown in Figure 4.9 show that the corrosion rates versus the exposure time in 0.3M NaCl also gave an increase in corrosion rate at day four after which there was no significant increase in corrosion rate.

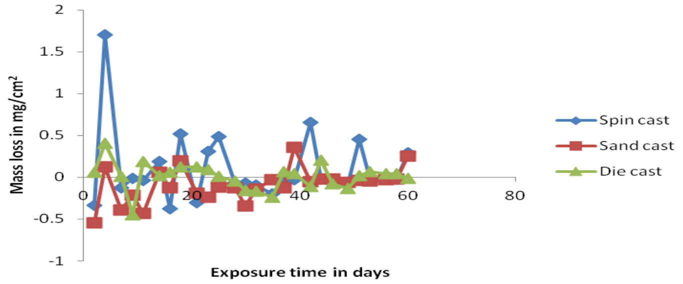

Figure 4.8. Variation mass of loss against exposure time of cast products in 0.1M NaCl

Figure 4.11 also followed the same trend as in Figure 4.6 and Figure 4.8. The decrease in the corrosion rate of the three cast samples in three different concentrations can be attributed to the ability of aluminum alloy to form passive films this is in agreement with Ekuma and Idenyi [12] and Oguzie [13], who studied the influence of alloy compositions on the passivation layer characteristics of Al-Zn alloys systems.

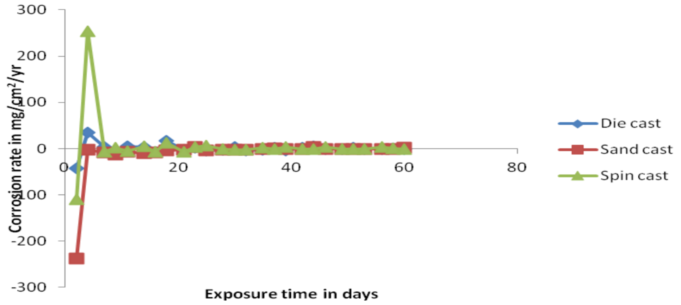

Figure 4.9. Variation of corrosion rate of cast products in 0.3M NaCl

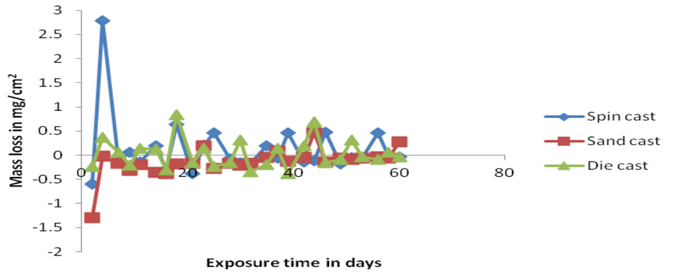

Figure 4.10. Variation of mass loss against exposure time of cast products in 0.3 NaCl

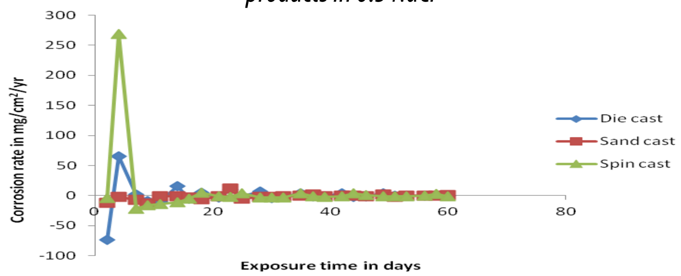

Figure 4.11. Variation of corrosion rate of cast products in 0.5M NaCl

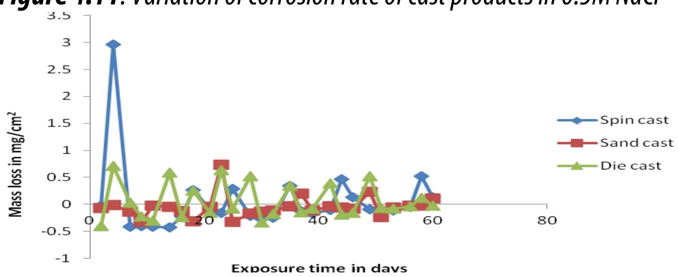

Figure 4.12. Variation of mass loss against exposure time of cast product in 0.5 NaCl

The mass loss profiles in Figure 4.7, Figure 4.9 and Figure 4.12 however show that sand casting has a better corrosion resistance as a result of higher in weight gain while spin casting show high corrosion susceptibility at day four, after which there was drop mass loss, die casting gave a better result as compared to spin casting.

CONCLUSIONS

In the research work, the effect of spin and die casting methods on corrosion behaviour of Al-Mg-Si alloy NaCl and H_2SO_4 were investigated. On the strength of the results presented, the following conclusions were drawn:

- The microstructure of the spin casting revealed that magnesium and silicon were well dispersed in the aluminium matrix as compared to sand die casting.
- The die casting products exhibit better corrosion resistance in 0.1M, 0.3M, and 0.5M H_2SO_4 as compared with spin and die casting.
- The products produced from spin, sand and sand exhibit a good corrosion resistance in 0.1M, 0.3M, and 0.5M NaCl.

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