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Investigation of Molding Characteristics of Acacia Gum Arabic Grade 1 for Making Green Sand Cores

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ABSTRACT

Investigation of moulding characteristics of Acacia gum arabic grade 1 was carried out. On addition of 0.50-2.50% Acacia gum arabic, the green moulding characteristics such as compression, shear strength, shatter index, compactability, bulk density, permeability number and flowability are in the range of 36.40-53.90 kPa, 0-9.80 kPa, 13.90-38.50%, 20.00-32.00%, 1300.00-1360.00 kg/m^3, 112.00-80.00 and 96.60-74.50% respectively. The moulding characteristics show that the compression and shear strengths, shatter index, bulk density and compactability increased with percentage addition of acacia gum arabic, while the permeability number and flowability decreased with percentage addition of the gum. The moulding characteristics of the gum were found to be within accepted standard sand core characteristics. To validate the results, cores were produced with 2% gum arabic and used to produce simple bushings. It was observed that the sand cores were strong enough to withstand the molten metal pressure; they maintained location and collapsed only after molten metal solidification. The bushings were seen to be sound. Thus, acacia gum arabic grade 1 can be used as a binder in green sand core making for non-ferrous metal castings.

Keywords: Acacia Gum Arabic, Characteristics, Green Sand Cores, Investigation, Moulding

I. INTRODUCTION

Gum arabic has been the oldest and best known natural gum since 2650 BC [1]. It is a natural resin that contains arabin; a semi solidified sticky fluid oozing from incision made on the bark of acacia trees [1, 2, 3, 4, 5, 6, 7]. The acacia tree is a plant gum produced mostly in the Sahel region of Africa including northern Nigeria where four different commercial grades of the gum are produced, namely: Acacia Senegal-grade 1, Acacia Seyal-grade 2, Combretum-grade 3 and Neutral-grade 4 [5, 6, 8, 9]. Nigeria is second ranked largest world producer of gum arabic after Sudan [1, 2, 8, 10]. Gum Arabic is cultivated in Borno, Yobe, Jigawa, Sokoto, Bauchi States of Nigeria as potent weapon in fighting against land desertification and soil degradation [1, 10, 11, 12, 13]. It also has the potentials of improving soil fertility through the dropping of its leaves during dry season. The gum tree survives well in desert (Sahel) regions-it thrives well in soils that are sandy, droughty and low in organic nitrogen; it can tolerate a wide range of mean annual temperature of between 14 ^{0}C and 43^{0}C with 800 mm rainfall annually [12]. Gum tapping and collection has been a source of income in rural areas [11]. It has been generating foreign exchange of about $16.4 million annually to the nation [1, 11, 12]. The gum has been useful in industrial applications such as in foods, beverages, pharmaceuticals, cosmetics, textiles, confectionary, printing, etc. [1, 2, 6, 11, 12, 14].

Little or none was the importance of gum arabic known in foundry industries than recently when it was used as admixture as an additive in green sand moulds/cores [1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 15]. Acacia gum arabic grade 1 is available in large quantities in Yola. It is a cheap gum. It can be used as a binder in making green sand cores. Sand cores form undercuts, cavities, intricate shapes in metal casting that cannot be obtained through other machining or manufacturing methods l15, 17, 18]. This study is aimed at investigating the moulding characteristics of acacia Gum arabic grade 1 for making green sand cores.

II. MATERIALS AND METHODS

Materials

One kilogram of acacia gum arabic, two kilograms of River Gongola silica sand and one kilogram of aluminium scraps.

Methods

Acacia Gum arabic grade 1 was obtained from GeseDado Farms in Yola, Adamawa State. The aluminium scraps and the silica sand were sourced locally.

Sand Moulding

The following steps detailed the sand moulding process.

1) Sample Preparation

100 grams of the gum Arabic were soaked in 5 % of water for 24 hours [17]. The gum fluid was used as a binder for the experiment.

2) Mixture Composition

Based on the standard recommended data on water soluble sand core binder, the following percentage mass composition of 0.5-2.5 % of gum and 700 grams of silica sand were adopted for the moulding [15, 16, 17]. The mixture composition was made in such a way that the sum fraction of each level equals unity [15]. That is,

$$X_1 + X_2 = 1 \quad (1)$$

Where X_1 –acacia gum arabic mass fraction and X_2 - silica sand mass fraction.

