

TENSILE STRENGTH COMPARISON OF FOUNDRY SAND CORES BONDED WITH DIFFERENT GRADES OF NIGERIAN GUM ARABIC EXUDATES.

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ABSTRACT

The empirical tensile strength values of baked sand cores bonded with each of the four commercial grades of exudates of Nigerian gum Arabic (acacia species) were experimentally measured using established standard procedures in foundry industry. The experimental test specimens which were shaped like the number 8 were made from silica sand bonded with different grades of gum Arabic exudates. The specimens were classified, oven baked at 160⁰C, 200⁰C, 220⁰C and 250⁰C for periods of 1-3 hours, oven cooled and then subjected to strength tests using a standard universal strength machine in foundry shop of Ajaokuta Steel Company Limited, Nigeria. The research result showed that expendable foundry sand cores bonded with Nigerian gum Arabic baked at 160⁰C for 1-3 hours didn't reach optimum strength. Grades 1 and 2 acacia bonded cores gave peak tensile strength when baked at 200⁰C. Those bonded with grades 3 and 4 gum Arabic gave optimum tensile strength when baked at 220⁰C. At 250⁰C, cores were observed to burn and loose strength. For process economics gum Arabic grade 4 is best for foundry core application as it was cheapest in price and cores bonded with it attained required tensile strength at least baking temperature within the shortest baking time. This was followed by gum Arabic grade 3, grade 1 and gum Arabic grade 2 in that order.

KEY WORDS: Foundry, cores, oven, baked, tensile, strength.

INTRODUCTION

Gum Arabic exudate is the natural resin that exudes from the bark of a species of trees called acacia species. It is a semi solidified sticky fluid that contains arabin [1]. Nigeria produces grade 1 (acacia Senegal), grade 2 (acacia seyal), grade 3 (combretum) and neutral grade in commercial quantities [2]. Gum Arabic (5%) was added to 10% sugar and protein in gelatinous mix derived from amino acid to bind expendable foundry cores for casting in USA. It is used in the hot box core process of core production in United Kingdom [3]. It was combined with sugar, urea formaldehyde resin and boric acid to bind cores for sand casting [4]. This paper is one of the series aimed at finding foundry application for Nigerian gum Arabic especially as one of the solutions to problems facing foundries in Nigeria that has depended on imported sand binders [5].

Ademoh and Abdullahi [6, 7, 8, and 9] in their work with various grades of Nigerian gum Arabic as binders for foundry sand moulds found the four commercial grades suitable for casting different alloys at defined compositions. The aim of this paper is to compare tensile strength of sand cores bonded with each grade of Nigerian gum Arabic exudates as sole core binder in order to establish their hierarchy of performances and foundry usability. The main objectives are to produce foundry sand cores oven baked at 160⁰C, 200⁰C, 220⁰C and 250⁰C for different periods, later subject them to tensile test and compare the result of specimens bonded with each acacia exudates. The work differs from previous ones in that it mainly compares variation in tensile strength of expendable foundry cores bonded with different

Nigerian acacia grades so as to draw up conclusions on the acacia grade and baking conditions that are most suitable for particular alloy casting.

MATERIALS AND METHOD

Materials:-The materials used for the research experiment included silica sand with a predetermined clay content of 0.3%, quantities of each of four commercial grades of gum Arabic exudates produced in Nigeria, paper desiccators and tap water. The research equipment included mechanically vibrated sieve, a standard universal strength testing machine, an electrically powered baking oven, milling machine, foundry sand mixer, split wooden core box and sand rammer.

