American-Eurasian Journal of Scientific Research 4 (2): 97-102, 2009
ISSN 1818-6785

Estasbishment of the Beneficial Effects of Addition of Linseed Oil to Foundry Sand Cores Bonded with Nigerian Gum Arabic Grades 2 and 4

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Abstract: The effect of addition of linseed oil to Nigerian gum Arabic grades 2 and 4 on baked tensile strength of sand cores used as implants in foundry moulds was studied. Defined quantities of gum Arabic and linseed oil were mixed together and used to bind sand cores that were later baked at 180°C and 200°C and then analysed for tensile strength to establish any property improvements over cores bonded with plain gum Arabic. Core specimens shaped like figure eight in accordance with foundry practice were baked in an electrically powered oven and then tested with a universal strength machine after oven cooling them to room temperature. The research showed that addition of linseed oil to plain grades 2 and 4 Nigerian gum Arabic caused property enhancements. The effects were in the form of increased tensile strength of baked cores of about 12% and reduced baking period of about 1 hour. Permeability and shatter index were marginally reduced by about 3% over cores bonded with plain gum Arabic. values were still within acceptable ranges for core applications.

Key words: Linseed oil · Gum arabic · Cores · Effects

INTRODUCTION

Linseed oil is one of the traditional materials used in foundry binder for sand cores. It belongs to the group classified as drying oils [1]. Gum Arabic is natural resin that contains arabin; a semi solidified sticky fluid that oozes from incisions made on the bark of acacia trees [2]. Gum Arabic was combined with different organic resins to produce high quality core binders for foundry uses like addition of 5% of the material to 10% sugar and protein in a gelatinous mix derived from amino acid to bind expendable cores for sand casting and combination of it with sugar, urea formaldehyde resin and boric acid to bind sand cores [3], [4]. Grade 2 Nigerian gum Arabic was used to bind foundry core specimens baked at 180-220°C for 1-3 hours and analysed for properties that proved the material suitable for different alloys [5]. Grade 4 gum Arabic proved suitable for binding expendable cores in another study in a series of researches to find extensive foundry uses for Nigerian gum Arabic [6].

Nigerian foundries including those of the integrated steel plants at Ajaokuta and Aladja depend on imported core binders like linseed oil due inadequate research on the potentials of local materials like gum Arabic that is abundant in the country [7]. A research study by Aponbiede [8] revealed that some indigenous vegetable oils are suitable for binding foundry cores but with each suffering from certain technical limitation. On this basis, this study is aimed at combining Nigerian gum Arabic with linseed oil to produce high quality core binder to ease. The objective of this paper is to mix each of grades 2 and 4 Nigerian gum Arabic exudates with quantities of imported linseed oil to bind core specimens, analyse specimens for permeability and tensile strength and compare result with standard in Table 1 [9] and previous works to ascertain property enhancement over cores made with plain single binders.

Experimental Methodology: The green permeability, shatter index and baked tensile strength of specimens bonded with different blends of each of Nigerian gum Arabic grades 2 and 4 with linseed oil were experimentally measured with a standard permeability meter, shatter machine and universal strength test machine using normal procedures of foundry laboratory. These properties critically determine ability of cores to withstand interior thermal stresses imposed on them and to enable them allow easy exit of the evolved gasses during casting for

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Table 1: Desired permeability and tensile strength property ranges of sand cores

Type of alloy castingapplications	Green Permeability (No)	Baked Tensile Strength (KN/m^2)
Class I iron/steel cores	130-150	700-1000
Class II iron/steel cores	100	500-700
Class III iron/steel cores	100	350-600
Class IV iron/steel cores	70	200-300
Class V iron/steel cores	70	80-150
Copper bronzes coresCopper brasses cores	9060	400-600500-700
Intricate Aluminium coresNon-intricate Aluminium cores	10080	500-700400-600
Magnesium cores	80	300-500

Fig. 1: Samples of green permeability test specimens showing cores bonded with grade 2 gum Arabic/linseed oil in front rows and those bonded with grade 4 gum Arabic/linseed oil in back row