Table 1 details the composition levels for the experiment.

Mixing

The mixture was thoroughly hand mixed at the core bench. The mixing was properly made so that the cores possess homogenous properties.

Table 1: Mixture Composition of Acacia Gum Arabic Sand Cores

S/No.	Material	Percentage mass composition				
1	Acacia gum arabic (%)	0.50	1.00	1.50	2.00	2.50
2	Silica sand (%)	99.50	99.00	98.50	98.00	97.50

3) Ramming

Φ50 x50 mm sand core specimen was positioned in the specimen rammer and rammed with three drops of the standard mass of 6.4 kg at the height of 50mm. The rammed specimen was ejected from the tube with the aid of the specimen extractor [17]. Level sand cores specimens were produced for the determination of the moulding characteristics.

4) Green Permeability

The rammed core specimen inside the tube was mounted on the permeability machine. The machine was switched on. Air through an orifice was allowed to pass through the core for twelve seconds. The degree of the permeability of the core was indicated on the dial-gauge of the machine [17]. The result was recorded.

5) Shatter index

The core specimen was ejected from the specimen tube and was allowed to fall through a height of two meters of shatter index machine on a mesh of 13.2 mm sieve. The specimen mass that remained on the sieve was weighed. The shatter index was calculated as a percentage of the mass that remained on the test sieve to the total mass of the test sample. The shatter index can be expressed as [17]:

Shatter index $S_i = m_{r/m_s}$ (2)

Where S_i- Shatter index, m_r- retained mass on the sieve and m_s-test sample total mass

6) Flowability

The flowability of the mixture was determined after the normal third ramming of the specimen was made. Further fourth ramming was made. The height of the specimen tube was taken. Another fifth ramming was made on the specimen. The height was also recorded. The difference in height of the cylinder after the fourth and the fifth ramming was recorded. The difference in height was used to calculate the flowability [17]. Thus:

Flowability $F_w = 100 - 4\Delta H$ (3)

Where F_w-percentage flowability, 4-Multiplication factor and ΔH-difference in height between fourth and fifth drops of ramming.

7) Green Bulk density

Bulk density is the weight per unit volume of the standard specimen including the open and closed pore spaces. The mass M and the height H of the specimens were measured. The green bulk density is given by [17]:

Green bulk density GBD = $0.05\frac{M}{H}$ (4)

Where GBD-green bulk density, M-sample mass and H-sample height

8) Compactability

The test was performed by using test tube of Φ50 x 50 mm. The tube was filled with the mixture. The mixture was rammed three times. While the rammer head was in contact with the rammed specimen, the rammer height was directly indicated by a top gauge on the machine. The gauge reading was taken as specimen compactability [17].

9) Green compression strength

The green compression strength was carried out with the universal strength testing machine. The fresh prepared standard sand core sample was positioned in the compression head of the machine. The sample was loaded gradually while the magnetic rider moves along the measuring scale. As soon as the sample reached its maximum strength, it failed. The magnetic rider remained at the position of the ultimate strength while the load was gradually released. The green compression strength for the sample was recorded at the position of the magnet [17].

10) Green shear strength

The Green shear strength is the measure of the shear strength of the test sample when shear load was applied to it. The universal testing machine used for the determination of the green compression strength was used also. The only difference is that the compression head was replaced with the shear head. The shear strength was recorded at the point of failure of the sample [17].

III. RESULTS AND DISCUSSION

Plate 1 shows acacia Gum arabic grade 1 in semi-solidified form which was dissolved in water to form sticky fluid gum for binding the silica sand grains.

