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The Use of Copper-Nickel Alloys for the Production of Art-Industrial Products

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Abstract: The proposed study analyzes the problem of copper-nickel alloy inadequate use in the production of art-industrial products. The dynamics of the origin, composition change and alloy treatment method historical development is observed. The study examined the technological, ecological and aesthetic characteristics of copper-nickel alloy-German silver. The analysis of the alloy physical-mechanical properties in the annealed and deformed state is performed, the heat treatment modes are recommended-recrystallization and complete annealing which shall be applied depending on an alloy deformation degree to eliminate an unwanted hardening-cold hardening. The comparative analysis of physical-mechanical properties and the price of nickel silver and silver alloys is performed, its economic viability is revealed. The prospects of nickel silver use are determined in the production of art-industrial goods and design taking into account current technologies and various types of coatings such as silver coating, radioing, the use of cold enamels. The restriction of nickel silver use for jewelry is specified related with the presence of nickel in an alloy, the recommendations concerning performance problem elimination are provided. The classification of art-industrial products of German silver is developed, uniting two groups of products-jewelry and disposable objects.

Key words: The application of nickel silver, industry, jewelry production, ornament production, copper-nickel alloys, cold hardening, plastic deformation, the heat treatment of nickel silver, the classification of art-industrial products, design

INTRODUCTION

The role of metals and alloys in the development of human civilization is priceless. The first metal products appeared during the late Neolithic period in 5-6 millennium. Copper was one of the first metals obtained by a man. Unlike other native materials copper alloys are durable and easy to process. In ancient world, they were very popular and were widely used for the manufacture of jewelry and various handicrafts and decorative accessories. Even now copper-based alloys are used sometimes in order to manufacture some inexpensive jewelry: copper-nickel alloys (German silver, nickel silver), although these non-ferrous alloys have ample opportunities in the production of art-industrial products.

Under the pressure of industrial production the amazing processing methods of precious metals disappeared. The separation between the mass products of industrial production, made of precious materials and an actual art appeared. Some kind of rearrangement took place. "The study made precious metals with precious stones fell into the category of an expensive haberdashery" (according to M. Ilyn words) (Dronova, 2001). The products made of cheap materials were the result of artists and jewelers creative search, the embodiment of their ideas in a "precious" version lost all meaning.

Nowadays, art-industrial products are classified according to different characteristics, they are divided according to:

- The types of materials (precious and non-precious metals with stones and without stones)
- The manufacturing techniques (casting, stamping, engraving, filigree, etc.)
- The purpose (jewelry, utilitarian objects, dining items, premium products)

In modern jewelry industry and in arts and crafts the production of items made of precious metals is preferred. But the non-ferrous alloys such as nickel silver, German silver, etc. are rarely used for some reason. Today, during the era of crisis economy, taking into account the strategic importance, the use of precious metals, the

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manufacture of jewelry and decorative articles of base alloys is still relevant. Moreover, the introduction of modern technologies in industry reveals new possibilities for their replication.

Modern art-industrial performance from non-ferrous alloys have original design solutions, the versatility and manufacturability. They serve as new modern idea guides, therefore, they compete with the products made of precious metals which are more expensive but are often inferior in design decisions. The expansion of limits, the design application extends the range of design challenges faced by professionals, artists which naturally requires the known reconstruction of their consciousness, deepening and a constant enrichment of professional knowledge and culture as a whole (Kaukina, 2013).

This is reflected in creative works and the works of artists who preferred German silver and nickel silver. This group of artists is presented by I. Shvedov, A. Selivanov, Yu. Savelyev, L. Korneev, Z. Zenkova. At the same time, many exhibition works demonstrate other copper-nickel alloys such as bronze, copper, brass. The researchers of these works were: I. Bykova, V. Naumova, V. Timofeev and V. Zotov. Alloy structures and processing technologies were studied by the following engineers and metallurgists: K. Anderko, E. Brepol, K. Toybol, L.A. Gutov, A.V. Flerov, V.I. Marchenkov. The review of the current state of the problem concerning the use of non-ferrous copper based alloys are reflected in the works written by V.I. Kumanin, L.A. Kovaleva, S.N. Kraynov (Kovaleva *et al*., 2000).

Although, the analysis of the characteristics and the properties of copper-nickel alloys is described poorly, their use in jewelry industry is virtually absent.

The perspective of copper based composition use will open up new technological possibilities of product manufacturing process, will allow to reveal some new ways of jewelery and decorative item shaping with set properties for a wider use in industry and design. It predetermined the relevance of our research.

The presence of some positive technological and aesthetic characteristics for nickel silver such as broad technological capabilities, corrosion resistance, high quality gloss and color, reasonable price-all this distinguishes it from other materials and it conditioned our choice. Based on the foregoing, the need for further research on the use of copper-nickel alloy in the production of art-industrial products becomes an evident one (Kumanin and Livshits, 2012). The expansion of nickel silver alloy use in the design and manufacture of artistically-industrial goods is the aim of our study.

