BENEFICIAL EFFECTS OF THE ADDITION OF SOYA BEAN OIL ON THE TENSILE STRENGTH OF EXPENDABLE CORES BONDED WITH NIGERIAN GUM ARABIC.

BY

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ABSTRACT

Varied quantities of soya beans oil was mixed with each of the four commercial grades of Nigerian gum Arabic and used to bind foundry core sand. The cores were subjected to tensile strength tests after oven baking at 200°C for 1-3 hours to ascertain the benefits of soya beans oil presence over cores bonded with plain gum Arabic already studied in previous works [1, 2, 3, 4]. Experimental test specimens made with silica base sand were shaped like the figure number eight. A standard universal strength machine equipped with specimen attachments and meter to read tensile strength instantaneously was used in foundry laboratory of Ajaokuta Steel Company Limited, Nigeria. The research result showed that soya beans oil addition to gum Arabic bonded cores has beneficial effects on cores bonded with grades 1, 2 and 3 Nigerian gum Arabic as it improved tensile strength by averages of 10%, 7%, and ±2% respectively. It however depressed the tensile strength of grade 4 gum Arabic bonded cores by 2-6% depending on baking duration.

KEY WORDS: Soya beans, oil, tensile strength, foundry cores.

1.0 INTRODUCTION

This paper is one of a series aimed at exploiting the full foundry application potentials of Nigerian gum Arabic with or without additives as binders. Each of four commercial grades of the material produced in Nigeria was studied as plain core binder. The finding showed difficulty in cores easily attaining very high tensile strengths required for intricate iron and steel castings as typical of this group of organic binders [1, 2, 3 and 4]. The popular core binders in most modern foundries that easily attain such high tensile strengths usually make use of very robust self setting methods. They include such instantaneous hardening techniques like fast curing with gaseous and catalytic agents. Most of these current organic binders are predominantly based around phenol formaldehyde resins. They offer exceptional performance in respect of process robustness, easy breakdown and removal of core sand after casting but are however very toxic to humans and environmentally unfriendly.

They contain corrosive acids and volatile organic compounds whose thermal breakdown products give out very foul and pungent odours and waste streams that are hazardous to user health [5]. Moreover the binders are too sophisticated and expensive for foundries in developing countries with abundant natural raw materials but without needed advanced technologies for proper use of such resources. Soya bean oil is drying oil that is cheaply available in these foundries like Nigeria but due to its low iodine value of 125No and rigorous chemical test procedures, most core binder manufacturers do not favour it as a universal vegetable oil binder like linseed, tung, perrila, oiticica and fish oils. These are all well researched products of developed countries with sophisticated foundries [6, 7]. Soya bean (glycine max) is a leguminous food crop produced in Nigeria and other major gum Arabic producer countries. It is an important source of high quality and inexpensive oil with an average oil content of 20%. It is next only to groundnut in terms of oil yield among food legumes, accounting for roughly 50% of total seed oil production worldwide [6].

The urgent need for the development of easy core production processes using low cost indigenous materials as alternatives to the costly binders forms the aim of the research series a part of which is this study. The objective is to mix varied quantities of soya bean oil with each of four commercial grades of Nigerian gum Arabic, use it to bind foundry core sand, test cores for tensile strength and compare result with strength of plain gum Arabic bonded cores to ascertain any beneficial effects of soya bean oil addition. Tensile strength was considered as determinant variable because it is the most critical of all core properties. Suitable cores always give acceptable permeability and shatter index values for especially organic resin bonded cores as the sand is porous enough and readily collapses after casting. The significance of the research is that it will contribute to present state of knowledge on use of soya bean oil as property enhancing additive to gum Arabic core binder.

EXPERIMENTAL PROCEDURES

Material Sourcing and Preparation:-The research raw materials are purified water; silica sand with 0.3% clay that was pre-washed and oven dried at 110°C. It was classified with BS sieve of size range 40-72 mesh [8]. The refined soya bean oil was purchased from a supermarket in Ajaokuta. About 100 gram of each of four commercial grades of pre-sorted Nigerian gum Arabic exudates was sourced from Sokoto, Bauchi and Yobe States of Nigeria respectively. Gum Arabic is composed of polysaccharides [9]. Soya beans contain unsaturated fatty acids like oleic, linoleic, stearic and palmitic acids as the active ingredients [7]. Tensile strength test was adopted because as interior implants within mould cavities cores are usually subjected to severe thermal conditions. Thus they are prone to high temperature induced failures that can in turn cause casting defects [8]. Their values are most critical as they give indirect information on other salient properties of cores.

