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Full Length Research Paper

Characterisation of the core-binding properties of fatty - based oils

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Core-binding properties of beniseed and melon oils are hereby characterised with a view to finding alternatives to the imported foundry core oils that deplete Nigeria's foreign exchange. Clay and sand samples collected from Niger and Plateau states respectively were blended with varying proportions of core-oils in order to assess their functional properties. Baked strength of 3,223.41 kNm^{-2} obtained for the oils suggest that the oil samples can be used as substitute for imported core oil. On the basis of ranking according to functional properties, beniseed oil was found to possess more desirable functional properties in terms of bulk density, strength and collapsibility. Practical applications of these core oils reveal that they are suitable for castings of large, medium and small sizes.

Key words: Castings, cavity, collapsibility, fatty-based core oils, permeability.

INTRODUCTION

Sand cores are commonly employed, in foundry practice, to form complicated cavities in castings. Apart from being handled as separate entity in dry state during mould assembling, delicate and often complex sand cores are subjected to high stress during pouring due to hydrostatic pressure exerted by the molten metal. Therefore, cores must be able to sustain the hydrostatic pressure of the liquid metal without breakage or change in geometric configuration. This implies that possession of sufficient strength in dry state after baking or curing is very important. In addition, cores are also expected to break easily (collapsibility) during shake out in order to release sand mass out of the inner and hidden cavities of solidified casting. Fumes and gases evolved during pouring must again be easily conveyed out via the core through the mould to avoid the formation of gas cavities in the casting. However, it is difficult to obtain natural sand that possess these properties, thus, sand cores are synthetically prepared by the combination of many ingredients such as sand grains, core binders and special additives.

Meanwhile, construction of efficient sand cores for castings demands enormous consumption of resources and significant manufacturing costs. Therefore, an efficient core binder, sourced locally in a developing economy such as Nigeria, represents a major advancement in obtaining sand cores of desirable performance and high strength in reducing the cost of production of castings. Core oils, synthetic resin, clays and cereal binders had been identified by Gilson (1993), Beeley (2001) and Jain (2003), as widely used core binders. It worths noting that each of these core binders has its merit and limitations. For example, clay binders are cheap, facile and convenient for core-making, but, they are rarely used because of their low bonding strength and poor permeability. Synthetic resins have high strength and good moisture resistance but their high cost, high gas forming capacity and non-recycling feature restrict their widespread applications in foundry practice. Fatty-based core-oils belong to the organic category.

According to Mikhailov (1989), fatty-based oils are combustible and can be destroyed by heat, thereby contributing some degree of collapsibility to the core mixture. Heine et al. (1976) discovered that core oils are used in many core sand mixes in an amount of 0.5 to 3% by weight depending on the fineness required of the core. Mathew and Wainko (1983) reported that cottonseed and soya beans oil were unsuitable as binders for heavy casting because the two oils produce fast collapsing cores. When the cotton seed oil was added to the clay – bonded core sand and baked at a temperature of 200°C, the tensile strength and hardness optimum values in-

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creased with oil content. Meanwhile, a search through the literature on locally available core oils in Nigeria indicates that an extensive investigation of these groups of foundry materials has not been carried out.

Therefore, this study was undertaken to investigate the functional properties of the locally available fatty based oils and to test for their suitability as core binders. These oils are cheap and abundantly available all over Nigeria and if found suitable, their use can practically lower the production cost of castings.

MATERIALS AND METHODS

The consumables used for this study included clay, sand, wheat cereal (*alikama*), water, beniseed oil and melon oil. The clay and sand were collected from Chanchaga clay depot Chanchaga, Niger state and Kowa, Plateau states of Nigeria respectively. *Alikama* cereal binders were collected and prepared into gelatinized form while beniseed and melon oils were extracted from beniseed and melon respectively (Ibitoye and Afonja, 1996).

