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Investigation on Influence of Naturally Available Additives on Green Sand Mould Properties-A Case Study

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ABSTRACT:-

The quality of castings in a green sand mould is influenced by its properties such as green compression strength, green shear strength, permeability, etc. Additives play a very important role on green sand mould to enhance specific mould properties. The experimental study aims to investigate the effect of various additives on the green sand mould properties, as a particular combination of additives could yield desired sand properties. The input parameters selected were moisture and additives (Coal dust, Corn flour powder and Tamarind powder) at three different levels. On the basis of Taguchi's L9 Orthogonal Array, experiments were conducted to understand the behavior of sand mould properties namely; green compression strength, dry compression strength and permeability. Analyses of means were calculated for each of the responses produced by different additives. It was found that the permeability of corn flour containing sand mould was highest and the strengths of tamarind powder containing mould were maximum.

Keywords: Green Sand Mould, Design of Experiments (DOE), Compression Strength, Permeability Number.

1. INTRODUCTION

Casting is the oldest known process to produce metallic components. The first metal casting was produced during the period of 4000-3000 BC. Since then, various casting processes have been developed. In casting process, the liquid material is poured into a cavity (die or mould), which corresponds to the desired geometry of the part to be produced. Then, the casting is solidified and removed from the cavity as a solid part [1]. Though sand casting is the least accurate casting process, yet it is very common and most widely used for manufacture of parts. It involves pouring of molten metal into a sand mould which is made from typically 80% silica sand, 5-10% clay binders (mostly bentonite), 2-6% tempering water and a variety of additives. When the moulding sand contains moisture, it is known as green moulding sand [2].

Moulding sand is comparatively cheap, possessing high refractory property for use in foundries. Different types of refractory sands used for moulding are silica sand, zircon, magnetite, graphite, olivine [3]. Generally, green sand is fine, light, soft and porous. Green sand mould possesses moulding properties such as good compression strength, shear strength, hardness, permeability, mouldability, etc, which makes it highly suitable for production of ferrous and non-ferrous castings. Statistical approach is the best tool for studying green compression strength and permeability number of green sand moulds [4-5]. Ihom [6] found that the green compressive strength of the moulding sand increases with increase in fineness of sand grains, although it decreases with coarseness of the grains. Additives play a very important role in determining the sand mould properties. It has been found that the additives such as wood flour, fly ash, iron fillings, coal dust, sea coal, starch, husk, etc., when added to the green sand mould produces fine casting and decreases sand adhesion to casting thereby reducing casting defects [7-10].

Thermal power station produces fly ash as one of the residues which contains silica. Coconut shell powder and tamarind powder are agricultural wastes which are used as additives in sand moulding process to improve the surface finish of the casting. Among the additives, namely coconut shell powder, fly ash and tamarind powder, coconut shell powder moulded sand exhibited highest compressive strength and fly ash containing moulding sand demonstated fine permeability [11]. Bentonite possesses properties such as colloidal properties, water absorption ability, viscosity, etc., which makes it suitable as binding material in the moulding sand. Atanda et al [12] found that the moulding sand possessed very high green and dry strengths when both cassava and bentonite powder were combined together. Among fly ash, coconut shell powder and tamarind powder, it has been found that the tamarind powder gives highest sand strength [13].

Clay content and moisture content have positive effect on green compression strength [4]. Compression strength and moisture content are the control factors which has significant effect on quality control [14]. Seidu and Kutelu [15] investigated the effect of sawdust, coal dust and iron filling additives on silica sand mould properties. It was found that sawdust containing sand mould showed higher green strength, whereas coal dust containing sand mould exhibited improved sand porosity and permeability thereby reducing casting defects including blow hole. The synergic effect of 25% of sawdust, coal dust and iron filling on the moulding sand gave the optimum green shear strength value of 54.49 kPa. In the present study, the authors have tried three different additives i.e. coal dust, corn flour powder and tamarind powder separately in the green sand mould so as to study their effect on the responses namely, permeability number, green compression strength and dry compression strength.