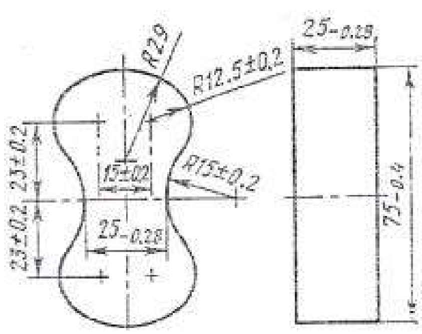

Fig. 2: Design shape of the cores for tensile strength test analysis (dimensions are all SI units).

good production control [9]. Test samples were made silica sand of BS standard size 40-72 with 0.3% clay content oven dried at 110°C to remove free water. Specimens were bonded with 3% of each of grades 2 and 4 gum Arabic admixed with varied quantities by weight (0.5-3%) of linseed. The permeability and shatter test specimens were cylindrical in shape, 2 inches diameter, 2 inches height and weighed 130g after compacting while tensile strength test specimens were shaped like figure eight shown in Figure 2 in compliance with standard foundry practice [9]. Each specimen was moulded in a split core box and compacted with three blows each weighing 6.5Kg from a height of 2 inches in a standard rammer [9]. Samples of permeability specimens as obtained from rammer before tests are as shown in Figure 1.

The tensile strength specimens were oven baked at 200°C for 1-3 hours and then oven cooled to room temperature before the tests. The permeability and shatter index specimens were made and tested in the green state. For permeability tests, a steadily and standard air pressure of 9.8x10^{2}N/m^2 was passed through specimen in sample tube placed in the meter and after 2000cm^3 of air had passed through, the permeability was instantaneously read in numbers [9]. Shatter index specimens placed in container of shatter machine were pushed upwards over the stripping post until it struck anvil, fell and shattered. The retained and over size sands were measured and then used to compute the shatter index [9]. For tensile strength, a steadily increasing tensile force was applied on specimen by the universal strength machine until failure occurred and the tensile strength read instantaneously. The test equipments were designed and calibrated by the manufacturers to instantaneously convert raw test data into numerical values of the properties measured. Results were processed into graphs as presented in Figure 3-6.

Research Experimental Results

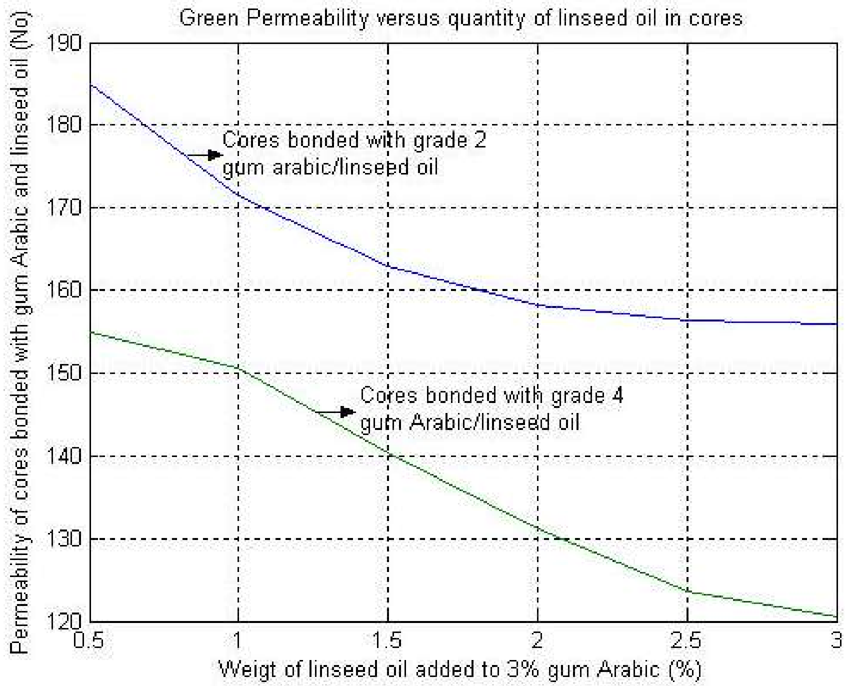

Fig. 3: Green permeability (No) of cores bonded with gum Arabic grades 2 and 4 mixed with linseed oil