Sand samples were collected from ten different points and were mixed thoroughly, washed and allowed to dry. A representative sample of the dried sand was taken by the cone and quartering sampling method for experimentation as described by AFS Mould and Core Test Handbook (1963). It was sieved through sieve aperture 1.40 mm. The dried sand samples were weighed and placed in a mixing container where a known quantity of clay, water, wheat and core oil was added. A fairly homogenous mixture was obtained by mulling the mixtures. Core-sand mixtures (sand, clay, wheat, water) containing either beniseed or melon oil in varying proportions were prepared.

Five different mixes containing 1, 1.5, 2, 2.5 and 3% of beniseed or melon oils were prepared. The mixes comprises of 6% clay, 5% water and 3% cereal binder (*alikama*). The proportion of sand in each of the mixture is 85, 84.5, 84, 83.5 and 83% for 1, 1.5, 2, 2.5 and 3% core oil binders respectively. Each of the mixture weighed 800 g and then further sub-divided into five portions of 160 g each. By means of universal sand tester and using AFS standard procedure, five of the prepared specimens were tested for green permeability, Green Compression Strength (GCS), Green Shear Strength (GSS), Baked Compression Strength (BCS) and bulk density (AFS Mould and Core Test Handbook, 1963). The various tests utilized the Ø50 mm X 50 mm cylindrical AFS specimen prepared by subjecting a weighed quantity of sand core mixes to three blows adjusted to produce a close tolerance specimen, which was expelled from the tube on a striping post. Freshly made specimens were used for green properties testing such as green permeability, compression and shear strength. To determine the baked compression strength, specimens were baked for 200˚C at 2 h (Mathew and Wainko, 1983). The whole of these procedures were repeated, five times, for mixes containing varying amounts of melon oil as core binder. The baked collapsibility was determined by loading standard AFS specimens into the collapsibility testing machine with an in-built furnace heated to 600 oC by soaking at that temperature for about eight minutes (AFS Mould and Core Test Handbook 1963). Thereafter, time taken to rupture was recorded.

In order to assess the practical applications of the local core oils under investigation, three bushings made in large, medium and small sizes were cast in an aluminium alloy as described in Olakanmi (2001). Core sand mixes consisting of 2% of each of melon and beniseed core oils, 6% clay, 5% water, 3% cereal binder (*alikama*) and 84% sand were baked in an oven at a temperature of 200° C for 2 h according to AFS standard procedure (AFS Mould and Core Test Handbook, 1963). Functional properties of the baked cores (of varying sizes) were assessed. The baked cores of varying sizes were then placed into the core cavities with the core prints enabling the cores to be positioned properly in the moulds as described in Jain (1986). Molten aluminium alloy melted in a 5 kg capacity crucible (pot) furnace at a temperature of 700℃ was poured into the readily prepared sand mould cavities (Jain, 1986). After casting was allowed to solidify, the mould was knocked out and the cavity of the casting was observed for its internal surface finish and general out look (Jain, 1986).

RESULTS AND DISCUSSION

Green permeability

Figure 1 presents the effect of core oil binder content on the green permeability of the core sands containing beniseed and melon oils. It is evident that the addition of 1.0 wt% of each of beniseed and melon oils to the core sand mixes produced initial green permeabilities of 420.0 and 350 ml/min respectively. Thereafter, permeability values for core sand mixes containing either beniseed or melon oils continued to decrease as content of core oil binders in the core sand mixes increases (Figure 1). Comparison of the green permeability graphs of both beniseed and melon oils indicate that the core sand mix containing beniseed core oil binder has higher green permeability than that of the melon core oil binder for the range of 1.0 to 2.0 wt% core oil content (Figure 1). The permeability of the core sand mix containing melon oil was suddenly noted to be greater than that of the beniseed oil at 2.5 and 3.0% core oil content.

Analysis of the values obtained for the green permeability of the core sand mixes containing either melon and beniseed oils (irrespective of proportion) indicate that gases and vapour can easily permeate the pores of the cores made in these core oils, thereby, minimising the incidence of defect formations in the castings (Olakanmi, 2001).