2. EXPERIMENTAL SET UP AND METHODOLOGY

First, green sand and different additive powders were weighed using an electrical weighing balance. Once the desired moisture content was achieved, the standard specimens (2 inch height × 2 inch diameter) were prepared using a sand ramming machine as shown in Fig. 1 (a). The green strength and permeability of the standard sand specimen were measured using a Universal Testing Machine (Fig. 1 (b)) and Permeability meter (Fig. 1 (c)). For measuring dry compression strength test, each specimen was heated in an oven (Fig. 1(d)) at 105ºC for 2hr to remove the moisture from it. Standard sand specimen is shown in Fig. 1(e). The different inputs with their levels chosen for the study are moisture content (%) and additives (%), as shown in Table 1. The experimental plan was based on Taguchi's L9 Orthogonal array (OA). Experimental results recorded for corn flour, coal dust and tamarind powders are shown in Tables 2-4, respectively.

(a) (b) (c) (d) (e)

Fig. 1. (a) Sand rammer (b) Universal testing machine (c) Permeability meter (d) Hot air oven (e) Standard test specimen

Table 1. Input parametric setting and their levels

Parameters	Symbol	Levels		
Moisture content (%)	A	4	5	6
Additive (%)	B	1	2	3

Table 2. Experimental Results of chosen responses for additive Corn flour

Trial No.	Corn flour (A) (%)	Moisture (B) (%)	Permeability no.	Green compression strength (lbs/inch^2)	Dry compression strength (lbs/inch^2)
1	1	4	219	6.1	83
2	1	5	216	6.4	86
3	1	6	217	6.3	84
4	2	4	216	5.4	65
5	2	5	213	5.7	67
6	2	6	212	5.5	66
7	3	4	198	5.0	62
8	3	5	196	5.3	64
9	3	6	197	5.2	63

Table 3. Experimental Results of chosen responses for additive Coal dust

Trial No.	Coal dust (A*) (%)	Moisture (B) (%)	Permeability no.	Green compression strength (lbs/inch^2)	Dry compression strength (lbs/inch^2)
1	1	4	215	6.1	73.0
2	1	5	210	6.0	76.0
3	1	6	207	5.8	74.0
4	2	4	205	5.9	59.0
5	2	5	202	6.0	61.0
6	2	6	199	5.6	58.5
7	3	4	197	5.2	32.0
8	3	5	196	5.0	34.0
9	3	6	191	4.8	31.0

Table 4. Experimental Results of chosen responses for additive Tamarind powder

Trial No.	Tamarind powder (A°) (%)	Moisture (B) (%)	Permeability no.	Green compression strength (lbs/inch^2)	Dry compression strength (lbs/inch^2)
1	1	4	201	6.5	70
2	1	5	202	6.7	71
3	1	6	198	6.3	76
4	2	4	195	7.0	62
5	2	5	197	6.8	65
6	2	6	190	6.4	68
7	3	4	174	7.5	82
8	3	5	178	7.7	88
9	3	6	171	7.1	89

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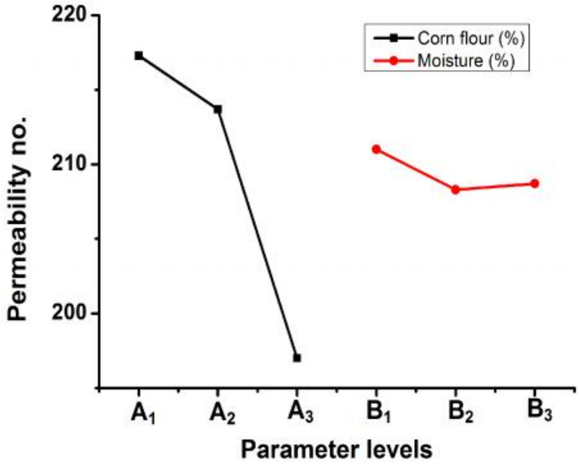
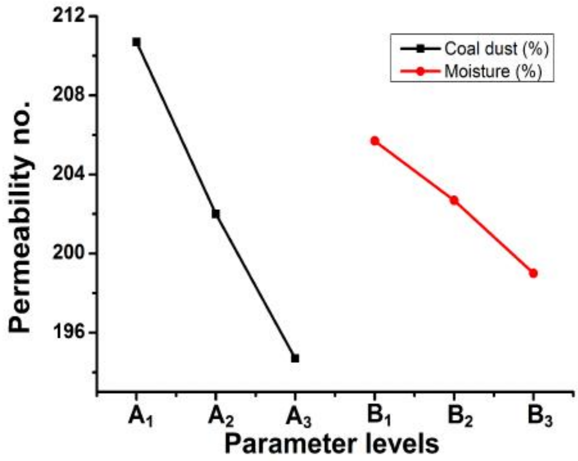
3. RESULTS AND DISCUSSIONS