Method:-The tensile strength is the most vital property of a core as it determines its ability to withstand thermal stresses imposed by hot molten metal during casting solidification [10]. This property was measured on specimens made up of silica sand bonded with 3% moisture and 8% of each grade of Nigerian gum Arabic exudates. The silica sand was classified with BS standard sieve and quantities of it in the range of grain size 40-72 mesh was separated out for production of the core specimen. The sand was first of all dried in the oven at 110⁰C to remove free water. The gum Arabic exudates were milled to the smallest possible grain size to enable even particle distribution in sand mix. The sand and quantities of each gum Arabic exudate grade were mixed in a roller for 10 minutes before moulding to specimen. The core test specimens were in accordance with standard foundry practice shaped like number 8 as shown in figure 1 [10]. The sand and gum Arabic were compacted into specimens in a split core box with a standard rammer with three blows weighing 6.5Kg from a height of 50mm. After oven baking specimens at 160⁰C, 200⁰C, 220⁰C and 250⁰C for period of 1-3 hours, they were oven cooled and tested with standard universal strength equipped with attachment to grip specimen as shaped and a meter that reads instantaneous tensile strength. A steadily increasing tensile force was applied on tensile specimen by universal strength machine until failure occurred. The instantaneous tensile strength was then read and recorded accordingly.

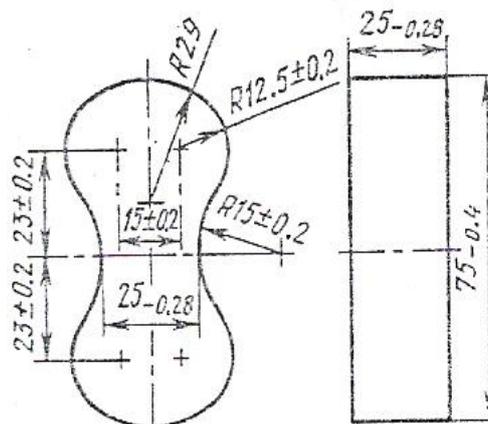


Figure 1: Design shape of the core tensile strength test specimen (all dimensions are in millimetres).

EXPERIMENTAL RESULTS

The results are as presented in figure 2-5. Figure 2 presents result of cores bonded with gum Arabic grades 1, 2, 3 and 4 baked at 160⁰C for 1-3 hours. Figure 3 presents the result of specimens baked at 200⁰C; figure 4 presents those baked at 220⁰C, and figure 5, those baked at 250⁰C for 1-3 hours.

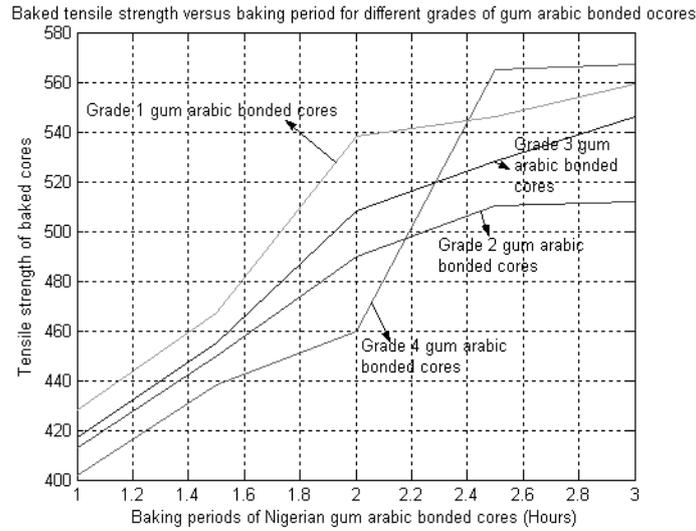


Figure 2: Result of the tensile strength analysis (in KN/m²) of Nigerian gum Arabic bonded cores baked at 160⁰C for varying periods of 1-3 hours.