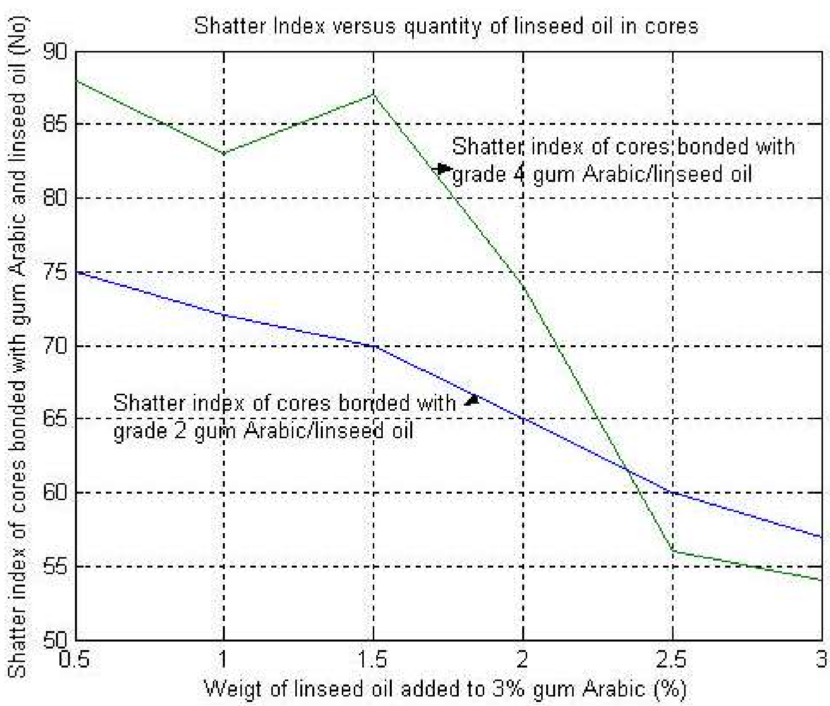

Fig. 4: Shatter index (No) of cores bonded with gum Arabic grades 2 and 4 mixed with linseed oil

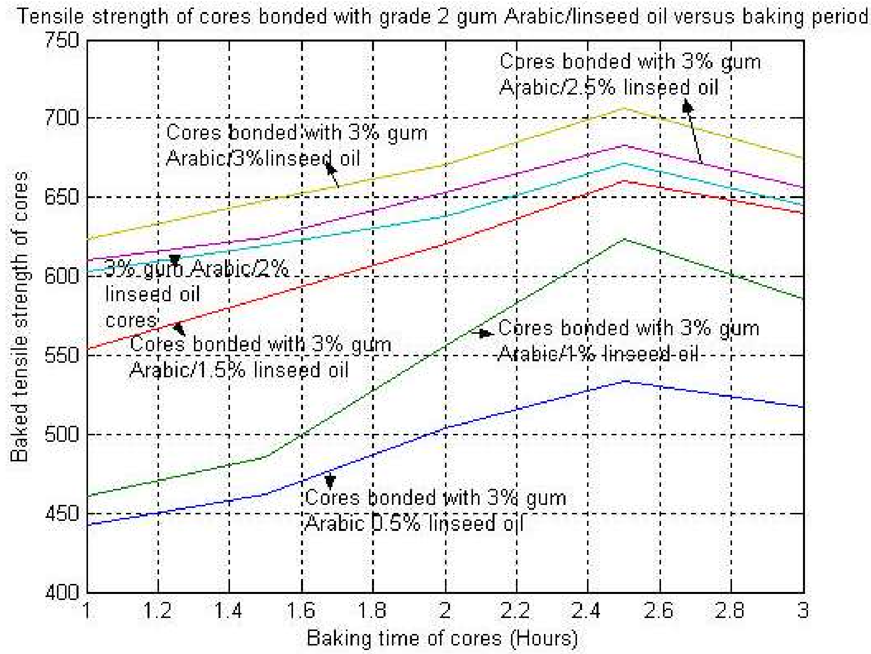

Fig. 5: Tensile strength values (KN/m²) of cores bonded with 3% gum Arabic grade 2 and varied amounts of Linseed oil baked at 200°C for varying periods in hours