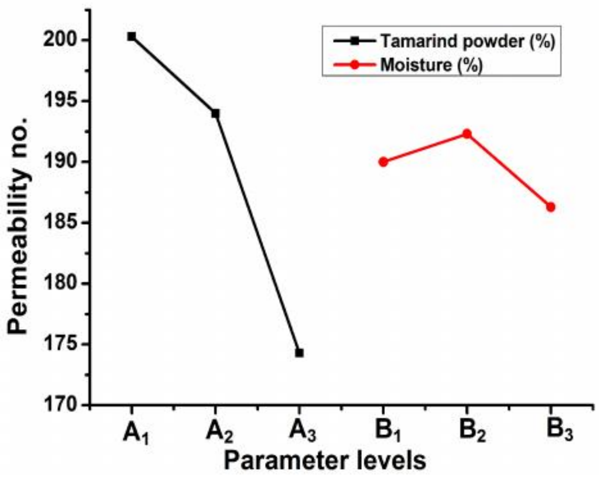
The experimental data recorded in Tables 2-4 were analyzed to identify the significance of input parameters on green compressive strength, dry compressive strength and permeability number using statistical software MINITAB. Analysis of means (ANOM) was applied to determine the optimum input condition for the chosen responses. It was desired to cast aluminum alloy in the sand mould and the main problem of the aforesaid alloy is porosity related defects in casting. Hence, it is desired that the mould porosity should be maximum with adequate green and dry strengths of the sand mould. In this study, Taguchi's Higher-the-better and Nominal-the-best criteria have been used for calculation of permeability no. and green and dry strengths by ANOM. Figs. 2-5 shows the ANOM graphs of permeability no., green compression strength and dry compression strengths of the moulding sand obtained by using corn flour, coal dust and tamarind powder, respectively. The optimal parametric combinations of different inputs are presented in Table 5.



(a)

