Green Sand Mould Production of Aluminum Alloy Bimetallic Castings

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Abstract

A green sand moulding system was applied to produce alumunum alloy bimetallic castings. Al alloys 6101 and 242 were combined in the production of the bimetals. Mould firing temperature, pouring temperature and grain fineness number taken at three levels were the parameters used in the study. This was done to know the number of times the experiments would be run using L_9 orthogonal array of Taguchi's approach to design of experiment. Nine experiments were conducted in all, taking into cognisance the role of design of gating system for each of the castings to avoid turbulence. UTS and hardness values were determined as core mechanical properties of the components. There was a down trend of the values as the values of the process parameters increased. However, there were exceptions to this pattern of behaviour perhaps some hot spots were in the castings that exhibited the kind of behaviour.

Keywords: castings, bimetallic, parameters, behaviour, pattern

1. Introduction

Lightweight applications in automotive and aerospace industries have made the lightweight metals/castings extensively popular. Situations arise that only one metal/material would not satisfy the conditions required for efficiency and high performance; cost also taken as a critical factor, then bimetallic design and production is inevitable. The bimetallic is a compound of two dissimilar metals produced by different techniques suitable for the purpose of application and user.

The trend in the automotive industries now is that lightweight metal-aluminum alloys are used to produce cylinder blocks which were mainly produced with steel. This has brought about reduction in weight of the automobiles and performance with service life is assured[1]. Lightweight materials are also applied in other areas of science, technology and manufacturing [2 & 3].

Bimetals, as composites are a combination of two metals or alloys which form two layers bonded together metallurgically, making a component. These constituents exhibit their properties independent of themselves, making bimetals unique. Bimetals are never a mixture of constituents. The common application of the bimetals is found in temperature measurements in which temperature change is converted to a displacement and achieved mechanically. Another application is found in tin cans where steel and tin are combined produce the cans. The steel is covered with tin to prevent corrosion.

For the production of bimetals some properties, physical and mechanical are critical and should be put into consideration in selecting the metal/alloys for the work to be able to achieve some essential characteristics like corrosion resistance, expansivity, thermal conductivity and wear resistance. The two metals/alloys in the bimetals in the play different roles. The exterior may be the one with good machining property and the interior may resist corrosion. The selection of the materials depends on the application; cost taken into consideration. The bimetals have been used widely in gaskets, bearings, radiators and

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instrumentation. Essentially, the combination of mechanical, physical, chemical properties and economics will ensure sound production of the bimetals[4].

This paper considers the production of bimetals using green sand moulding technique. Two alloys of aluminum were employed as casting materials for the bimetals.L_9 orthogonal array of Taguchi's design of experiment resulting in nine runs of experiments using mould temperature, pouring temperature and grain fineness number as experimental process parameters at three levels of treatment was employed in this study.

2. Materials and Methods

2.1. Materials

In this study some materials were used and are presented in Table 1

Table 1: The materials

S/N	Material	Source	Use
1	Material for pattern	Wood	To form cavity in the mould
2	Moulding material	River sand	To prepare moulds
3	Casting material	Al 6101 and 240	To produce bimetallic castings
4	De-gassing material	Hexachloromenthne	To de-gas the Al- alloy melt

2.2. Pattern material

Wood shaped into cylindrical figure was employed as the pattern material. It was used to create cavity inside the moulds during preparation. The name of the wood used is Mahogany. It is strong, hard, and can easily be worked upon.

2.3. Moulding Material (Green sand)

In the course of this research, river sand samples were collected from three different locations Their grain fineness numbers (GFN) were 60, 80, and 100, respectively which were determined by sieve analysis with the aid of a sieve shaker.

2.4. Casting Materials

The casting materials are aluminium alloy 6101 and 242. The elemental composition of the alloys was determined as presented in Tables 2 and 3. The experiment was run three times and the average and standard deviation were determined. Only the average values were recorded.

Table 2: Elemental Composition of AL-alloy 6101

Element	Mg	Si	Mn	Cu	Zn	Ti	Fe	B	Al	Sn	Pb
% Comp	1.277	0.106	0.230	1.106	0.3834	0.073	0.852	0.0005	96.05	0.027	0.011

Table 3: Elemental Composition of Al-alloy 242

Element	Mg	Si	Mn	Cu	Zn	Ti	Fe	B	Al	Sn	Pb
% Comp	0.360	0.670	0.0.79	0.046	0.059	0.016	0.613	0.0004	98.12	0.004	0.025

2.5. Equipment

The equipment that were used in the course of running the experiments are presented in Table 4.

