Technology for melting amber chips to produce a solid block

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Abstract. This research is relevant, because the bulk of the mined amber comes in amber chips. Therefore, we have decided to review the current ways of melting amber chips to develop the most technologically efficient algorithm and to use it further for producing decorative items. The purpose of the work is to perfect the technology of obtaining whole-piece amber from amber chips and to explore the usability of the obtained material in decorative items and jewelry.

1. Introduction

The Roman author, Pliny the Elder, was the first scientist to prove that fossilized tree resin is amber. He noticed the resinous smell and smoky flame produced when amber was burning. Moreover, transparent amber often contained particles of plants and fossil insects. Later on, German scientists tried to challenge this conclusion. In the XVI century, for instance, Georgius Agricola claimed that amber consisted of liquid bituminous substance; it was formed in the interior of the Earth and hardened when out on its surface. There was also a hypothesis at the beginning of the XVIII century that amber originated from oil combined with mineral acids. Ancient Russians knew amber well and called it alatyr or latyr-stone, attributing miraculous properties to it. Mikhail Lomonosov gave more reasons in favor of the organic origin of amber in his works ‘First Principles of Mining Science’ (1742) and ‘A word on the formation of metals from earth tremors’ (1757).

Figure 1. Amber chips.

Today we generally accept that amber (Figure 1) is a mineral of organic origin. It is fossilized resin of conifer trees that grew 30 to 60 million years ago. The first stage of amber formation was an abundant discharge of conifer resin, which scientists associate with dramatic climate warming at that time. Resin is formed in the cells and it usually fills round cavities and elongated channels inside a plant. The second stage of amber formation involved resin deposition in forest soils. In dry, wellaerated soil, resin hardened and became more chemically stable when exposed to oxygen. The third stage of amber formation included the washout, transfer and deposition of fossilized tree resin into water basins. The transformation of resin into amber is facilitated by oxygen-containing potassium-enriched alkaline silt water. The water reacts with the resin, which results in the formation of succinic acid and its ethers. The final stages of this process involve the formation of not only amber but also glauconite – a mineral that always accompanies amber deposits. Most of the mined amber is small rocks of up to 3 cm in cross section; very occasionally, 4…7 kg pieces can occur [1].

There are several patented techniques for processing amber chips. The first patented technique [2] for creating decorative items with amber filler (up to 20 mm thick and produced from amber or amber scrap) involves the preparation of a molding compound with the following composition: filler (10…15 %), caustic magnesite (20…25 %), sodium chloride solution (20…25 %), quartz sand (the remaining percentage). The obtained mixture is poured into a mold of a required size and is placed on a shake table for 0.5…1.0 min. Then the mold is dried in a chamber at 13…30 °C for 1…3 days, depending on the thickness of the item. After hardening the compound is removed from the mold and polished with diamond abrasives and polishing materials. Another technique suggested in the patent [2] involves creating an amber filler for decorative items by filling the casting mold with a fluid amber compound with a polymer binder, accelerator and hardening agent. Low-quality amber of various grades as well as amber scrap serves as a filler without grinding. The filler is grouped by color and size during preparation. Then each group is treated with a gel coat, and the amber to polymer binder mass proportion is calculated for each group. After that, the molding compound laid into designated molds is prepared, and the compound with the following mass percentage is obtained: filler (40…70 %), gel coat (3…4 %), unsaturated polyester resins (55…25 %), hardening agent (1…0.5 %), and accelerator (1…0.5 %). The product is formed via manual or vibration treatment for 20…40 min. After hardening, the product is removed from the mold and dried in a drying chamber for 3…4 h at 50…70 °C. This technique has a drawback that limits its practical use – it is very labor intensive, including the retrieval of the product from the mold. It is hard to retrieve due to the high adhesive power of the compound. Moreover, the surface of the cast product has relatively low cleanliness. In order to facilitate the removing of the cast product from the mold, its inner surface is covered with a protective gel coat or other materials that will reduce the adhesion. The used pigmented resins (gel coats) are classified as harmful in both the production process and subsequent product use. The patent [3] describes the production of large shapes from fine grains of natural amber. This technique involves loading ~10 mm amber grains into airtight molds, heating them up to 140 °C with subsequent gradual increase in pressure from 0 to 100 atm, while maintaining the press force in the process. This technique allows obtaining products that preserve the physical, chemical and aesthetic properties of natural monolithic amber. In this case grains of natural amber of varying sizes are used as a raw material: large pieces of amber, amber pebbles and chips, flawed crafted items as well as previously pressed amber. The raw materials can vary in terms of transparency and sizes. The raw material heated to 110…130 °C is loaded into the mold block pre-heated to 160…230 °C. The temperature of the amber and that of the mold determine the color of the final product which can be anywhere between that of the natural amber and dark cognac color. After reaching the operating temperature, the mold is placed into the hydraulic press. The punch die is forced down to the stop by the press in 30…40 s. After sealing the mold and breaking down of the raw material, the volume of the shape-forming mold block is maintained by locking the die punch with a retention mechanism. The pressure in the heated amber breaks intermolecular bonds, turning it into a heterogeneous mass. When the heated amber reaches the temperature of the mold, it expands and fills the entire volume of the part-forming mold cavity. The baking process occurs due to the inner reaction of the raw material confined within the part-forming cavity. Natural cooling is preferable to refrigeration, because the latter may cause the product embrittlement.