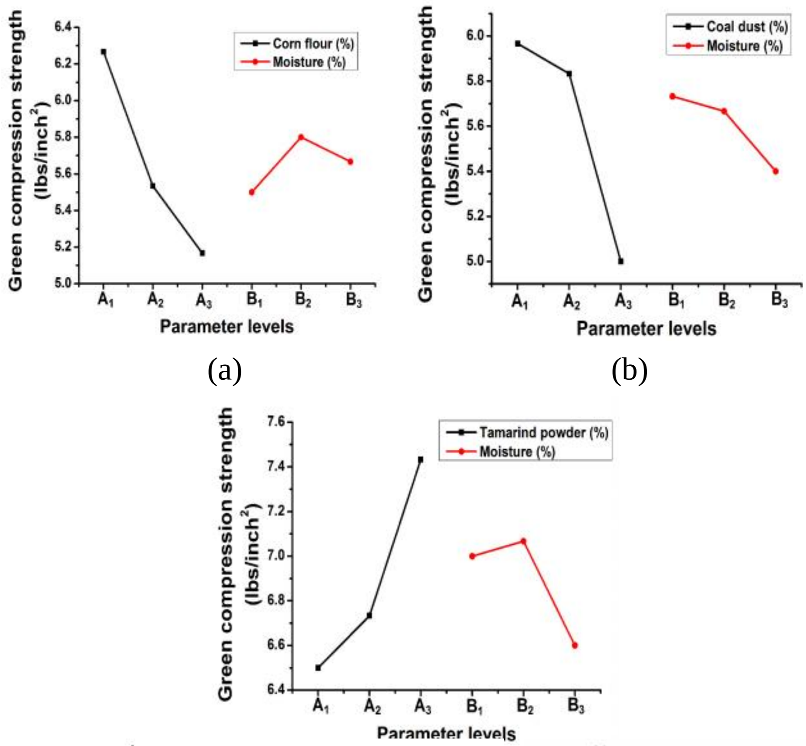


(b)



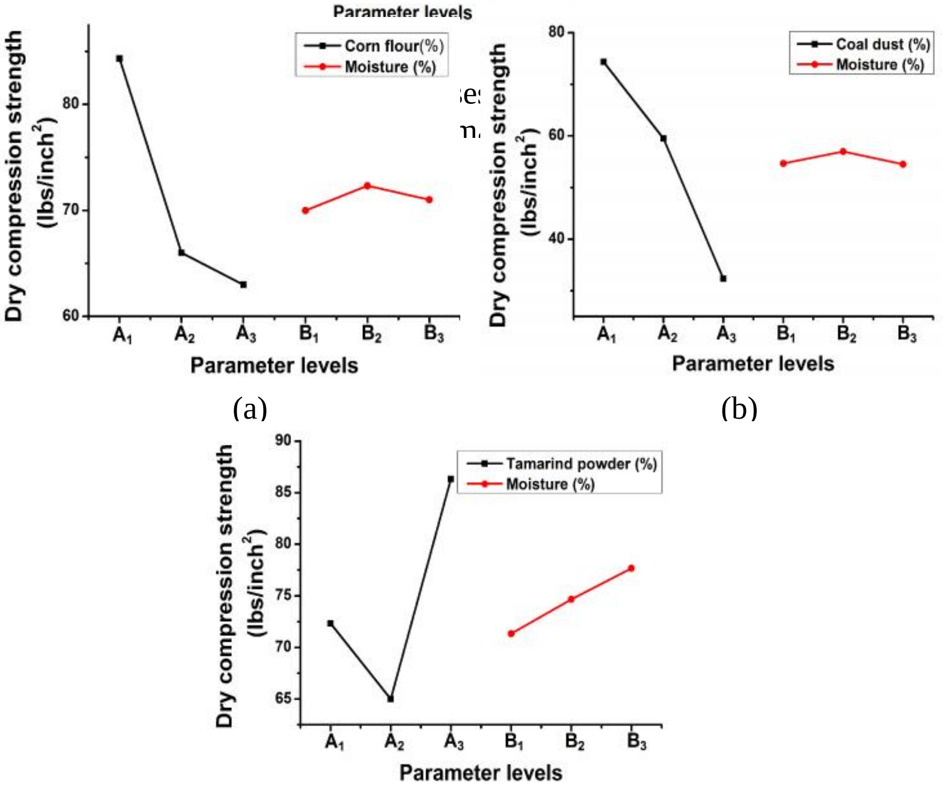
(c)

Fig. 2. Permeability no. verses Parameter levels (a) Corn flour (b) Coal dust (c) Tamarind powder



(a) (b)

Fig.



(a) (b)

(c)

Fig. 4. Dry compression strength verses Parameter levels (a) Corn flour (b) Coal dust (c) Tamarind powder

Table 5. Optimal parametric combinations of inputs for different additives

Additive (%)	Optimal parametric combination of process parameters		
	Permeability no.	**Green compression strength (lbs/inch^2)**	**Dry compression strength (lbs/inch^2)**
Corn flour	$A_1 B_1$	$A_2 B_3$	$A_2 B_3$
Coal dust	$A_1^* B_1$	$A_2^* B_2$	$A_2^* B_1$
Tamarind powder	$A_1^0 B_2$	$A_2^0 B_1$	$A_1^0 B_2$