Green compression strength

Figure 2 shows the effect of core oil on the green compression strength of the core sand mixes containing beniseed and melon oil core binders. It is clear that an increase in the core oil binder content correspondingly produces an increase in the green compression strength of the core sand mixes containing either beniseed or melon oil. The figure shows that increase in core oil, increases the green compression strength.

Figure 2 also reveals that the maximum green compression strength for the core sand mixes containing beniseed oil is 43.0 kNm^{-2} while that of melon oil is 37.0 kNm^{-2}. General comparison of the green compression strength values for both beniseed and melon core oil binder suggests that beniseed core oil binder imparts a slightly better green compression strength into the core sand mixes than is obtainable for the melon oil core binder.

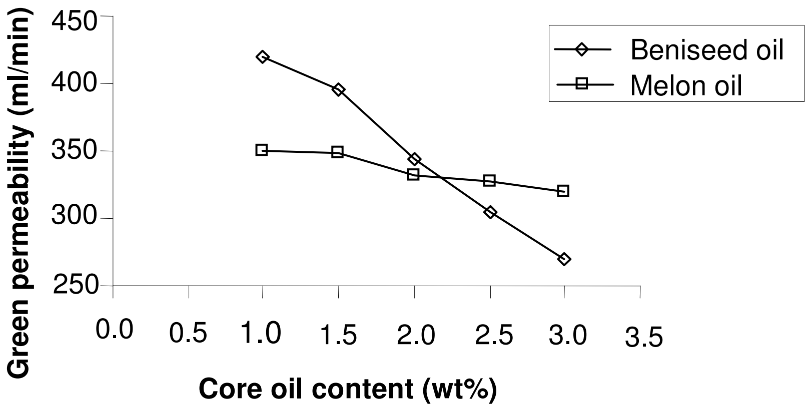

Figure 1. Effect of core oil binder content on the green permeability of the core sand mixes containing beniseed and melon oils.

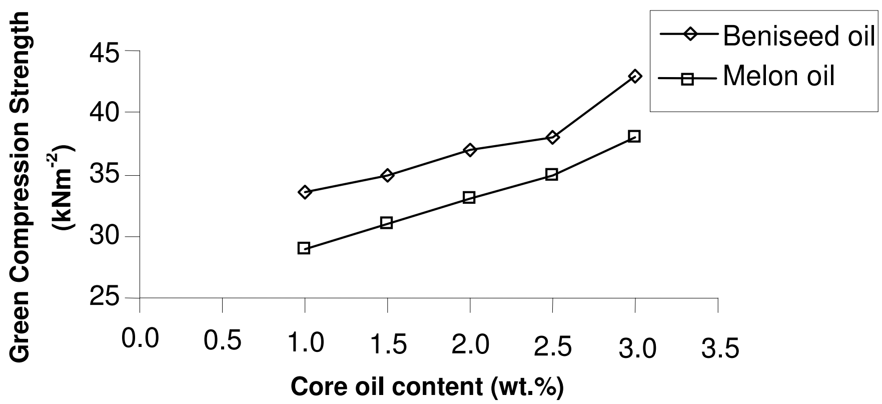

Figure 2. Effect of core oil binder content on the green compression strength of the core sand mixes containing beniseed and melon oils.