THE HISTORICAL ASPECT OF THE ISSUE

Despite the fact that an alloy is not particularly popular in modern jewelry industry, its origin history is presented by several thousand years and is covered by mysteries and puzzles.

In ancient China casting was highly developed. Multiple utensils and the objects of worship were cast from bronze and copper: elephants, turtles, cranes and many other objects (Kovaleva *et al*., 2000). But numerous defects, obtained during casting, required a serious upgrade of its composition. The first man who solved this problem was the imperial court caster Li Lyan Ying, who invented a new composition by mixing the metal components (zinc, nickel and bronze) in different proportions. The resulting product was a pleasant surprise for the inventor. It was highly flexible and malleable and did not pollute the form during casting.

By the order of the commander and the politician Duke of Zhou, a single metal coin was introduced in the country. But the Celestial Empire at that time had a lack of gold and silver. Thus, it was necessary to create some silver like alloy but from cheaper metals and the court alchemists started to invent it. Li Lyan Ying went to the regent and demonstrated his invention. The new alloy was named pakfong. So in the 8th century BC China had coins, jewelry and decorative items from this new alloy.

It was inexpensive, durable and replaced silver successfully, it melted easily and took the necessary forms. The Empire pakfong casting technology was a state secret, equal to the secret of silk production. In the 13th century Europe obtained pakfong items which attracted a lot of attention. The famous European alchemists Albertus Magnus, Paracelsus and Roger Bacon studied the secret “of Chinese silver”. But the performed studies and experiments did not produce positive results. They were able to establish that copper, nickel and zinc were present in pakfong. However, they failed to obtain such a composition within the terms of industrial production. The next attempt of “Chinese silver” obtaining was performed by German engineers at the end of 15th century. Thus, Saxony inventors managed to get pakfong samples. They called it a new silver or nickel silver. German nickel silver as well as Chinese pakfong was difficult to distinguish from real silver. In the future special varieties of it appeared.

German silver was brought in Russia by Germans. The name survived till modern times. Foreigners quickly adapted the production to the Russian mentality specifics.

Table 1: Characteristics of nickel silver alloy during 8-20th century

Date	Name	Composition	Mechanical properties	Technological properties
8th cent. AD	Pakfong	Cu-Ni	-	High casting
18th cent. AD	German silver	Cu-Ni-Zn	-	High casting
20th cent.	German silver	Cu-main one	σ_B-350 MPa	Ni-5-35%
		Zn-13-29%	δ-35%	High casting properties, may be
		Pb-1.8-5%	tpl-1050°C	machined and processed manually

The name "nickel silver" was not fixed immediately in Russia. The products made of this alloy were often called Polish silver, German composition, etc. But by the middle of the 20th century the name "nickel silver" won. Now this word passed into the category of special terms used in nonferrous metallurgy. And Chinese "pakfong" is found only in history books.

During pre-perestroika period a number of companies existed that were engaged in the production of jewelry and decorative articles made of copper-nickel alloy such as Perm Art Factory, Chelyabinsk Watch Factory, Ekaterinburg and Rostov enterprises. They were closed due to the economic crisis (Kaukina, 2013).

The historical analysis of nickel silver origin showed that, since the 8th century AD and to this day its name, properties and methods of treatment CHANGED (Table 1). There are many compositions of this alloy in current conditions, it became more technological and had not only good casting properties but is also processed splendidly using machines and in an manual mode.

SPECIFICATIONS OF GERMAN SILVER AND ITS ADVANTAGES

During the performance of practical studies, we found that the most abundant compound in the manufacture of art-industrial goods in Russia is nickel silver of MNTS brand 15-20 (Cu, Ni-15%, 20% of Zn). It has high optical performances, high values of color and gloss, does not oxidize in air, resistant to salt solutions and aggressive acids, i.e., it is a chemically resistant material. Also, it is widely used in the instrument production for the manufacture of technical utensils and medical instruments.

During the study of physical-mechanical, chemical and technological properties, we found that the alloy may be used for the manufacturing of art-industrial products by different techniques: bending, stamping, casting, etc. As nickel silver was compared always with silver we carried out a comparative analysis of these alloys (Table 2).