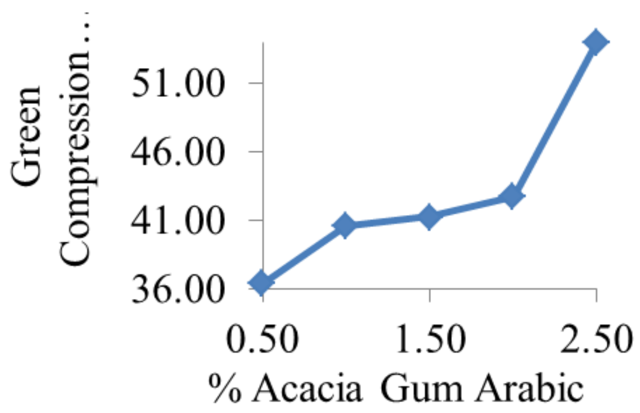
Plate 1: Acacia Gum Arabic Grade 1

Table 2 shows the moulding characteristics of acacia gum arabic sand cores and figure 1 shows the graphical representation of the characteristics. On addition of 0.50-2.50% acacia gum arabic, the green moulding characteristics such as compression, shear strength, shatter index, compactability, bulk density, permeability number and flowability are in the range of 36.40-53.90 kPa, 0-9.80 kPa, 13.90-38.50%, 20.00-32.00%, 1300.00-1360.00 kg/m^3, 112.00-80.00 and 96.60-74.50% respectively. It could be observed from both the table and the figure that the green compression strength-figure 1(a), green shear strength-figure 1(b), compactability-figure 1(c), shatter index-figure 1(d) and bulk density-figure 1(e) increased with percentage addition of acacia Gum arabic, while permeability number-figure 1(f) and flowability-figure 1(g) decreased with percentage addition of acacia gum arabic. That is, as the percentage of gum increases, the gum coats and binds the neighbouring sand grains more properly which resulted in sand cores to possess corresponding increase in compression and shear strengths, shatter index, bulk density and compactability. Conversely, with addition of more gum to the sand grains, the core sand does not flow easily to fill core box which makes flowability of the core sand reduced. That is, flowobility reduces with addition of percentage of the gum. Similarly, percentage addition of the gum to the grains, affects the permeability number of the sand cores. With increased percentage of the gum, the adjacent sand grains stick and bind the sand grains resulting to spaces or pores between the adjacent grains of the sand cores blocked. Consequently, core specimens tend to have blocked air passage. Permeability number therefore, reduces with addition of more gum.

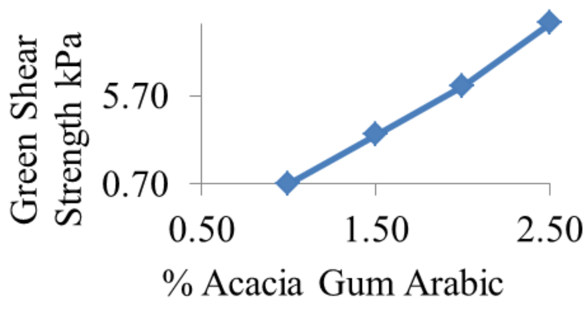
Table 2: Moulding Characteristics of Acacia Gum Arabic Green Sand Cores

S/No.	Acacia Gum arabic %	0.50	1.00	1.50	2.00	2.50
1	Green compression strength kPa	36.40	40.60	41.30	42.70	53.90
2	Green shear strength kPa	-	0.70	3.50	6.30	9.80
3	Shatter index %	13.90	18.60	23.30	30.50	38.50
4	Compactability %	20.00	24.00	27.00	30.00	32.00
5	Bulk density kg/m^3	1300.00	1320.00	1330.00	1350.00	1360.00
6	Permeability number	112.00	110.00	100.00	92.00	80.00
7	Flowability %	96.60	90.00	85.50	81.00	74.50

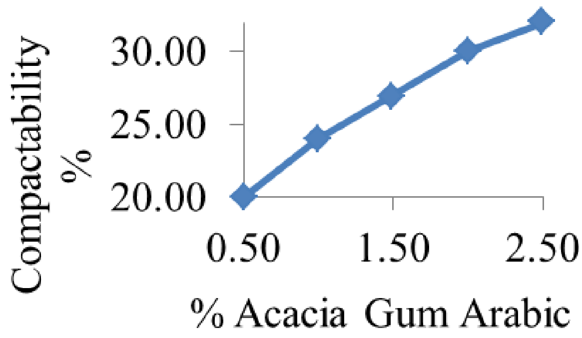
Sand cores were made. Plate 2 shows the moulding process. Plate 2(a) shows green acacia gum arabic sand core specimens which were used for investigating the moulding characteristics of the gum-bonded sand cores. Plate 2(b) shows the green acacia gum arabic sand cores which were used to form cavities in casting simple bushings. Plate 2(c) shows the cast. The fins and the collapsed sand cores were removed and the resulting simple bushing is shown in Plate 2(d). On examining the cast with the core and the bushing, it was observed that the sand core did not fail during molten pouring, it maintained shape and location, and collapsed after solidification of the molten metal. The simple bushing was seen to have good size. Therefore, acacia gum arabic grade I is a good binder in making green sand cores.