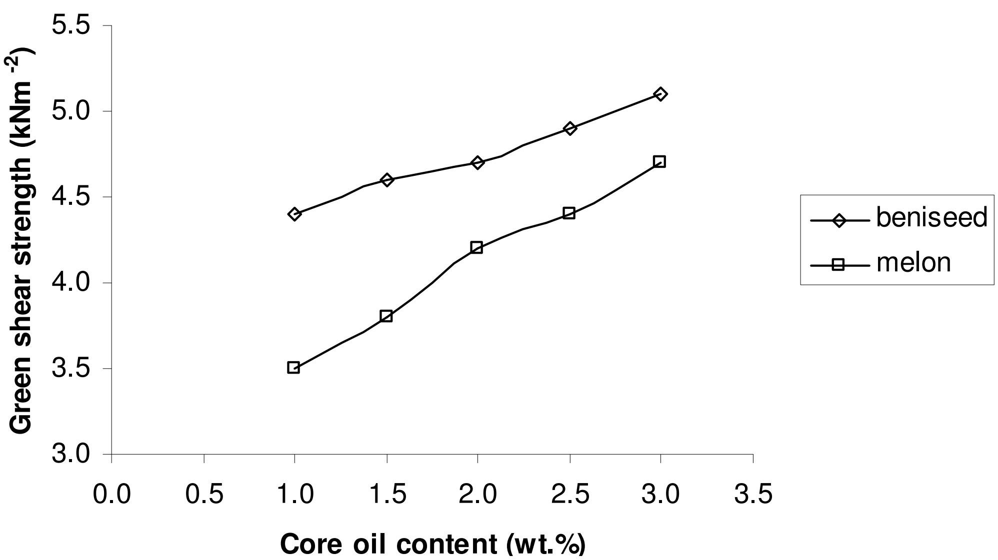

Figure 3. Effect of core oil binder content on the green shear strength of the core sand mixes containing beniseed and melon oils.

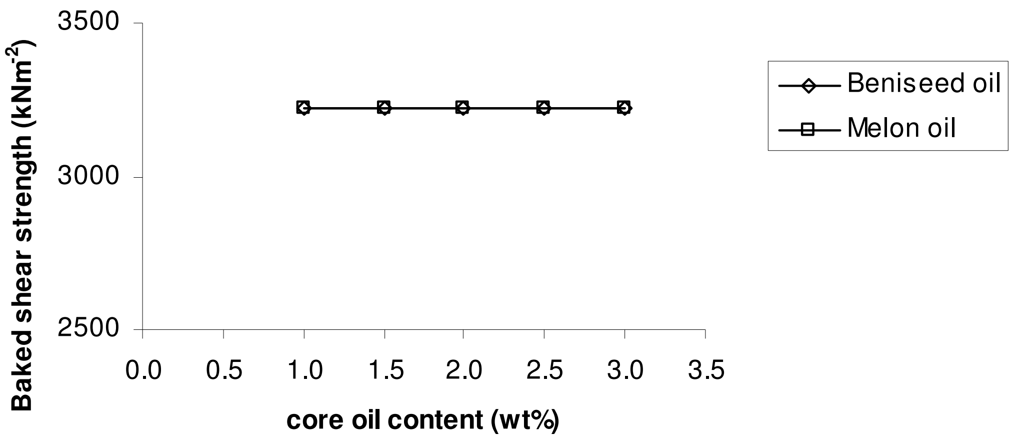

Figure 4. Effect of core oil binder content on the baked shear strength of the core sand mixes containing beniseed and melon oils.

Green shear strength

Figure 3 shows the effect of core oil binder content on the green shear strength of the core sand mixes containing beniseed and melon core oil binders. The result reveals that increasing content of the core oil binders produces increament in the green shear strength of the core sand mixes containing either beniseed or melon core oil binders. The values of the shear strength of the core sand mixes containing beniseed oil are noted to be slightly higher than containing the melon core oil binders for corresponding core oil content. Therefore, the beniseed oil mixture could be said to have imparted greater green shear strength on the core sand mixes than the melon oil core binder.

Baked compression strength

The results of the baked compression strength for core sand mixes containing beniseed and melon core oil binders are presented in Figure 4. Baked compression strengths for the core sand mixes containing either beniseed or melon core oil binder is 3223.4 kNm^{-2} irrespective of the core oil binder content (Figure 4). The development of baked compression strength could be explained by the organic nature of the core oil binders and the cereal binder which are combustible because they are easily destroyed by heat (Mikhailov, 1989). At the temperature of 200℃ at which the tests were performed, it is possible that all the water had been driven off. Therefore, it may be suggested that the clay content, the remains of the cereal binder and the core oil binder are possibly responsible for the binding of the neighbouring particles in the core sand mixes. Because the proportions of the bonding clay and the cereal binder are not varied in this study, it may be argued that the core oil binder content in the core sand mixes is the effective variable responsible for the development of the baked strength.