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2. Results and Discussion

The goal of this work is to use the patent data as well as strengths and weaknesses of each method to perfect the technology of obtaining whole-piece amber from fine grains, to research the properties and prospective use of the material obtained for decorative items. Two types of amber chips – polished and unpolished – of various grain sizes are used as the raw material. This technique involves loading 1.7 g of amber chips into the mold. Then the mold is heated to 140…180 °C for 1 to 2 h. After that, the mold is exposed to the pressure of 31.8 MPa or 63.7 MPa, depending on the experience, using a mechanical screw press, while controlling the press force with a dynamometer. Then the product cools under natural conditions. After the cooling completion, the samples are retrieved from the mold to measure their diameter, mass and height. Then the cross-section area, volume and material density are calculated. Normally, the density of natural amber is between 1.05…1.09 g/cm^3. Three-point bending tests are conducted on the GP 30 kN DLC test machine. See the Table 1 below for the research data:

Table 1. The dependence of density on temperature at 31.8 MPa.

	Dist. temp.	Pressure MPa	Heating time	Bending strength, MPa	Density, g/cm^3
Polished	140	31.8	1 hour	5.90	1.03
			2 hours	4.32	1.02
	160	31.8	1 hour	5.16	1.08
			2 hours	5.08	1.05
	180	31.8	1 hour	9.99	1.08
			2 hours	9.19	1.06
Unpolished	140	31.8	1 hour	2.11	1.01
			2 hours	2.47	1.03
	160	31.8	1 hour	3.26	1.07
			2 hours	2.17	1.04
	180	31.8	1 hour	6.73	1.08
			2 hours	6.12	1.05

Table 2. The dependence of density on temperature at 63.7 MPa

	Dist. temp.	Pressure MPa	Heating time	Bending strength, MPa	Density, g/cm^3
Polished	140	63.7	1 hour	3.72	1.04
			2 hours	3.93	1.03
	160	63.7	1 hour	4.71	1.04
			2 hours	6.09	1.06
	180	63.7	1 hour	7.73	1.06
			2 hours	6.82	1.06
Unpolished	140	63.7	1 hour	0.85	1.00
			2 hours	1.32	0.99
	160	63.7	1 hour	3.05	1.04
			2 hours	3.23	1.06
	180	63.7	1 hour	4.76	1.05
			2 hours	5.08	1.06

Figure 2 shows dependence of density on heating temperature of the samples exposed to deformation stress of 63.7 MPa for 1 h and 2 h.

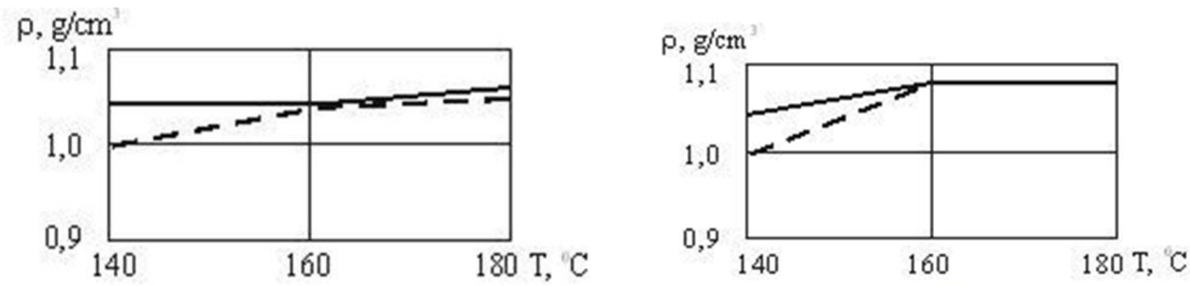
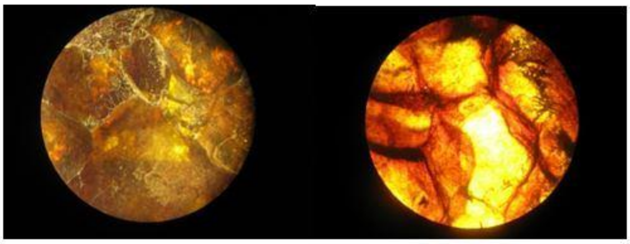


Figure 2. Dependence of amber density on the distortion temperature:
heating time – 1 h (a), 2 h (b)

It follows from the diagrams that the density of samples increases with rising temperature. The heat distortion temperature markedly affects the color of amber. With rising heating temperature, the color of the samples changed from natural to dark cognac (Figure 3a, b).



a b

Figure 3. A visual appearance of samples produced at the temperatures of 140 °C (a) and 180 °C (b) from unpolished amber.

The variety of jewelry made of amber is very diverse. Most often, amber serves as a filler in jewelry. For a decorative item, we chose a composition of a cast brass mount with an inserted piece of amber. The brass substrate was produced by means of investment casting [4]. The item was designed in the CorelDRAW graphics editor (Figure 4), and then the model was laser cut from a 4 mm acrylic sheet by means of the Speedy 100 fiber Laser Engraver. We then obtained wax models using a rubber die mold, connecting them with a gating system, formed them, poured the metal and obtained casts, which were then mechanically processed for marketable appearance. We chose unpolished amber for the insert, which makes it possible to obtain a wider variety of colors than with the polished one (Figure 5).

Figure 4. A brass mount design.

Figure 5. A decorative item

3. Conclusion

We have developed a technology for melting amber chip to produce a solid block with the same density as that of natural amber. Experiments with various pressure have shown that the density of amber increases with the rising heat distortion temperature, but the color of the sample becomes darker. We have also produced a decorative item with an amber insert.

References

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