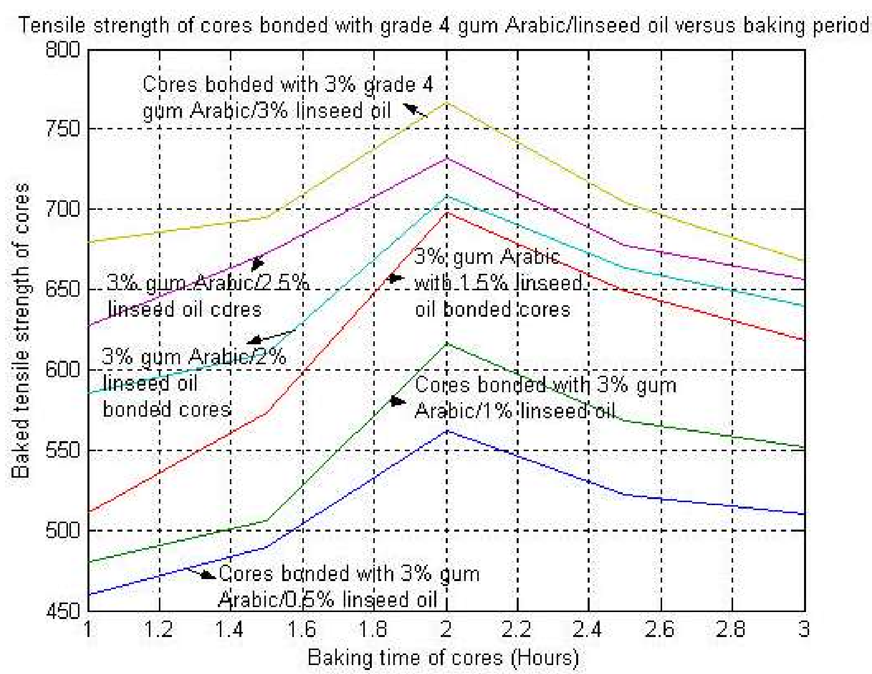

Fig. 6: Tensile strength (KN/m²) of cores bonded with grade 4 gum Arabic and varied amounts of linseed oil baked at 200°C for varying periods in hours.

Presentation of Results: The raw results generated from the research experiment were processed into graphs and are presented in figure 3-5. Figure 3 presents the result of the green permeability test. Figures 4-5 presents the result of the tensile strength test of core specimens bonded with Nigerian gum Arabic grades 2 and 4 mixed with linseed oil baked at 200°C for 1-3 hours. The baked tensile strength of the specimens measured their abilities to withstand thermal expansion stresses during pouring of molten metal and casting solidification to enable cores give the desired clean and accurate cavities in components. Permeability measured the ease with which gasses evolved during casting escape from the mould/cores assembly.

RESULTS AND DISCUSSION

The result of green permeability analysis of specimen cores bonded with Nigerian gum Arabic grades 2 and 4 mixed with linseed oil is presented in Figure 3. Permeability decreased from 185 No at 3% grade 2 gum Arabic/0.5% linseed oil to 156 No at 3% gum Arabic/3% linseed oil while it decreased from 155 to 121No for same compositional range of grade 4 gum Arabic/linseed oil. The trend shows that added linseed oil reduced permeability as it created more bonds and decreased the pores available for gas escape. Grade 2 gum Arabic/linseed oil combined binder gave higher permeability values than grade 4 gum Arabic/linseed oil. In comparison with the previous work with plain grades 2 and 4 gum Arabic bonded cores [6],[7], permeability of gum Arabic/linseed oil bonded cores are less by about 2%. The result when compared with the standard in Table 1 shows that each of the combined binder is suitable for core applications for all categories of alloy castings contained in the table.

