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Evaluation of Obudu Beeswax for Lost-Wax Casting Process

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I. Introduction

As defined by Encyclopedia Britannica, beeswax is a commercially useful animal wax secreted by the worker bee to make the cell walls of the honeycomb. The honeycomb is generally discarded as waste in the open field thus polluting the environment. Also, this dump site attracts bees and consequently posing severe health and safety concern to the people. Beeswax are used in various applications which include; candle making (religious ordinances often specify its use for ceremonial church candles), artificial fruit and flowers, modeling wax, manufacture of furniture and floor waxes, leather dressings, waxed paper, lithographic inks, cosmetics, and ointments.

There are no known references that deal with the physical and mechanical properties of Obudu beeswax as well as its use for casting activities. The corresponding literature review vindicates this.

Graig et al., 1967, studied the use of beeswax in dentistry at the University of Michigan and reported that the strength properties are particularly important when significant expansion takes place in the investment for dental applications.

Kissi in 2011, evaluated casting of hollow artifacts produced by Ghanaian traditional metals miths and suggested that the use of molten wax to produce hollow wax patterns in P.O.P molds should be employed to ensure direct duplication of the original object without creating parting lines in the inner walls of the model.

Hossain et al., 2009, studied the physical and mechanical properties of paraffin and beeswax to simulate the rocking behavior for water jet drilling and concluded that natural beeswax could be a good substitute for reservoir rocks.

Giuseppe et al., in 2015 studied the thermal and mechanical properties of halloysite nanotubes (HNT)/beeswax composites at various compositions and stated that a slight loss of beeswax crystallinity occurred upon HNT addition.

Zhang et al., 2011, investigated the thermal behavior of four insect waxes and obtaineda melting point of 70.34°C and melting enthalpy of 168.1J/g for beeswax.

In 2000, Dong-Joo et al. studied the effect of mold temperature and cooling rate on mechanical properties of press consolidated thermoplastic composite and the results show that crystallinity decreased with increasing cooling rate with the slow cooled specimen having high fracture toughness.

The characteristic properties of Obudu beeswax will be of interest from an academic viewpoint as well as in the industry since these properties are novel. The knowledge of the characteristics of Obudu beeswax is also important since it is locally available and has no known engineering, medical and other applications. Mechanical and thermal properties are therefore imperative for foundry and related applications since the wax is subjected to forces that arose during investment and setting of molds and to temperature changes resulting from curing reactions, especially during the water glass molding process. In situations where shrinkage takes place, as it is always the case during the setting of the investment, a lot of stresses are applied to the wax pattern which they should be able to

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withstand and maintain dimensional accuracy of the mold and its various intricate regions.

This work, therefore, investigated the suitability of Obudu beeswax for lost-wax molding by determining its melting point, compressive strength and mold surface finish.

II. Materials and Methods

a) Materials

The scrap honeycomb, which contains beeswax, was obtained from beekeepers in Obudu, Cross River State, Nigeria.

b) Methods

i. *Rendering*

This is the removal of foreign materials such as dead bees, dirt, and twigs embedded in the honeycomb. Figure 1 show the sorted scrap honeycombs which were melted with large quantity of water and then filtering through qualitative filter paper. During melting, the temperature of the water was constantly below 100°C (boiling point of water). Below the boiling point of water, there was no spillover of the molten beeswax, which is flammable, into the heating source, thereby preventing violent fire outbreak. Water and wax passed through the filter paper, leaving behind some residues. The clean beeswax which solidified as a hard-yellow mass upon cooling floated on top of the water. It was then removed for test sample preparation and pattern making. Figure 2 shows rendered beeswax.

Figure 1: Sorted out honeycomb containing beeswax

Figure 2: Rendered beeswax

ii. *MDSC Analysis*

Modulated Differential Scanning Calorimeter, MDSC 2920, manufactured by TA Instruments was used for the analysis. Samples of 20mg each cut with stainless steel scissors and tweezers were weighed on Sartorius BP410 digital laboratory balance. Figure 3 shows the weighing of sample and aluminum hermetic sample pan with lid, TA Instruments 900793.901.

Figure 3: Weighing of the sample with hermetic aluminum sample pan with the lid on Sartorius BP410 digital laboratory balance

Selection of Aluminum pans with lids for both the sample and empty reference pans and placement in their respective positions in the heating cell.

Experimental parameters (sample and instrument information) were keyed in through the TA universal controller 2000. The ramp rate of 5°C/min and an end temperature of 300°C were selected. By pressing the START key on the instrument Control program, the instrument automatically ran the experiment to completion. Figures 4 and 5 show the MDSC 2920 and the experimental parameters respectively. A real-time plot was generated simultaneously. Both the experimental considerations and the real-time plot automatically saved in the system for subsequent recall and analysis. Figure 6 shows the thermo gram of the experimental result.