Commensurate quantities of sand, each grade of the gum Arabic exudates; soya bean oil and water were measured using digital scale, mixed in roller mill for 10 minutes and moulded into test cores. The specimens were shaped like figure number eight dimensioned as shown in figure 1 [10]. Each gum Arabic was decontaminated and powdered to BS sieve size of 20-50 mesh before it was added to sand mix. Test cores were bonded with mixtures of 3% of each of grade of Nigerian gum Arabic and 0.5-3% varied weights of soya bean oil. Each specimen was moulded in a split core box and compacted with three blows each weighing 6.5Kg from a height of 50mm in a standard rammer in compliance with AFS standard [8]. They were then oven baked at 200°C for 1-3 hours and oven cooled to room temperature before testing.

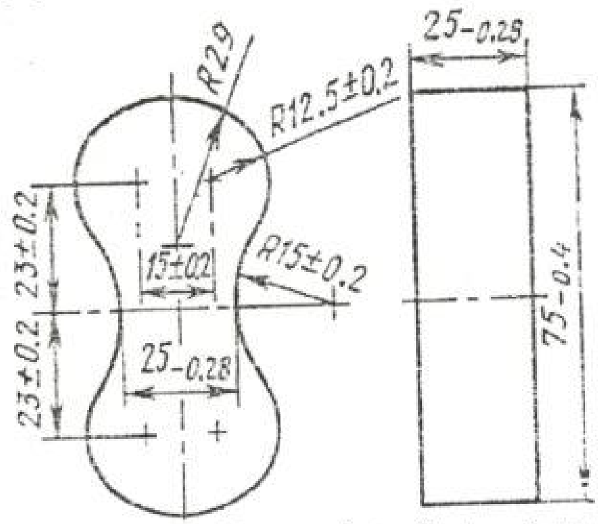

Figure 1: Design of the cores for tensile strength test analysis (dimensions are in millimetres).

2.2 Specimen test: - A standard universal strength machine equipped with specimen gripping attachments and an instantaneous strength reading meter was used to conduct test. Each specimen was gripped with attachment of testing machine and a steadily increasing tensile force was applied on it until failure occurred and the strength was read instantaneously.

2.3 Experimental data processing:-The raw results obtained were tabulated, processed into graphical plots, analysed and compared with the standard foundry test data in table 1 and previous works [1, 2, 3 and 4] to draw useful conclusions for the research.

Type of alloy casting applications	Baked Tensile Strength (KN/m^2)
Class I iron/steel cores	700-1000
Class II iron/steel cores	500-700
Class III iron/steel cores	350-600
Class IV iron/steel cores	200-300
Class V iron/steel cores	80-150
Copper bronzes cores Copper brasses cores	400-600 500-700
Intricate Aluminium cores Non-intricate Aluminium cores	500-700 400-600
Magnesium cores	300-500

RESULTS AND DISCUSSIONS

3.1 The results are as presented in figure 2-6. Figure 2 presents result of cores bonded with 3% grade 1 gum Arabic and 0.5-3% soya bean oil baked at 180°C for 1-3 hours. Figure 3 presents result for cores bonded with 3% grade 1 gum Arabic and 0.5-3% soya bean oil; figure 4 is that for cores bonded with 3% grade 2 gum Arabic and 0.5-3% soya bean oil; figure 5 is that for cores bonded with 3% grade 3 gum Arabic and 0.5-3% soya bean oil. Figure 6 presents that for cores bonded with 3% grade 4 gum Arabic and 0.5-3% soya bean oil; all baked at 200°C for 1-3 hours.

