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Effect of Additives on Silica Sand Mould for Aluminum Castings

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***Abstract*—In the present work, attempt has been made to study the effect of variation in the percentage of additives on quality of moulds and hence the properties of aluminum castings. In this direction, three different additives namely, Fly-ash, Tamarind powder, and Coconut shell powder were used in different percentages. By using the best composition of moulding sand for each additive, sand moulds were prepared to cast Aluminum. On these Aluminum castings, hardness tests and surface roughness tests were conducted. The castings prepared using silica sand with 1% coconut shell powder, 7% of water, and 8% of bentonite have shown better Surface finish and hardness in comparison with tamarind powder and fly ash.**

***Index Terms*— silica sand, Fly-ash, Tamarind powder, Coconut shell powder, Permeability number, Shear strength, Compression strength.**

I. Introduction

Aluminum finds wide application in automobile and aerospace industries. For casting aluminum, generally Silica sand moulds are used. The composition of moulding sand affects the properties of aluminum castings. To obtain a good casting, selection of right type of sand and additives are important. Additives are generally used along with water and bentonite to provide the bonding strength to the sand.

Three different additives namely, Fly-ash, Tamarind powder, and Coconut shell powder are used in different percentages. The effect of variation in the percentage of additives on quality of moulds has been studied using Silica sand as base sand .Silica sand is commonly used in the foundry industry. With a high melting point of 160°C, the silica sand is normally sintered in a high-temperature furnace. However, silica with contents of calcium, aluminium, magnesium, and chlorine, etc. can form low-melting point eutectics. The most common constituent of sand, in inland continental settings and non-tropical coastal settings, is silica (silicon dioxide, or SiO_2), usually in the form of quartz, which, because of its chemical inertness and considerable hardness, is resistant to weathering.

Water and bentonite are two ingredients of moulding sand, the percentage of which influences the quality of mould. Bentonite is one of the clay binder most commonly used for bonding moulding sands, they produce strongest bonds in foundry moulding sands. Bentonites are the weathered products of volcanic ash and are soft creamy white powders.

As a first step, the percentage of water and bentonite was optimized. The optimum percentage of water was determined by performing shear, compression and permeability tests on the standard specimens prepared by

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varying percentage of water and keeping percentage of bentonite and additives constant. Similarly optimum percentage of bentonite was determined. Using these optimum percentages of water and bentonite, standard test specimens were prepared by varying the percentage of additives in the order of 0.2, 0.4 through 1.0 for all above said additives. Sand mould properties like compression strength, shear strength and permeability number were determined by performing tests on standard specimens consisting of different percentages of additives.

The green compression strength of foundry sand is the maximum compressive strength a mixture is capable of developing when it is in moist condition. The mould has to resist compressive stress due to pressure exerted by the molten metal.

Shear strength is the ability of sand particles to resist shear stress and stick together. Insufficient strength may lead to collapse of sand in the mould or its partial destruction during handling. The mould may also be damaged during pouring of the molten metal by washing of the walls and core by molten metal. The moulding sand must possess sufficient strength to permit the mould to be formed to the desired shape and retain thin shape even after the hot metal is poured into mould. In shearing, the rupture occurs at 45°, to the axis of the specimen.

Gases and water are released in the mould cavity by the molten metal and sand. If they do not find the opportunity to escape completely through the mould, they will get entrapped and form gas holes or pores in the casting. The sand must therefore be sufficiently porous to allow gases and water vapour to escape out. These properties of sand are expressed using permeability number.

By plotting graphs using the data obtained from the above tests, composition of the moulding sand exhibiting better properties was determined for each additive. Using these compositions of the mould sand, mould cavity was prepared to cast aluminum. The Hardness and surface roughness tests were conducted on these castings. Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. Hardness was determined using Brinell's Hardness testing machine.

The surface roughness of the casting is generally affected by a combination of factors. These factors include, grain size of the core sand, metal pouring temperature, type and quantity of core bonding agent, presence of core coating, and gating design. Surface roughness in the present work has been determined using dial indicator.

II. METHODOLOGY

In the present work, chromite sand was subjected to sieve analysis to find their grain fineness number. The test for fineness was conducted by screening sand grains by means of set of standard sieves that are graded and numbered according to fineness of their mesh. The grain fineness number was found using BIS sieve shaker. The fineness number was calculated using the equation 1;

$$GFN = \Sigma (D*C)/ \Sigma C \qquad \text{----} \qquad (1)$$

Where, GFN = grain fineness number

C = % sand retained in each sieve

D = corresponding multiplier for each sieve.