Figure 4: TA Instruments, MDSC 2920

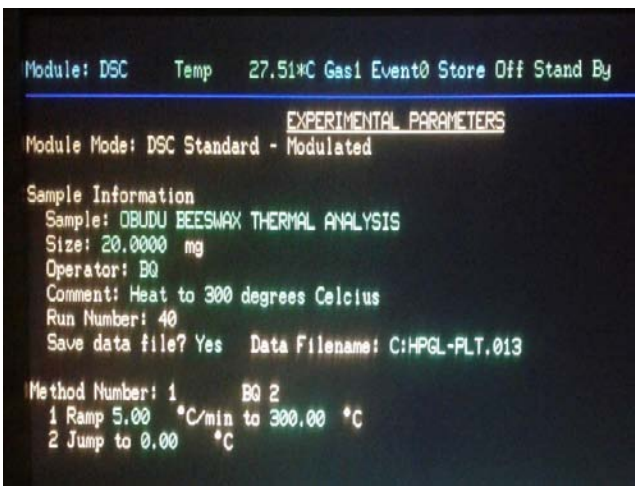

Figure 5: MDSC experimental parameter of Obudu beeswax

Figure 6: Thermogram of Obudu beeswax

iii. *Density evaluation*

The density of the beeswax was determined by using the relationship between mass which was 25.92 gand volume. The metrological dimensions of the sample, diameter 24.16mm and a length of 60.12mm were measured using Mitutoyo Absolute Digimatic vernier caliper and gave a volume of 27.55cm^3. A density of 0.941g/cm^{3}was derived using the following expression;

$$Density = \frac{Mass}{Volume} \tag{1}$$

iv. *Mechanical properties evaluation*

The compression specimens were prepared by re-melting the rendered beeswax and pouring it into preheated split stainless-steel molds. Figure 7 shows the samples cooled in various media; air, liquid nitrogen, and refrigerator.

Figure 7: Beeswax samples cooled in various media; air, liquid nitrogen, and refrigerator.

Uniaxial compression tests were performed on the beeswax samples using a retrofitted Ametek EZ 250 tension/compression tester, Figure 7. The dimensions of the specimens were diameter 24.16mm and 60.12mm length. The length-to-diameter ratio was about 2.5. The force applied was at a travel rate of 15mm/minute. Figure 8 shows the beeswax samples in the tension/compression strength test machine with digital readout of linear travel and applied force. The compressive strength calculated by dividing the measured peak force value by the cross-sectional area of the sample according to the stress equation:

$$\sigma = \frac{\text{Peak Force}}{\text{Cross -sectional Area}} \tag{2}$$

Figure 8: Beeswax samples on tension/ compression tester

Table 1: Compressive Strengths at various cooling media

SN	Cooling medium	Compressive Strength (kPa)
1	Liquid Nitrogen	471.5
2	Refrigerator	541.9
3	Natural Air	577.7

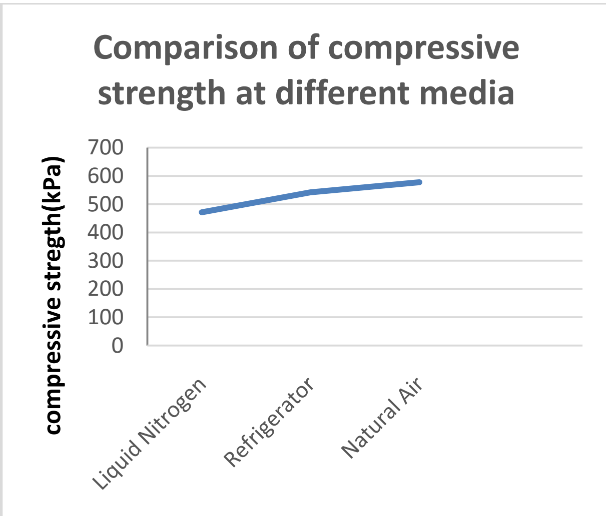

Figure 9: Compressive Strengths at various cooling media

III. Results and Discussions

a) MDSC Analysis

The results of the modulated differential scanning calorimetry showed a melting point of 66.31°C which is in agreement with works of Royal Bees, 2018, who obtained a range of 62 to 72°C. The melting enthalpy was 165.5J/g, which is close to values obtained by Zhang et al., 2011. From the the rmogram, we can see that the wax was stably liquid from the melting point to 172°C, after which a decrease in heat flow occurred. This effect is suggestive of some exothermic reaction and possible vaporization of the beeswax. Therefore, all wax must have been lost from the mold before this temperature is reached provided here is an adequate channel for its exit.