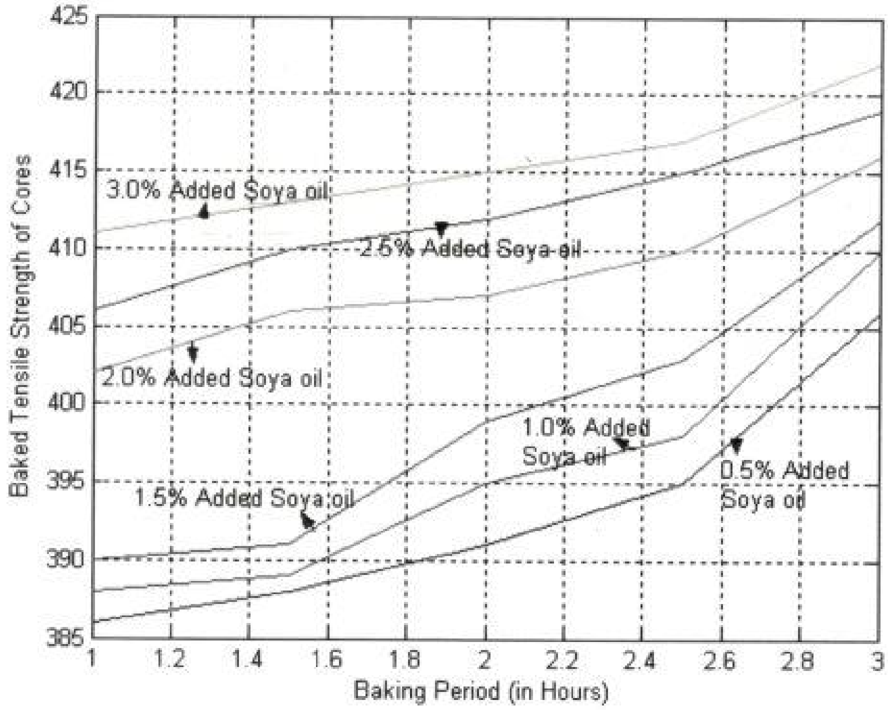

Figure 2: Tensile strength (in KN/m²) of cores bonded of 3% grade 1 gum Arabic mixed with 0.5-3.0% refined Soya bean oil baked at 180°C for 1-3 hours.

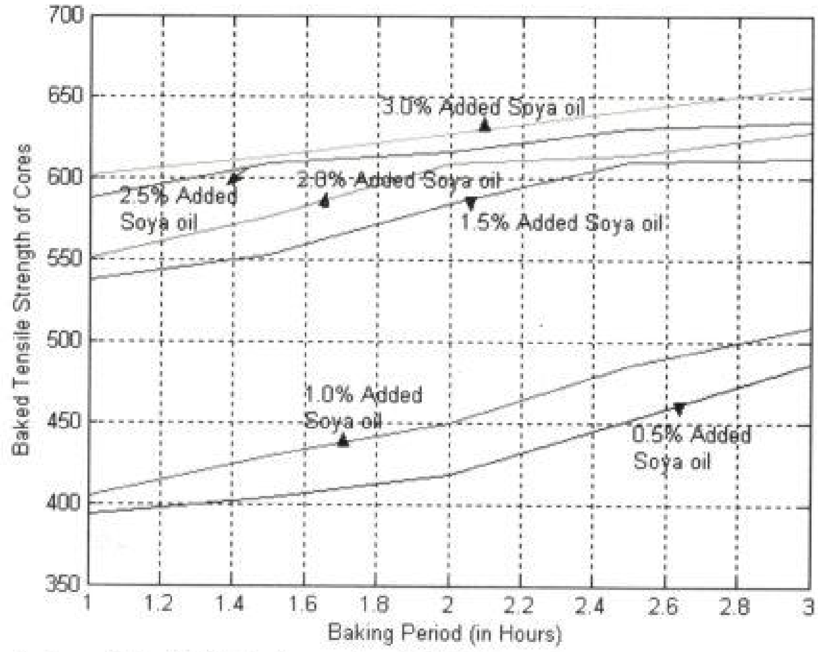

Figure 3: Tensile strength (in KN/m²) of cores bonded of 3% grade 1 gum Arabic mixed with 0.5-3.0% refined Soya bean oil baked at 200°C for 1-3 hours.