Average grain fineness number of silica sand = [∑ (D*C)] ÷ [∑C] = 4774/98.5 = **48.45**

After the GFN was found, the optimum percentage of water was determined by performing shear, compression and permeability tests on the standard specimens prepared by varying percentage of water in the order of 5, 6, 7, through 10 and keeping 6% of bentonite and 0.2% of Fly-ash constant. Similar tests were conducted at 0.4, 0.6, 0.8 and 1.0% of fly-ash.

Similarly, optimum percentage of bentonite was determined by performing shear, compression and permeability tests on the standard specimens prepared by varying percentage of bentonite in the order of 5, 6, 7, through 10 and keeping 5% of water and 0.2% of Fly-ash constant. Similar tests were conducted at 0.4, 0.6, 0.8 and 1.0% of fly-ash.

After these experiments, optimum percentages of water and bentonite were found to be 7% and 8%. Using these optimum percentages of water and bentonite, standard test specimens were prepared by varying the percentage of additives in the order of 0.2, 0.4 through 1.0 for all above said additives.

Using the above said combinations of the moulding sand, standard tests specimens were prepared to find the properties of the moulding sand. These standard test specimens were prepared using the different ingredients of molding sand such as silica sand, bentonite, water, and additives with required percentages as mentioned above. These specimens were prepared using AFS (American Foundry men Society) Rammer.

In the following sections the details pertaining to tests for determining the compression strength, shear strength and permeability number of moulding sands has been presented.

A. Compression strength

Specimens prepared as mentioned above, tested for compression strength using the compression shackles as shown in Fig 1 using Universal sand testing machine.

Fig.1: Compression shackles

B. Shear Strength

Specimens prepared as mentioned above, tested for shear strength using the shear shackles as shown in Fig 2 using Universal sand testing machine.

Fig.2: Shear shackles

C. Permeability Test

Permeability is that property of the moulding sand which allows the escape of hot gases and water vapour generated in the moulds during solidification process. Specimens prepared as mentioned above, tested for permeability test using the permeability testing machine. The permeability number is given by the equation 2;

$$PN = (V*H)/ (P*A*T) \quad --- \quad (2)$$

Where, V = volume of air pass through the specimen = 2000CC
H = height of the specimen = 50.8 mm;
A = area of the specimen = $\pi d^2/4$
T = time taken to pass 2000cc of air through the specimen in minutes
P = air pressure recorded by the manometer in g/cm^2

These tests were conducted to find the best combination of moulding sand for each additive. After the best combination for the mould is obtained, sand mould was prepared for each additive. Using these sand moulds, aluminum castings were prepared and tested to know their surface roughness and Hardness.

Rectangular pattern was used to create the mould cavity and Aluminum molten metal was prepared using electrical resistance furnace.

D. Testing

Surface roughness

Surface roughness is used to measure the surface texture of the cast specimen using a dial indicator. The RMS and CLA values were found using this dial indicator. The corresponding RMS and CLA values were calculated using the equations 3 and 4,

$$RMS\ value = \sqrt{((h_1^2+h_2^2+h_3^2+ \ldots. +h_n^2)/ n)} \quad -- \quad (3)$$

$$CLA\ value = (h_1+h_2+h_3+ \ldots\ldots +h_n)/ n \quad -- \quad (4)$$

Where, h_1= dial indicator deflection at the first division on the specimen,
h_2 = dial indicator deflection at the second division on the specimen,
h_n = dial indicator deflection at the nth division on the specimen,
n = number of divisions on the reference line drawn on the specimen.

Brinell hardness test

This test is used to determine the Brinell Hardness Number (BHN) of the cast specimen. The Brinell hardness test consists of indenting the cast specimen with a 5 mm diameter hardened steel subjected to a load of 3000 kg. The BHN is calculated by dividing the load applied by the surface area of the indentation. The BHN was calculated using the equation 5,

$$BHN = P/ (\pi D/2)\ [D-\sqrt{(D^2-d^2)}] \quad \text{-- (5)}$$

Where, d= diameter of the indentation on the specimen

P = Load applied = 3000Kg

D = Diameter of the indenter = 5mm

III. Results and Discussion

TABLE I. SILICA SAND WITH VARYING PERCENTAGE OF FLY-ASH

SN	% Sand	% Bentonite	% water	%flyash	Compression Strength		Shear strength		Permeability number	
					g/cm2 (*100)	MPa	g/cm2 (*100)	MPa	indicated	calculated
1	84.8	8	7	.2	4.6	.045126	1	.009810	230	195
2	84.6	8	7	.4	4.2	.041202	1.3	.01275	190	171
3	84.4	8	7	.6	5.1	.050031	1.3	.01275	210	190
4	84.2	8	7	.8	4.8	.047088	1	.00981	210	190
5	84	8	7	1	4.8	.047088	1.3	.01275	200	185