Figure 4 presented the result of shatter index test of core specimens. Shatter index varied from 75No for 3% grade 2 gum Arabic/0.5% linseed oil to 57 No at 3% gum Arabic/3% linseed oil and from 88 to 57 No for same compositional range of grade 4 gum Arabic/linseed oil. Unlike permeability grade 4 gum Arabic/linseed oil cores had higher shatter index than grade 4 gum Arabic/linseed oil bonded cores. Shatter index results for grades 2 and 4 gum Arabic/linseed oil bonded cores are about 5% less than those obtained from plain grades 2 and 4 gum Arabic bonded cores [6],[7]. However these lower values are still suitable for different alloy castings allowed by permeability results stated above.

The result of the baked strength analyses are presented in Figures 5 and 6. Figure 5 presented result of cores specimens bonded with grade 2 gum Arabic/linseed oil baked at 200°C while Figure 6 presented that of specimens bonded with the grade 4 gum Arabic mixed with varied quantities of linseed oil and also baked at 200°C. In Figure 5 baked tensile strength varied from 440 KN/m^2 for cores bonded with 3% grade 2 gum Arabic/0.5%linseed oil baked at 200°C for one hour to 702 KN/m^2 for those bonded with 3% grade 2 gum Arabic/3% linseed oil baked at 200°C for 2.5 hours. It varied from 460 KN/m^2 to 764 KN/m^2 for grade 4 gum Arabic/linseed oil cores of same compositional range and baking temperature for 2 hours. This shows grade 4 gum Arabic/linseed oil combinations offered stronger bond strength than grade 2/linseed oil mixed binder at shorter baking period of 30 minutes difference.

The result in Figure 5 when compared with foundry standard in Table 1 shows 3% grade 2 gum Arabic with 0.5% linseed oil sand bonded cores baked at 200°C for one hour is suitable for magnesium, non-intricate aluminium, copper bronzes and classes I, II, III iron and steel castings. Cores bonded with 3% grade 2 gum Arabic mixed with 1% linseed oil baked for two hours and those bonded with 3% grade 2 gum Arabic with 1.5% linseed oil baked for one hour are suitable for intricate aluminium, copper brasses and class II iron and steel alloy castings. Increase in linseed oil content of the binder increased the baked tensile strength and also reduces the effective baking period of cores. The tensile strength of cores rapidly depreciated when baked at a period longer than two and a half hours. Therefore for process economics these cores should not be baked longer than two and a half hours.

The tensile strength result in Figure 6 in comparison with the standard in Table 1 shows that 3% grade 4 Nigerian gum Arabic with 0.5% linseed oil baked for one hour is suitable for cores for magnesium, non-intricate aluminium, copper bronzes and classes I, II, III iron and steel castings and suitable for intricate aluminium, copper brasses and class II iron and steel castings when baked for two hours. Cores bonded with 3% grade 4 gum Arabic/1% linseed oil baked for only one hour is also suitable for these applications. Similarly, cores bonded with 3% grade 4 gum Arabic mixed with 2-3% linseed oil baked for two hours is suitable for class I iron and steel casting applications. Strength decreased at above 2 hours of baking. A comparison of result in Table 4 with that in Table 5 shows that admixed binders made of grade 4 gum Arabic and linseed oil gave cores with higher tensile strength of about 10% than those bonded with grade 2 gum Arabic/linseed oil. Grade 4 gum Arabic/linseed oil mixed binder is cheaper due to shorter baking period and lower heat consumption. In comparison with 6% plain grades 2 and 4 gum Arabic bonded cores [6, 7], a combined binder made of 3% each of gum Arabic and linseed oil shows an average of 12% improvement of baked strength over the former.

CONCLUSIONS

The foregoing has shown that linseed oil has property improvement effects on cores bonded with the grades 2 and 4 gum Arabic of Nigerian origin. The effects were pronounced on the tensile strength of baked cores in the form of increased values of about 12% and reduced baking period of about 1 hour. However permeability and shatter index were marginally reduced by about 3% due to the presence of linseed oil though the values are still within the acceptable ranges for core applications.

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