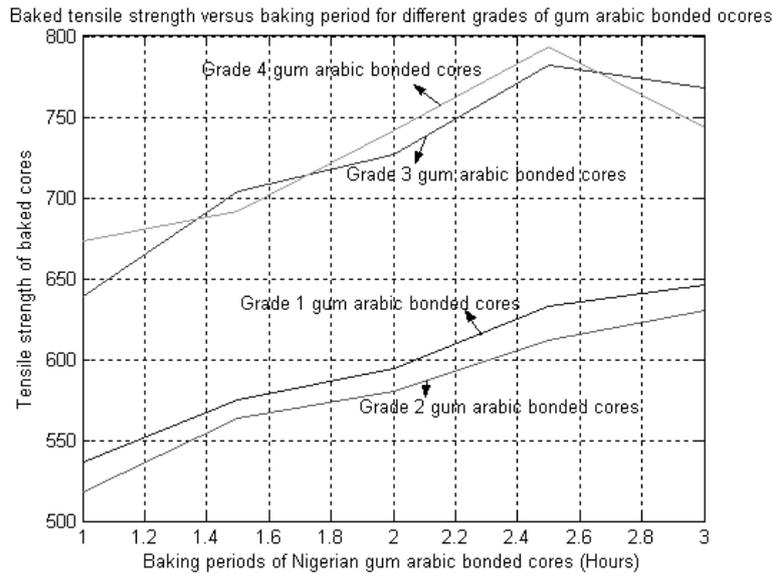


Figure 3: Result of the tensile strength analysis (in KN/m²) of Nigerian gum Arabic bonded cores baked at 200⁰C for varying periods of 1-3 hours.

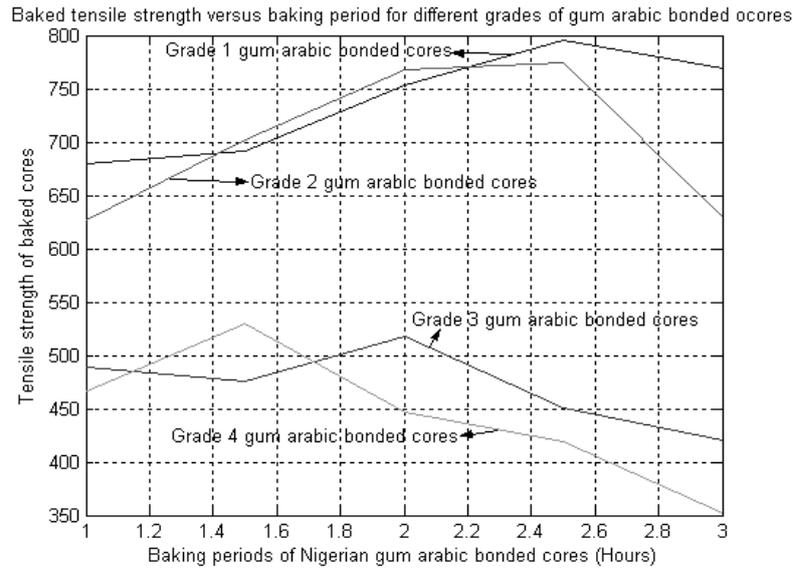


Figure 4: Result of the tensile strength analysis (in KN/m²) of Nigerian gum Arabic bonded cores baked at 220⁰C for varying periods of 1-3 hours.

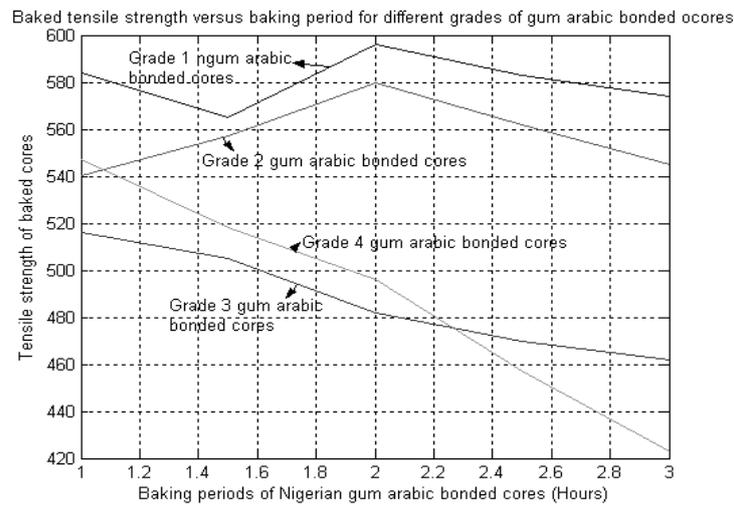


Figure 5: Result of the tensile strength analysis (in KN/m²) of Nigerian gum Arabic bonded cores baked at 250⁰C for varying periods of 1-3 hours.