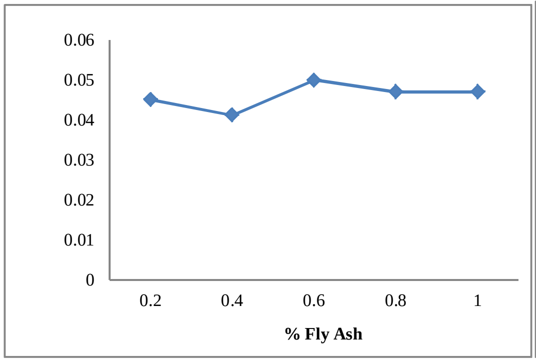

Fig.3: compression strength VS % of Fly-ash

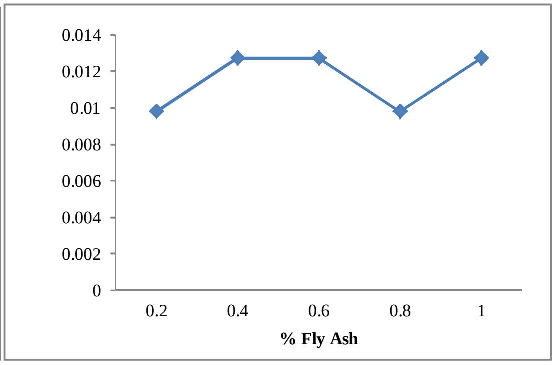

Fig.4: shear strength VS % of Fly-ash

Similarly, tests specimens were prepared using tamarind powder as the additive at different percentages and results are tabulated in table II.

TABLE II. SILICA SAND WITH VARYING PERCENTAGE OF TAMARIND POWDER

SN	% Sand	% Bentonite	% Water	% Tamarind powder	Compression Strength		Shear strength		Permeability number	
					g/cm2 (*100)	MPa	g/cm2 (*100)	MPa	indicated	calculated
1	84.8	8	7	.2	4.7	.046107	1.2	.011772	210	185
2	84.6	8	7	.4	4.6	.045126	1.1	.010791	160	140
3	84.4	8	7	.6	5.2	.051012	1.2	.011772	180	160
4	84.2	8	7	.8	5.5	.053955	1.5	.014715	160	146
5	84	8	7	1	5.2	.051012	1.1	.010791	180	156

Similarly, tests specimens were prepared using coconut shell powder as the additive at different percentages and results are tabulated in table III.

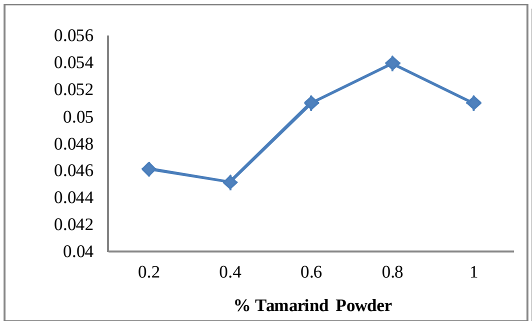

Fig.5: compression strength VS % tamarind powder

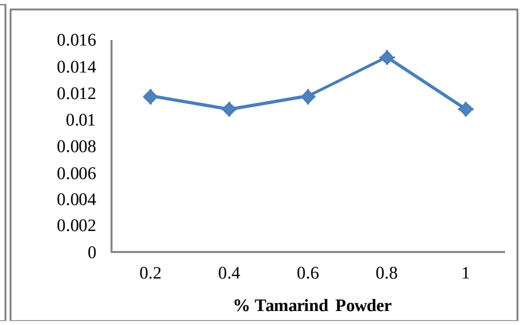

Fig.6: shear strength VS % of tamarind powder

TABLE III. CHROMITE SAND WITH VARYING PERCENT OF COCONUT SHELL POWDER

SN	% Sand	% Bentonite	% Water	% Coconut shell powder	Compression Strength		Shear strength		Permeability number	
					g/cm2 (*100)	MPa	g/cm2 (*100)	MPa	Indicated	Calculated
1	84.8	8	7	.2	4.7	.046107	1	.00981	200	180
2	84.6	8	7	.4	4.6	.045126	1.2	.011772	190	171
3	84.4	8	7	.6	4.2	.041202	1.1	.010791	200	185
4	84.2	8	7	.8	4.6	.045126	1.1	.010791	180	163
5	84	8	7	1	5.2	.051012	1.1	.010791	160	150