Table 4: List of equipment

S/N	Equipment	Source	Use
1	Pit Furnace	Available at foundry shop	To melt the Al-alloys
2	Ladle	Available at foundry shop	To pour the liquid metal
3	Lathe	Available at foundry shop	To machine tensile test pieces
4	Sieve shaker	Available at Soil laboratory	To sieve the moulding sand to determine the grain fineness number
5	Thermocouple	Market	To take the temperatures of the liquid melt and prepared mould

2.6. Design of Experiment

L_9 orthogonal array of Taguchi's design of experiment was used. The parameters were three at three levels (Table 5). The total number of experiments was nine. Table 6 presents the runs in the design of experiment.

Table 5: Range of parameters

S/N	Process parameters	Range	Level 1	Level 2	Level 3
1	Pouring temperature (^{0}C)	650-750	650	700	750
2	Grain fineness number (GFN)	60-100	60	80	100
3	Mould firing temperature (^{0}C)	100-300	100	200	300

Table 6: Runs in the design of Experiment

	Process Parameters		
S/N	Pouring temperature(^{0}C)	Grain fineness number (GFN)	Mould temperature (^{0C})
1	650	60	100
2	650	80	200
3	650	100	300
4	700	60	200
5	700	80	300
6	700	100	100
7	750	60	300
8	750	80	100
9	750	100	200

2.7. Gating system design

Cylindrical rods were the nine castings that were produced. The design of the gating system was informed by the volume of molten metal poured into prepared moulds to produce the

rods. Step by step design led to the values of the parameters presented in Table 7. Parting line gating design was used. The casting is presented in Figure 1

Table 7: Gating system design parameters

S/N	Parameters	Dimensions
1	Dimensions	200x25
2	Volume mm^2	98.187
3	Casting mass (kg)	0.262
4	Yield of casting	60%
5	Casting weight (kg)	0.437
6	Choke area mm^2	78.53
7	Diameter of sprue exit (mm)	10
8	Diameter of sprue entry mm	18
9	Area of sprue base well mm^2	287.8

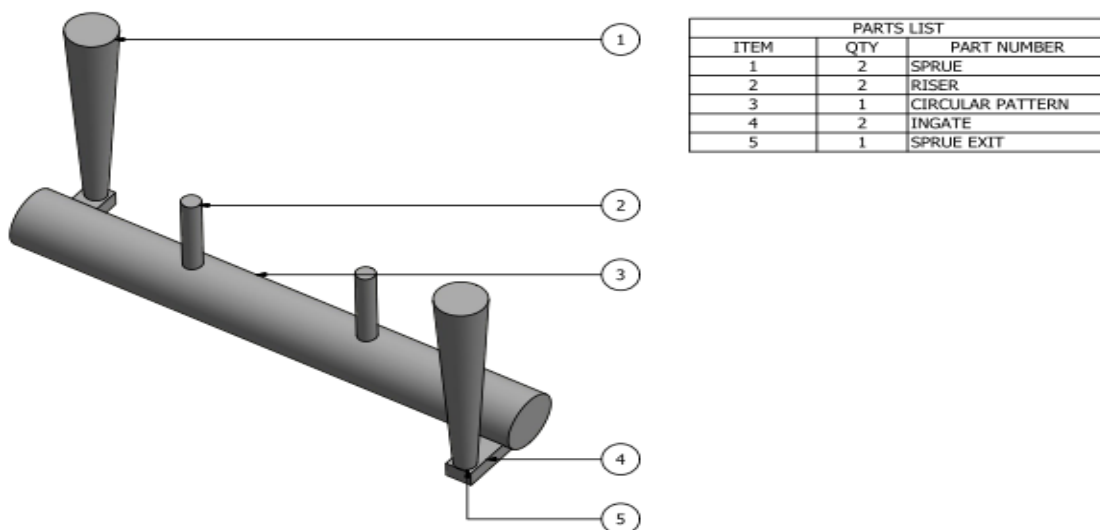| PARTS LIST		
ITEM	QTY	PART NUMBER
1	2	SPRUE
2	2	RISER
3	1	CIRCULAR PATTERN
4	2	INGATE
5	1	SPRUE EXIT

Figure 1: Rod with feeding system

2.8. Production of the bimetals

The green sand samples of varying GFN from different locations were prepared by thorough turning and mixing to allow for flowability of the grains in the mould flasks. Each of the runs of experiment was done by taking into consideration the process parameters. After the moulds had been produced, the melt from the pit furnace contained in ladle was poured. De-gassing was done to get rid of the gasses absorbed in the furnace and atmosphere. The pouring was done in two phases. One alloy was poured. Thereafter the other was poured through another opening on top of the mould. The opening is regarded as pouring cup. The process must be fast otherwise the melt would lose heat thereby bringing down the temperature. The pouring temperature must be observed at all costs. The solidification and cooling of the casting takes place inside the mould to allow for uniform cooling and mechanical properties. Felting of the casting comes after the moulds are broken up.