(a)



(b)



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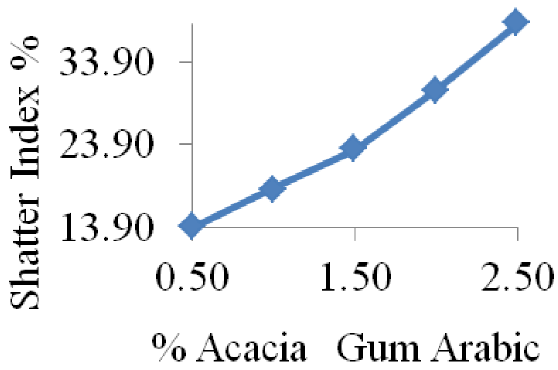

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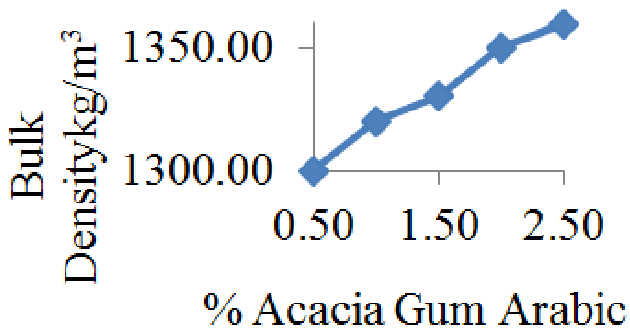
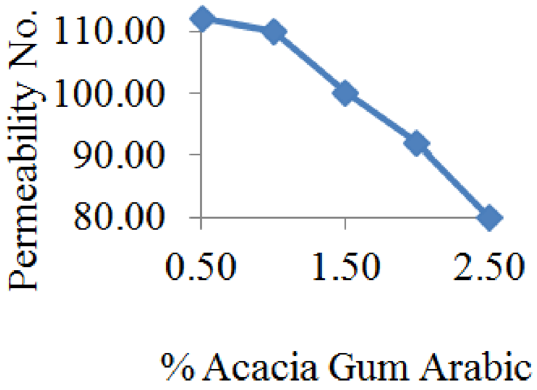
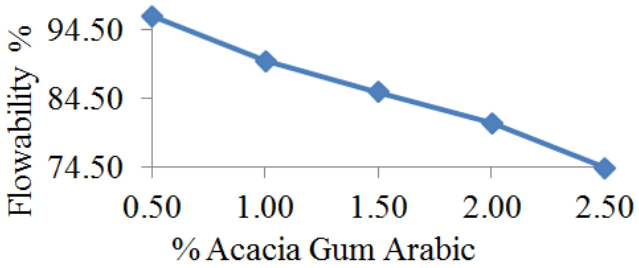


(e)



(f)



(g)

(a)- Variation of Green Compression Strength with Percentage Acacia Gum Arabic, (b)- Variation of Green Shear Strength with Percentage Acacia Gum arabic, (c)- Variation of Shatter Index with Percentage Acacia Gum Arabic, (d)- Variation of Bulk Density with Percentage Acacia Gum Arabic, (e)- Variation of Compactability with Percentage Acacia Gum Arabic, (f)- Variation of Permeability with Percentage Acacia Gum Arabic, (g)- Variation of Flowability with Percentage Acacia Gum Arabic

(a)

(b)

(c)

(d)

Figure 1: Moulding Characteristics of Acacia Gum Arabic Green Sand Cores

(a)-Sand Core Specimens, (b)-Gum Arabic Sand Cores, (c).Cast and (d) Simple Bushing
Plate 2: Moulding Process

IV. CONCLUSION

Investigation of the moulding characteristics of acacia gum arabic grade 1 for making green sand cores was carried out. The performance of the gum-sand bonded cores was seen to be satisfactory. The simple aluminium bushings produced were also observed to have good dimensions and shape. Therefore, acacia gum arabic grade 1 is a good binder which could be used for making green sand cores to produce fins, intricate shapes, cavities, etc. in non-ferrous metal castings.

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