During the manufacture of products made of German silver MNTS 15-20 (Cu; Ni-14.2%; Zn-20.8%) and the samples made of 925° silver (Ag-92.5%; Cu-7.4%) the following features were revealed the reduction of nickel silver plasticity, even with little deformation. This complicates significantly the process of product soldering and mounting. Silver alloys have very high ductility indices, the hardening during deformation is absent, making it easier to work with this alloy but since the melting temperature is lower than that of nickel silver some difficulties arise during item soldering. After the study of deformed and annealed nickel silver properties we have the following results:

- The breaking strength σ_B in the annealed condition makes 350 MPa and relative elongation (δ) makes 35%
- δ in the deformed state the tensile strength makes 550 MPa and relative elongation (δ) makes 1%

Along with numerous advantages the investigated alloy has a significant drawback, the ability of hardening (cold hardening). This feature is by the presence of nickel in an alloy which causes a number of difficulties in the practical use of the products. In order to eliminate an unwanted hardening we recommend alloy thermal treatment modes. They are presented as follows: at little plastic deformation of an alloy of up to 10% it is necessary to conduct the recrystallization (recovery) annealing at t-270±310°. If the deformation degree exceeds 15% or more, it is necessary to use conditioned full annealing at the temperature of 680±710° to remove an internal stress and return some plasticity. The compliance with these thermal conditions will allow to avoid some unwanted defects during the production of art-industrial products.

Analyzing the studied alloys, it is necessary to draw attention to such an important indicator as price. Nickel silver in this regard is best of all. According to the latest economic summaries the cost of silver alloy ranges from 30-32 rubles per gram of refined metal and 14.5 US dollars per ounce. The dynamics of price increase for precious metals is observed since 2005. The market price of nickel silver makes 940-1150 rubles per kilogram. The difference in price makes >30 times. All above mentioned details are shown in Table 3.

Despite all the foregoing, the application issue on the use of alloys in the industry remains open. On this basis, we propose a number of recommendations for further universal application of the composition in the artistic-industrial products on the basis of the developed

Table 2: The compositions and properties of studied alloys in an annealed condition

	Composition							
Alloy	Cu (%)	Ni (%)	Zn (%)	Ag (%)	tpl (°C)	δ (%)	σ_B (MPa)	HB
MNTS 15-20	65.0	14.2	20.8	-	1050.0	35	350	70
Silver 925°	7.4	-	-	92.5	960.5	41	260	57

Table 3: Comparison of mechanical properties, the cost of silver alloy (925°) and nickel silver

	Compositions			
	MNTS		Cpm (900°-925°)	
Indicators	Deformed	Annealed	Deformed	Annealed
δ (%)	1	35	4	35-43
σ_B	550	350	450-500	310-240
Price in rub. per 1 g	0.94-1.15		30.4-32.2	

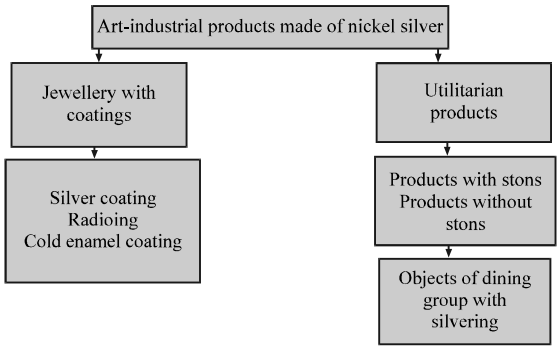

Fig. 1: Classification of artistic industrial items made of nickel silver

classification (Fig. 1). We offer to divide the existing types of products into two groups: utilitarian group decorations and jewelry. Speaking of jewelry one needs to specify the current limit. It is presented in the following: all nickel alloys may provoke allergic reactions on skin. According to statistics >50% of women are prone to such manifestations. This fact can not be ignored and we recommend the use of special coatings for jewelry group such as silver coating, radioing, cold enamels to eliminate undesirable consequences. In the framework of modern production these technologies are very real and do not require large financial costs. This restriction is not necessary for utilitarian group of products, except for tableware which are silver coated traditionally.

SUMMARY

Summarizing our study we can say that in the production of artistic and industrial products the prospects of copper-nickel alloy-nickel silver use is quite obvious. It is proved by its technological characteristics and economic viability. Moreover, stipulating the restrictions on the manufacture of jewelry, we open new opportunities not only for the safe use of the alloy but also the enormous potential of design solutions and the creative ideas of designers. The use of different types of coatings provides unlimited opportunities for the range of products expansion. These positions require additional study which proves the versatility of the German silver prospects use and the relevance of the trend we chose.

CONCLUSION

- The use of copper-nickel alloys is known since the 8th century AD changing the composition, name, properties and methods of treatment
- The changes of tensile strength σ_B and relative elongation δ values in annealed and strain state established the tendency of nickel silver to the formation of hardening-cold hardening
- The heat treatment modes of nickel silver are proposed to eliminate an unwanted alloy stress depending on the degree of deformation
- An alloy use limitation and the ways of its elimination are stipulated
- The prospects of the alloy use in the production are determined taking into account modern technologies, the classification of artistic-industrial products made of German silver is proposed

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