2.9. Mechanical testing of the castings

Tensile test pieces were machined from the castings that were cleaned and ready for use. The test piece is presented in the Figure 2.
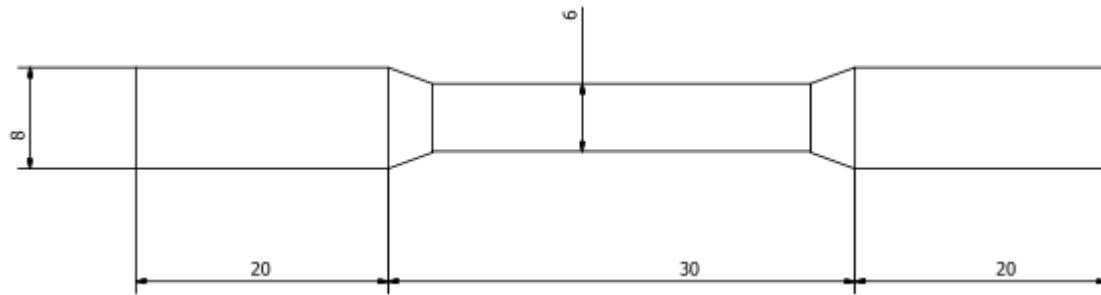
Figure 2: Tensile test piece (all dimensions in mm)

For the UTS three repetitions were made for each run of test and the average value was taken. Istron digital tensile testing machine was employed for the test. It is presented in Figure 3.

Figure 3: Instron tensile testing machine

Test pieces were also cut from the parent castings to evaluate the hardness property of the bimetals. To achieve soundness in the result of the hardness testing, surfaces of the test samples must smooth devoid of scratches which was achieved by polisher before applying a load of 490.3MN from the hardness tester on the test pieces. The tester gives its values in Vickers. Figure 4 shows the machine.

Figure 4: LECO Microhardness Testing Machine

3. Results and Discussion

Nine runs of experiments were carried out for the production of the bimetallic castings. From each of the castings three test pieces were machined to determine the values of the ultimate tensile strength (UTS, elasticity modulus (MOE) and %elongation. Tensile testing machine was used. The hardness values of the bimetals were determined with microhardness tester. The results are presented in Table 8.

Table 8: Values of mechanical properties of the bimetallic castings

S/N	UTS (MPa)	MOE (MPa)	%Elongation	Hardness (Vk)
1	122.07	14435.88	4.41	36.2
2	119.22	14143.00	3.14	27.1
3	88.34	12791.15	2.10	24.6
4	126.23	15412.90	4.35	31.8
5	100.43	11624.58	2.99	28.4
6	66.02	11227.62	2.25	26.1
7	96.03	13590.08	2.41	26.9
8	90.45	13058.65	2.01	25.9
9	48.26	11784.03	1.91	25.5

From the results a decrease in values of the properties that were investigated as the parameters increased was noted. The down ward trend was normal and expected of mechanical behaviour of aluminium alloys cast with increasing pouring temperature [5, 6, & 7]. This was attributed to effects of the experimental process parameters on structures of castings. For example as the pouring temperature increased, the grain sizes were expected to increase. However, there are exceptions to this downward trend in the properties evaluated in this study. For example, the value of the UTS in experiment 4 did not follow the pattern. It was expected that the value should be lower than the one obtained in experiment 1. This may be attributed to slag or some form of impurity in the melt which produced the casting of experiment 4 [8 & 9]. This study could not account for how an impurity got into the furnace. Usually, in tensile test, necking develops from where there is hot spot in the casting. Impurity is the cause of the hot spot in castings. This results in the value of the UTS in experiment 4. The same goes for the values of the hardness obtained in experiments 5 and 6.Truely, they are supposed to follow the pattern, but deviated, which means that some hot spots must have developed in the original castings.

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