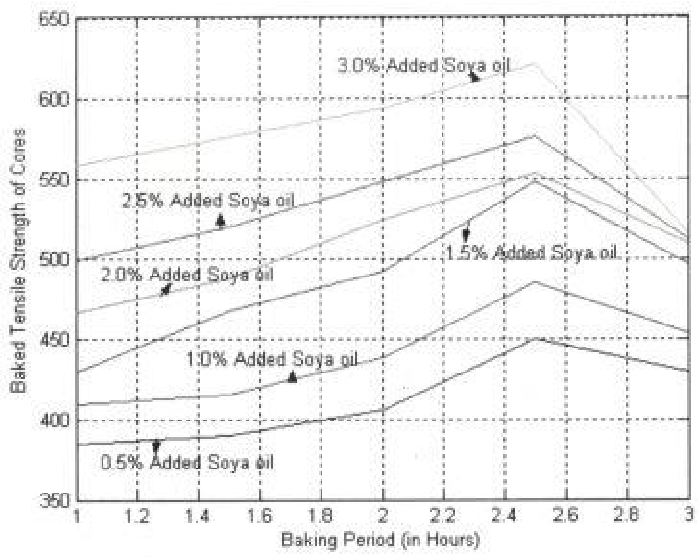

Figure 4: Tensile strength (in KN/m^2) of cores bonded of 3% grade 2 gum Arabic mixed with 0.5-3.0% refined Soya bean oil baked at 200^{0}C for 1-3 hours

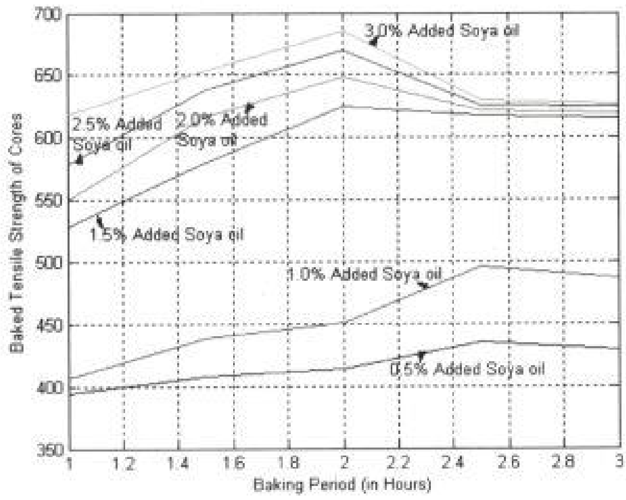

Figure 5: Tensile strength (in KN/m^2) of cores bonded of 3% grade 3 gum Arabic mixed with 0.5-3.0% refined Soya bean oil baked at 200^{0}C for 1-3 hours.

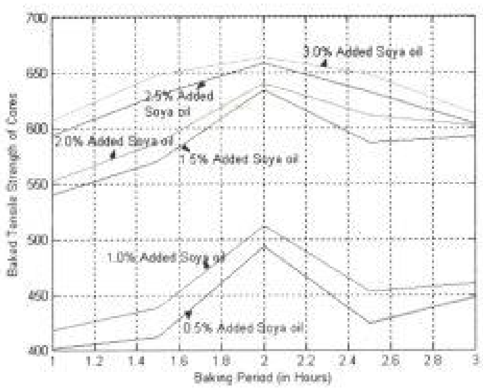

Figure 6: Tensile strength (in KN/m^2) of cores bonded of 3% grade 4 gum Arabic mixed with 0.5-3.0% refined

Soya bean oil baked at 200°C for 1-3 hours.

3.2 Discussion of Results

Tensile strength in figure 2 increased with soya bean oil and baking time. Longer holding of cores at baking temperature enabled sand and binder molecules to acquire higher reaction energy needed for stronger bond. Increasing soya bean oil provided more binder molecules to react with more sand for better bond. Tensile strength continuously increased as baking temperature was below the melting point (210°C) of gum Arabic grade 1 [9] above which burning of some the molecules and weakening of strength could occur. Temperature wasn't enough to cause vaporization of soya oil. Gum Arabic is insoluble in organic solvents like vegetable oil. The soya bean oil and gum Arabic independently reacted with sand as they couldn't react into a composite binder before reaction with sand. The result as compared with table 1 shows cores bonded with 3% grade 1 gum Arabic with 0.5% soya bean oil; baked at 180°C for 1hour is suitable for magnesium and class III-IV iron and steel. Sand cores bonded with mixtures of 3% grade 1 gum Arabic and 2-3% soya bean oil; baked for 1 hour is suitable for copper bronze and non-intricate aluminium casting. When compared with previous work that bonded foundry cores with plain grade 1 gum Arabic under similar conditions [1]soya oil didn't cause much change in core strength, because as gum Arabic wasn't melted at baking temperature its full bond forming potential with sand was not realizable. Moreover the non reactive soya oil shielded away some sand particles from contact and reaction with gum Arabic.