DISCUSSION OF RESULTS

The result of cores baked at 160⁰C in figure 2 shows that tensile strength progressively increased with baking temperature for each gum Arabic grade. This is because as a class 3 core binder it melts at elevated temperature to bind sand and cools to form a strong bond. At 160⁰C no grade attained melting point at which this property is fully displayed, accounting for continuous increase in tensile strength as the peak strength wasn't attained. Strength increased with baking time as longer soaking allowed cores more time to energise for better reaction. The melting point of Nigerian gum Arabic was determined in a previous work [8] as 200-210⁰C, 190-194⁰C, 184-188⁰C and 178-182 for the grades 1, 2, 3 and 4 acacia respectively. The baked tensile strength follows a trend of proximity of baking temperature to melting point of each acacia grade due to higher fluidity that lead to faster molecular mobility and chemical reactivity. At every hour of baking grade 4 gum Arabic bonded cores had the highest strength followed by those of grade 3, grade 1 and grade 2. This shows a trend of usability. However

strength of gum Arabic grade 2 bonded cores was overtaken by with grade 1 bonded cores due to overriding factors like chemical reactivity, adhesivity and water solubility.

The result of cores baked at 200⁰C for 1-3 hours is as in figure 3. The curve of tensile strength for grades 3 and 4 gum Arabic bonded cores increased with baking period up to 2.5 hours at which it sloped. Curves for grades 1 and 2 bonded cores continuously increased with baking time without reaching its peak. These are explained by the fact that 200⁰C is about 20⁰C, 12⁰C and 6⁰C above the melting points of grades 4, 3 and 2 gum Arabic and 5⁰C below melting point of gum Arabic grade 3 respectively. Thus grades 3 and 4 attained peak tensile strength at 2.5 hours of baking while grades 2 and 1 gum Arabic bonded cores didn't reach optimum strength. Cores reached optimum strength at 200⁰C imply lower production costs than those that didn't in terms of the needed heat energy. Comparatively tensile strength of 8% acacia grade 1 bonded cores are about 3.7% higher than those of grade 2; 7.8% and 8% lower than those of grades 3 and 4 respectively after 2.5 hours of baking.

Figure 4 presented result of cores baked at 220⁰C. Due to excess heat grades 3 and 4 acacia bonded cores (40⁰C-32⁰C above melting range) strength decreased as some binder got burnt with increased soaking. Grades 2 and 1 gum Arabic bonded cores acquired sufficient heat to display their optimum binding properties as strength climaxed at 2.5 hours. Grade 1 bonded cores gave highest strength followed by grade 2, grade 3 and then grade 4. Tensile strength of grade 1 bonded core was about 2%, 40% and 45% higher than those of grades 2, 3 and 4 respectively, meaning order of suitability. In figure 5 for cores baked at 250⁰C, grades 4 and 3 acacia bonded cores decreased in strength after soaking for one hour, those of grade 1 increased up to 2 hours of soaking and grade 2 acacia bonded cores increased up to 1.5 hours and thereafter sloped. All the cores gave strengths much lower than figure 4 because of burning of binders suggesting that this category of cores should not be baked at or above 250⁰C. In a previous work [8], grade 1 acacia was shown to be most expensive followed by grade 2, grade 3 and then grade 4. A consideration of the costs of baking at 200⁰C and purchase shows that grade 4 acacia is most economical followed by grade 3, grade 1 and then grade 2.

CONCLUSIONS

The research showed that expendable foundry sand cores bonded with Nigerian gum Arabic baked at 160⁰C didn't give optimum tensile strength. Grades 1 and 2 acacia bonded cores gave optimum strength when baked at 200⁰C and those of grade 3 and 4 give optimum tensile strength when baked at 220⁰C. For economics grade 4 gum Arabic is best followed by grade 3 grade 1 and then grade 2.

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