b) Density measurement

The experimentally calculated density is 0.941g/cm^{3}was close to 0.947 - 0.985g/cm^{3}obtained by Charles et al., 1940 and 0.96g/cm^3 by Khamdaeng et al., 2016. It notes that properties of beeswax vary by location and method by which the honey was cultured (Charles et al., 1940). The density value which was less than 1g/cm^3, the density of water, was responsible for the floating of the beeswax on water.

c) Compressive strength

The compressive strength depends on the rate of cooling. The experiment shows that fast cooling has a negative effect on compressive strength, i.e., the slower the cooling rate, the higher the compressive strength. Thus, the naturally air-cooled samples had the highest value of 577.7kPa, followed by samples cooled in the refrigerator, 541.9kPa and lastly in liquid nitrogen fumes, 471.5kPa. This behavior is in line with the behavior of polymers. Slowly cooled polymer specimen had high fracture toughness than fast cooled ones (Dong-Joo et al., 2000).

Natural air-cooling offered the best alternative regarding yielding good compressive strength, reduced cost as no additional facilities were required, especially in safe handling liquid nitrogen.

d) Prototype beeswax pattern and mold

The prototype mold was made by first making a beeswax pattern. Letter Q and number 6 were drawn on cardboard paper and traced on the solid beeswax. They were subsequently carved out with sculptor's scrapper and smoothened. See Figure 10. Refractory slurry made of Plaster of Paris molded on the pattern contained in a metal flask. After setting and curing, the mold was gradually heated to a temperature of 120°C at a rate of 2°C/minute for 60 minutes to lose the wax. Figure 11 shows the revealing mold cavities.

Figure 10: Beeswax pattern

Figure 11: Dried mold revealing the mold cavities

IV. Conclusions

Evaluation of Obudu beeswax for lost-wax casting process was successful.

The melting point of 66.31°C, which is considerably low, lends itself to ease of beeswax use.

The long-range liquid phase, from 66.31 to 172°C, makes it possible to lose all wax from the mold provided there is an adequate channel for its exit.

The air-cooled samples had the highest compressive strength of 577.7kPa, which was responsible for achieving the high dimensional accuracy and good replication of intricate details.

The prototype sample mold made from beeswax 'Q6' pattern showed excellent surface finish, good replication of intricate details as well as good dimensional accuracy.

References Références Referencias

1. Beeswax (2012), Encyclopædia Britannica Ultimate Reference Suite, Chicago, Encyclopædia Britannica.
2. Charles S. B., George B. V., Walter B.D. (1940), Investigations on the physical and chemical properties of beeswax, Technical bulletin no. 71. United States Department of Agriculture. Washington D. C.
3. Craig R.G., Eick J.D., Peyton F.A., (1967), Strength Properties of Waxes at Various Temperatures and their Practical Application. Journal of Dental Research. First Published January 1, 1967 Research Article Copyright © 2018 by International & American Associations for Dental Research.
4. Dong-Joo, L., Ick-Jae, S., and Seung-Wook, L. (2000), Effect of mold temperature and cooling rate on mechanical properties of press consolidated thermoplastic composite.
5. Giuseppe C., Giuseppe L., Milioto, S., Parisi, F., and Sparacino, V., (1940),Thermal and dynamic mechanical properties of beeswax-halloysite nano composites for consolidating waterlogged archaeological woods, https://doi.org/10.1016/j.polymdegradstab.2015.07.007
6. Hossain, E. M., Ketata, C., and Islam, R. (2009), Experimental study of physical and mechanical properties of natural and synthetic waxes using uniaxial compressive strength test. Proceedings of the third International Conference on Modeling, Simulation and Applied Optimization, Sharjah, UAE.
7. Khamdaeng, T., Wongsiriamnuay, T., Panyoyai, N., Narkprasom, K., and Intagun, W., (2016), Mechanical properties and melting conditions of beeswax for comb foundation forming. Agricultural Engineering International: CIGR Journal, 18(3):282-293.
8. Kissi, B. S. (2011), Evaluation of beeswax and core materials for lost wax casting, thesis submitted to Faculty of Art, College of Art and Social Sciences, KNUST, Ghana.
9. Royal Bees (2018), Royal Bees Factory, 2A RojenStr. 4190 Saedinenie, Bulgaria, Production and trading with bees products and beekeeping equipment, http://www.royalbees.bl/newsletter/tradingandbookkeeping.
10. Zhang, H, Feng, Y., Li. K., Zhang, W., (2011), Thermal analysis of four insect waxes based on differential scanning calorimetry (DSC). Procedia Engineering 18 (2011) 101 –1061877-7058doi: 10.1016/j.proeng.