In figure 3, tensile strength increased with soya oil content and baking period as explained above. In comparison with foundry standard in table 1, it shows that sand bonded with 3% grade 1 gum Arabic and 0.5% soya oil baked at 200°C for 1½ hours is suitable for class III-IV iron/steel, copper bronze, non-intricate aluminium and magnesium cores. Sand bonded with 3% gum Arabic and 1½-3% soya bean oil baked for an hour is suitable for class II iron/steel, brass and intricate aluminium cores. Tensile strength of cores baked at 200°C in figure 3 is generally higher than that in figure 2 for cores bonded with similar mix baked at 180°C because of higher molecular mobility caused by higher heat/reaction energy available to both sand and binder. Tensile strength was improved by an average of 10% over that of plain gum Arabic grade 1 bonded core [1] baked at similar conditions. Apart from the reactions being facilitated by the elevated baking temperature the presence of oleic, linoleic and stearic acids in soya oil brought in the associated double bonded diradicals which are more reactive with sand than dense polysaccharides of gum Arabic. The diradicals form peroxides, polyperoxides and hydroperoxides with sand to form fast strong bonds.

Result in figure 4 followed similar trend to figures 2 and 3. Tensile strength increased with soya oil and baking time but dropped at 2½ hours of baking because of preliminary vaporization and charring of some soya oil and gum Arabic after melting and holding for excessive baking time. Grade 2 Nigerian gum Arabic melts at about 200°C, coinciding with baking temperature at which as a class 3 binder it became very reactive and caused strong bonding of cores on cooling to room temperature. Unsaturated fatty acids of soya oil in mixed binder acquired heat energy that enabled sand oxygen to attack the diradicals to form more stable stronger bonded polymerised molecules. Using foundry standard in table 1 to the measure suitability of each binder, it is observed that sand bonded with 3% grade 2 gum Arabic and 1% soya oil baked for 1-1½ hours is suitable for suitable for class III-IV iron/steel, copper bronzes, magnesium and non-intricate aluminium cores. Sand bonded with 3% gum Arabic grade 2 and 2-3% soya oil baked for 2 hours is suitable for class II iron/steel; brass and intricate aluminium cores. At similar binder compositions, cores bonded with plain grade 2 Nigerian gum Arabic this result shows 5-9% tensile strength increase [2].

In figure 5 tensile strength increased with increasing soya bean oil content and baking temperature but drooped at 2.and 2½ hours of baking at selected binder compositions. This was due to charring and vaporization of some of the two constituents of combined mixed binder. The 200°C was about 10°C above its melting point [9]. When compared with foundry standard in table 1; mixed binders of 3% grade 3 gum Arabic and 0.5% soya bean oil baked at 200°C for 1hour are suitable for copper bronzes; non-intricate aluminium, magnesium and class III-V iron and steel cores. Sands bonded with 3% gum Arabic grade 3 and 1½-3% soya oil baked for an hour are suitable for class II iron and steel; copper brasses and intricate aluminium cores. In comparison with previous work with plain Nigerian gum Arabic grade 3 under similar conditions [3] the soya bean oil addition increased/decreased tensile strength by an average of about ±2%.

