Technology of obtaining gold and silver imitation nuggets for jewelry design purposes

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Abstract. Acceleration of the liquid metal crystallization process by pouring the hot melt directly in the cooling liquid results in irregular shape casts. Analysis of the processes influencing brass and tin cast shaping, as well as determination of the required technological parameters allow obtaining quality imitation precious metal nuggets as promising jewelry design materials.

1. Introduction
Precious metal nuggets have been used as adornments since the ancient times, and are still of interest in the contemporary jewelry design, being considered promising materials. This gives a ground for the development of techniques that allow obtaining quality gold and silver nuggets at a minimum cost. The article presents the key aspects of the research aimed at defining the technological parameters of brass and tin casting for making gold and silver nuggets.

2. Materials and methods
In the experimental study of pouring the metal in the cooling liquid, brass B63 and pure tin are used because of their superficial resemblance to nugget gold and silver. Water is used as a cooling liquid. The casting is done in a bowl with the use of a gasoline burner.

3. Research results and analysis
When getting into the cooling liquid, the B63 brass melt can form elaborate irregular-shape casts with an uneven relief similar to alluvial gold nuggets. The cast shape depends on the degree of the metal surfusion controlled by changing the liquid temperature (water temperature modes being: 0-5, 10-15, 20-25, 30-35… 80-85 °С), while the cast melt temperature being kept constant, 970 ±5 °C. The experiments show that the higher the surfusion degree is, the more elaborate the cast shape is [1]. Using water with a temperature of 0-5, 10-15, 20-25 °C allows making brass samples with the required aesthetic parameters: golden-yellow color, bright metallic shine, irregular shape and uneven surface relief. The increase in the water temperature by 10-20 °C and higher results in thin oxide films on the cast surface explaining the darker color and partial shine reduction. Further increase in the water temperature results in simpler shapes and higher surface oxidation. In the water of 80-85 °C, the brass melt forms smooth-surface casts, the shape contour being close to a circle, with a dense oxide layer [2]. The obtained results are presented in Table 1.
Table 1. Dependence of the brass cast shape on the cooling liquid temperature.

| Experiment number | Water temperature, °C | Cast appearance |
|-------------------|-----------------------|-----------------|
| 1                 | 0-5                   | ![Cast Appearance 1] |
| 2                 | 10-15                 | ![Cast Appearance 2] |
| 3                 | 20-25                 | ![Cast Appearance 3] |
| 4                 | 30-35                 | ![Cast Appearance 4] |
| 5                 | 40-45                 | ![Cast Appearance 5] |
| 6                 | 50-55                 | ![Cast Appearance 6] |
| 7                 | 60-65                 | ![Cast Appearance 7] |
| 8                 | 70-75                 | ![Cast Appearance 8] |
| 9                 | 80-85                 | ![Cast Appearance 9] |

The experiments on tin casting show somewhat different results. The tin melt having undergone accelerated crystallization, gives more elaborate cast shapes combining one-piece metal elements and fragile dendrite-shaped lumps. The presence of the dendrites in the shape makes the latter similar to alluvial silver nuggets. At the same time, one can observe the dependence of the cast shape on the melt surfusion degree: the lower the degree, the simpler the shape and the smaller the number of the dendrites, and vice versa. The surfusion degree in this case is regulated by changing the cooling liquid and the melt temperature modes. Water of different temperature modes (0-5, 10-15, 20-25, 30-35… 60-65 °C) is used as a cooling liquid. The tin melt of 250 ±5 °C, 300 ±5 °C, 350 ±5 °C and 400 ±5 °C, is poured in the water of every temperature mode [2]. The examples of the casts obtained are presented in Table 2.

For a more complete understanding of the processes taking place in the metal when forming the casts, a study of all the obtained samples has been done. The brass casts have undergone structural analysis, the results being presented in Figure 1. The analysis has found the presence of β-phase in the cast microstructure. The sample obtained by pouring the brass melt in the cold water (Figure 1, b) has much smaller grains than the sample formed in the hot water (Figure 1, c) [5].

In order to analyze the aesthetic parameters of the brass casts, a chart has been built reflecting the dependence of the samples shape and relief on the cooling liquid temperature (Figure 2, a). For this purpose, a numeric relief index has been derived, showing the average number of the pronounced surface irregularities (cavities and bumps) forming each cast’s relief. The chart shows that the lower the cooling liquid temperature, the higher the index value is. Also, a color scale has been formed...
(Figure 2, b) that demonstrates the change in the cast color caused by the oxide film formed on the cast surface, depending on the water temperature.