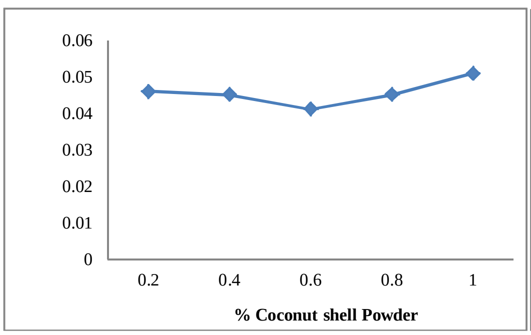

Fig.7:compression strength VS % of coconut shell powder

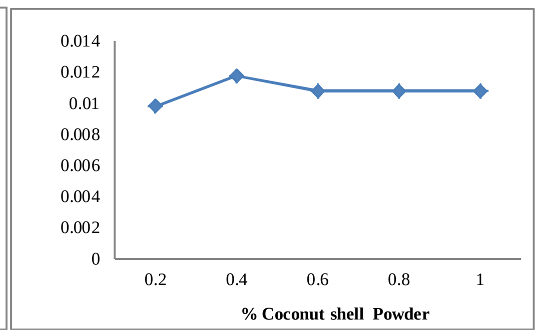

Fig.8**:** shear strength VS % of coconut shell powder

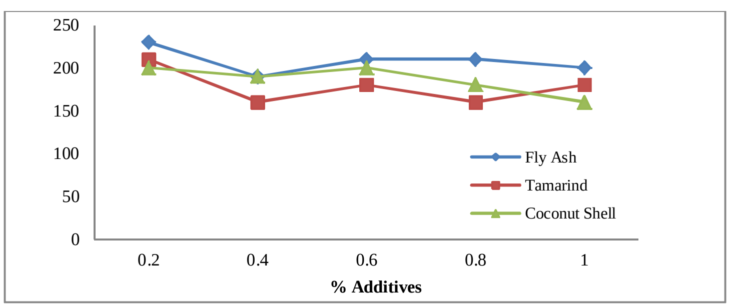

Fig.9: variation of permeability number at different percentages of additives

TABLE IV. PERCENTAGES OF INGREDIENTS USED TO PREPARE MOULD FOR CASTING ALUMINUM

S.No.	Base sand (silica sand) in %	Water in %	Bentonite in %	Additive in percentage
Mould 1	84.4	7	8	0.6% of Fly-ash
Mould 2	84.2	7	8	0.8% of tamarind powder
Mould 3	84	7	8	1% of coconut shell powder

TABLE V. SURFACE ROUGHNESS VALUES AT DIFFERENT POINTS ON ALUMINUM CASTING

No of Divisions	FA	TP	CSP
1	0.51	-0.55	0.57
2	0.66	-0.43	0.81
3	0.39	-0.65	0.79
4	0.71	-0.45	0.74
5	0.55	-0.49	0.92
6	0.78	-0.50	0.58
7	0.65	-0.35	0.74
8	0.70	-0.25	0.49
9	0.73	-0.50	0.73
10	0.54	-0.30	0.55
11	0.49	-0.32	0.68
12	0.52	-0.44	0.74
13	0.75	-0.52	0.55
14	0.66	-0.54	0.68
15	0.76	-0.55	0.78
16	0.62	-0.50	0.80
17	0.66	-0.40	0.73
18	0.52	-0.33	0.92
19	0.61	-0.50	0.80
20	0.71	-0.44	0.52
CLA value	0.626	-0.45	0.706
RMS value	0.634	0.4610	0.7163

FA = fly ash, TP = tamarind powder, CSP = coconut shell powder

TABLE VI. BHN VALUES OF ALUMINUM METAL FOR VARIOUS COMBINATIONS OF ADDITIVES

Additive used	BHN
Fly ash	74.71
Tamarind powder	71.31
Coconut shell powder	77.18

IV. CONCLUSION

It was observed that, 8 percent of bentonite and 7 percent of water in moulding sands provides better compression strength, shear strength and permeability. Silica sand with 0.6% of fly ash, silica sand with0 .8% of tamarind powder and silica sand with 1% of coconut shell powder were used to prepare the mould cavity, among them, silica sand with 1% of coconut shell powder has shown better surface finish and Hardness when compare to other two additives.

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