Baked tensile strength in figure 6 rose with increasing soya oil content and baking temperature but dropped drastically at 2.0 hours of baking like figure 5 for similar reason. The cores were baked at over 20°C above the melting point of grade 4 gum Arabic [9]; more binder was burnt due to over baking. The result when compared with table 1 shows that a mixed binder of 3% gum Arabic grade 4 and 0.5% soya oil baked at 200°C for 1hour is suitable for class III-V iron/steel, copper bronzes, non-intricate aluminium and magnesium cores while that of 3% Nigerian gum Arabic grade 4 and 1½-3% soya oil baked for an hour is suitable for class II iron and steel; copper brasses and intricate aluminium cores. It showed 2-6% decrease in baked tensile strength of cores over for cores bonded with plain gum Arabic grade 4 in a previous study [4]. A cross comparison of figures 2, 3, 4, 5 and 6 shows that soya oil addition was most beneficial with grade 1, followed by grade 2 then grade 3 Nigerian gum Arabic but depressed the strength of grade 4 gum Arabic bonded cores. Soya bean oil gave less improvement in tensile strength than linseed and neem oils that improved strength by about 12% and 7% respectively when added to Nigerian gum Arabic for core applications [11, 12].

4 CONCLUSIONS

Soya bean oil addition to plain Nigerian gum Arabic as mixed binder for foundry core is beneficial as it causes improvement of tensile strength. However this improvement is very sensitive to baking temperature and time such that depression of strength occurs if cores are baked at more than $10^{0}C$ above melting point of a particular grade of the material and baking duration exceeds two hours.

REFERENCES

1 Ademoh N.A and Abdullahi A.T (2009):-"The use of grade 1 gum Arabic (acacia species) exudate for expendable sand core production in foundry". Nigerian Journal of Engineering, Faculty of Engineering, ABU, Zaria. Vol. 16 (1), Pp. 53 - 59. ISSN 0794-4756.

2 Ademoh N.A and Abdullahi A.T (2009):- "Assessment of efficacy of grade 2 Nigerian acacia species exudates for binding foundry sand cores". Nigerian Journal of Engineering, Faculty of Engineering, ABU, Zaria. Vol. 15 (2), Pp. 1212-126. ISSN 0794-4756.

3 Ademoh N.A and Abdullahi A.T (2010):- "Evaluation of the effective baking conation for grade 3 Nigerian Acacia species bonded foundry sand cores". Research Journal of Applied Science and Engineering Technology. Maxwell Science Organization Publications. Vol. 2 (5), Pp. 504 - 507. ISSN 2040 – 7467

4 Ademoh N.A and Abdullahi A.T (2008) "Evaluation of the mechanical properties of expendable foundry sand cores bonded with Nigerian gum Arabic grade 4". Middle East Journal of Scientific Research, IDOSI Publications. Vol. 3 no 3, Pp. 126-133.

5 Busby A.D (1992)-"Phenolic ester process-the past, present and future", The American Foundry men's Society Congress, Chicago, AFS Transactions 93-172. Pp. 621-633

6 http://www.nigeriaembassychina.com/eco/PRODUCE%200F%20NIGERIA.htm(2007):- Produce of Nigeria

7 Aponbiede O (2000):- "Development of oil cores using local vegetable oils". Ph. D degree dissertation in Metallurgical Engineering, ABU Zaria, Nigeria. Pp 6-17.

8 American Foundry Men Society (1989)- "Mould and Core test Handbook". 2nd Edition Procedure 113. Pp 74-78.

9 Ademoh N A & Abdullahi A T (2008)[b] - Determination of physico-chemical properties of Nigerian acacia species for binding foundry sand. Research Journal of Applied Science, Engineering and Technology. © Maxwell Scientific Organization Publications. Vol. 1 (3): Pp. 107 - 111. ISSN: 2040 - 7467

10 Titov N.D & Stepanov Y.U (1982)-"Foundry practice". Translated by Ivanov P.S. Mir Publishers, Moscow. Pp. 49 - 101.

11 Ademoh N A (2009)[a]:-"Establishment of the beneficial effects of addition of linseed oil to foundry sand cores bonded with Nigerian gum Arabic grades 2 and 4". American-Eurasian Journal of Scientific Research. IDOSI Publications, Vol.4 (2), ISSN 1818-6785.Pp.97-102

12 Ademoh N A (2008)[c]:-"Evaluation of the tensile strength of foundry sand cores made with hybridized binder composed of neem oil and Nigerian gum Arabic". International Journal of Physical Sciences. nalhttp://www.academicjours.org/IJPS. Vol. 5 (5). Pp. 557 - 563 ISSN 1992 – 1950.