**Table 2.** Dependence of the tin casts on the cooling liquid and melt temperature.

| Water temperature, °C | Tin melt temperature, °C | 250 | 300 | 350 | 400 |
|-----------------------|--------------------------|-----|-----|-----|-----|
| 0-5                   |                          | ![Image](image1) | ![Image](image2) | ![Image](image3) | ![Image](image4) |
| 10-15                 |                          | ![Image](image5) | ![Image](image6) | ![Image](image7) | ![Image](image8) |
| 20-25                 |                          | ![Image](image9) | ![Image](image10) | ![Image](image11) | ![Image](image12) |
| 30-35                 |                          | ![Image](image13) | ![Image](image14) | ![Image](image15) | ![Image](image16) |
| 40-45                 |                          | ![Image](image17) | ![Image](image18) | ![Image](image19) | ![Image](image20) |
| 50-55                 |                          | ![Image](image21) | ![Image](image22) | ![Image](image23) | ![Image](image24) |
| 60-65                 |                          | ![Image](image25) | ![Image](image26) | ![Image](image27) | ![Image](image28) |

**Figure 1.** Brass microstructure with 400-fold magnification: a – one-phase B63 brass before the experiment; b – two-phase brass with smaller-size grains, obtained by pouring the metal melt in the water of 0-5 °C; c – two-phase brass with bigger-size grains, obtained by pouring the metal melt in the water of 80–85 °C.
The study of the tin casts shape is done by a comparative mass analysis of the dendrites percentage in the samples. All in all, 10 samples obtained in each temperature mode have been studied, with the average dendrites amount index for each sample. Based on the obtained values, a chart is built showing the dependence of the tin cast shape on the cooling liquid and tin melt temperatures (Figure 3), with the help of which one can easily elicit the following regularity: the higher the tin surfusion degree, the more dendrite elements are in the cast.

4. Discussion
The experimental study of pouring the brass and tin melt in the cooling liquid and the analysis of the obtained results allow us to elicit the key factor influencing the cast appearance - i.e. accelerated crystallization. However, it does not completely explain the reasons of the above shapes formation.

Even purest metals in any aggregate state contain some amount of gases such as hydrogen, oxygen and nitrogen [3]. The gases are present in the form of either independent elements or different chemical compounds [4]. When pouring the metal melt in water, surfusion of the metal mass is accelerated and is of an uneven character.

The high velocity of the metal external layer crystallization results in pressure under which the intrametallic gases concentrate in the melt being crystallized and, seeking exit, deform the metal layers.
that have not been yet hardened. Another important observation is that the water around the melt starts boiling forming a ‘steam jacket’ which, in turn, creates pressure around the metal body [5].

The distinctive feature of pouring metal in water is that the casts are formed in a free unlimited space, which is a strong ground for suggesting that it is the combination of the above factors that influences the metal mass in the cooling liquid and facilitates the formation of elaborate irregular shape casts similar to alluvial precious metal nuggets.

5. Conclusion
The study of pouring the brass and tin melts in the cooling liquid, as well as the analysis of the obtained results, allows determining the technological parameters for quality precious metal imitation nuggets making. For gold imitation nuggets: usage of the cooling liquid (water) within the temperature interval 0-25 °C and the temperature of the metal melt by the moment of pouring, 970 ±5 °C. For silver imitation nuggets: usage of the water within the temperature interval 0-55 °C and the tin melt temperature of 300-400 ±5 °C (depending on the required dendrites amount).

![Figure 4. “Nugget” necklace as an example of gold imitation nugget usage.](image)

Such gold and silver imitation nuggets are a promising material for jewelry design [6]. An example of the practical use of a gold imitation nugget in jewelry is shown in Figure 4.

References
[1] Sorokina V E 2017 *The peculiarities of brass crystallization in the cooling liquid /ISTU Bulletin* 6 pp 128-134
[2] Sorokina V E 2017 Dependence of the metal cast aesthetic parameters on the cooling liquid temperature in making gold and silver imitation nuggets *Proc. Int. Conf. Geosciences-2016* 16 pp 285-289
[3] Turovtseva Z M and Kunin L L 1959 Analysis of gases in metals (Moscow–Leningrad: Academy of Sciences of the USSR)
[4] Chernega D F and Bjalk O M 1982 Gases in nonferrous metals and alloys (Moscow: Metallurgy)
[5] Sorokina V E 2017 On formation of Cu-Zn alloy casts in the accelerated cooling conditions *Foundry engineering* 9 pp 18-21
[6] Von Neumann R 1963 *The design and creation of jewelry* (Philadelphia; New York)