Therefore, the development of the same amount of high baked strength in the core sand mixes irrespective of core oil binder content (Figure 4) could be attributed to the effective bonding mechanism of both beniseed and melon core oil binders which promotes formation of the cereal binder film which surround the core sand particles. Within the investigated range of core oil binder content, it possible that the cereal binder film surrounding each particle of the core sand is sufficiently thinner such that the inter-particles distance between neighbouring particles closes up, thus, leading to stronger bonds within the matrix of the core sand and consequently, high baked strength was developed in the core sand mixes containing either beniseed or melon core oil binders.

Moreover, the development of the equally high baked strength for core sand mixes irrespective of the type of core oil binders and their content could also be explained by the choice of the experimental baking temperature (200℃). High values of the baked strength developed in the samples could be possibly attributed to the binding capacity of both beniseed and melon core oils which is speculated to be stable at the chosen baking temperature.

Bulk density

The influence of core oil binder addition on the bulk density is graphically presented in Figure 5. The bulk density of the core sand mixes` containing beniseed and melon oil core binders could be seen to be increasing correspondingly as the core oil content increases with the beniseed oil imparting greater bulk density on the core sand mixes upon comparison with that of the melon oil. Given that the number of ramming action, the contents of clay and cereal binder employed in this study are constant, this outcome implies that the grain particle of the core sand mixes can be effectively bound together by the the proportion of the available core oil binder rather than

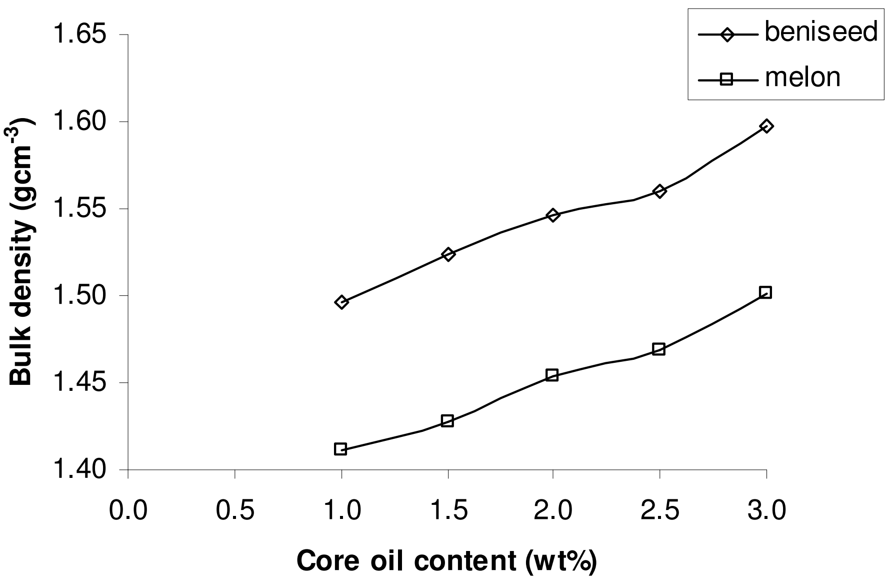

Figure 5. Effect of core oil binder content on the bulk density of the core sand mixes containing beniseed and melon oils.