3.1Additives affecting permeability no. of moulding sand

From Table 5, it is clearly seen that the permeability of corn flour containing moulding sand is highest at input parametric condition $A_1 B_1$ i.e. Corn flour percentage = 1% and Moisture content = 4%. This parametric combination belongs to experimental run no. 1 of Table 2 and the permeability no. is 219. The permeability of moulding sand containing coal dust is maximum at input parametric condition $A_1^* B_1$ i.e. Coal dust percentage = 1% and Moisture content = 4%. This parametric combination belongs to experimental run no. 1 of Table 3 and the permeability no. is 215. Further, the permeability of Tamarind powder containing moulding sand is utmost at input parametric condition $A_1^0 B_2$ i.e. Tamarind powder percentage = 1% and Moisture content = 5%. This parametric combination belongs to experimental run no. 2 of Table 4 and the permeability no. is 202. From the above analysis, it is obvious that the permeability of moulding sand consisting of corn flour powder is maximum which is followed by coal dust powder at equal weight percentage of moisture content. However, the moulding sand containing tamarind powder showed least permeability with increased moisture percent. The reason behind the phenomenon is that the particle size of corn flour added to the moulding sand was comparatively coarser in size and the coarse particle size leads to increased mould permeability, whereas fine particles decrease mould permeability. Tamarind powder was finest among all additives and thus, the moulding sand containing it was least permeable. Another important property of tamarind powder is that it possesses excellent water absorption property due to which the moisture content was more in the moulding sand containing it.

3.2Additives affecting green compression strength of moulding sand

The optimum green compression strength of moulding sand comprising of corn flour powder is found to be at input parametric condition of $A_2 B_3$ i.e. Corn flour percentage = 2% and Moisture content = 6%. This parametric combination belongs to experimental run no. 6 of Table 2 and the green compression strength at this parametric setting is found to be 5.5 lbs/inch^2. The optimum parametric settings of the moulding sand consisting of coal dust and tamarind powder were found to be $A_2^* B_2$ and $A_2^0 B_1$ respectively i.e. Coal dust percentage = 2%; Moisture content = 5% and Tamarind powder percentage = 2% and Moisture content = 4%. These parametric setting refers to the experimental run no. 4 for coal dust showing green compression strength of 6 lbs/inch^2 and experimental run no. 2 for tamarind powder showing green compression strength of 7 lbs/inch^2. Thus, it is seen that the tamarind powder modified sand mould exhibited highest green compression strength. It happened because it contains starch and gum which enhances the strength of the mould.

3.3Additives affecting dry compression strength of moulding sand

From Table 5, it is found that the optimum dry compression strength of moulding sand containing corn flour is $A_2 B_3$ i.e. Corn flour percentage = 2% and Moisture content = 6%. This parametric combination belongs to experimental run no. 6 of Table 2 and the dry compression strength at this parametric setting is found to be 66 lbs/inch^2. The optimum parametric settings of the moulding sand consisting of coal dust and tamarind powder were found to be $A_2^* B_1$ and $A_1^0 B_2$ respectively i.e. Coal dust percentage = 2%; Moisture content = 4% and

Tamarind powder percentage = 1% and Moisture content = 5%. These parametric setting refers to the experimental run no. 4 for coal dust showing dry compression strength of 59 lbs/inch^2 and experimental run no. 2 for tamarind powder showing dry compression strength of 71 lbs/inch^2. In this case also, the dry compression strength of moulding sand containing tamarind powder was found to be highest among all additives.

4. CONCLUSIONS

The following conclusions are drawn from the present study:

- The moulding sand containing corn flour exhibited highest permeability compared to other additives. So, when the permeability property of mould has to be increased, then corn flour is the best additive among the three to be incorporated in the mould.
- The moulding sand comprising of tamarind powder demonstrated highest green and dry strengths due to the inherent binding property of tamarind powder.
- This study shows that for low melting point alloys such as aluminium, permeability of the mould should be increased as mould strength is not an issue for these alloys. However, for high melting point alloys such as titanium, maximum mould strength is desirable.

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