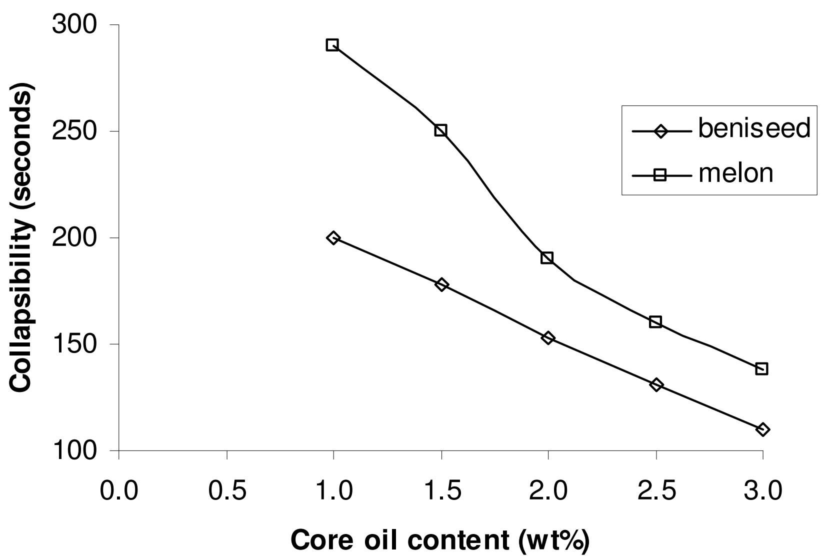

Figure 6. Effect of core oil binder content on the collapsibility of the core sand mixes containing beniseed and melon oils

only ramming action (Ibitoye and Afonja, 1996).

Collapsibility

It can be inferred from Figure 6 that the collapsibility of the core sand mixes containing either beniseed or melon core oil binder decreases as the core oil binder increases. In addition, the core sand mixes containing beniseed core oil binder have better collapsibility than that of melon oil core binder. This behaviour occurred probably because at the experimental temperature of 600°C at which collapsibility was measured, core oil and the cereal binders were burnt off, thereby, making it easier for the cores` to collapse more readily after they had solidified. According to Dietert (1950), collapsibility within the range of 60 – 120 s are considered as fast with the consequence of the production of cracks and warpage in castings whereas those greater than 480 s are regarded to be slow, thus, resulting in metal penetration in castings. However, moderate collapsibility, which is between fast and slow, recorded for core sand mixes containing both beniseed and melon core oil binder in this study is considered to be suitable for sand castings.

Practical applications of the core oils

Cavities of bushings which were previously made with imported fish oils were produced by using both melon and beniseed core oils. The core sand mixes containing either melon or beniseed oil were found to have the required green compression strength of 33 kNm^{-2}, significantly high baked shear strength of 3,150 kNm^{-2} and collapsibilities in the range of 180 to 260 s irrespective of the sizes of cores made for the bushings. The baked strength of the cores is thought to have enabled them to withstand the metallostatic pressure of the molten metal during. The internal surface finish of the castings was found to be good in quality upon observation.

Conclusion

On the basis of results obtained in this study, which are comparable to the literature, both beniseed oil and melon oil can be used as substitutes for imported core oils like linseed oil, corn oil and fish oil.

Beniseed core oil binder was found to be the most desirable for core making because it was able to impart higher bulk density, green and baked strength to the core mixes. Moreover, its collapsibility was faster than that of the melon core oil binder.

Practical applications of these core oils reveal that they are suitable for castings of large, medium and small sizes.

REFERENCES

American Foundrymen's Society (1963). Foundry Sand Handbook. 7th Ed; New York.

Gilson DM (1993). "The role of different core binder systems in iron casting production: effect of porosity defects and casting properties." AFS Trans. 101: 491–496.

Ibitoye SA, Afonja AA (1996). "Effect of starch addition on the bulk density, baked hardness and collapsibility of potter's clay – bonded core sand." Ife J. Technol. 6 (1): 25 – 30.

Jain PL (1986). Principles Of Foundry Technology, 2nd Edition, New Delhi, Tata Mc – Graw Hill Publishing Company, pp. 48-108.

Mathew P, Wainko SF (1983). "Suitability Of Some Local Oil As Core Binder". Niger. Eng. 56: 473.

Mikhailov AM (1989). Metal Casting, 2nd Ed; Moscow. Mir Publisher: pp 71 –90.

Olakanmi EO (2001). "Characterizations of The Locally Available Sands For Moulding And Core Making Purposes", M Eng. Thesis, Federal University Of Technology Minna.