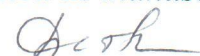


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Yulia D. Ditkovskaya

**RESEARCH OF TECHNOLOGY FOR
NEW 14-CARAT GOLD ALLOYS WIRE PRODUCTION AND
DEVELOPMENT OF SOFTWARE FOR ITS SUPPORT**

Master's Program Metal and Alloys Forming Under Pressure

The abstract of the Master's Thesis

Krasnoyarsk 2014

The thesis work is done at the Department of «Metal Forming Under Pressure» Federal State Autonomous Educational Institution of Higher Professional Education «Siberian Federal University»

Scientific supervisor:

Doctor of Engineering, Professor Sergey B. Sidelnikov

Peer Reviewer:

Evgeniy A. Pavlov, PhD of Engineering, Head of precious metals obtaining and their alloys control laboratory, JSC "V.N. Gulidovs Krasnoyarsk Nonferrous Metals Plant"

Defence takes place on July 2, 2014 at FSAEI HPE "Siberian Federal University":
95, Krasnoyarsky rabochiy ave, 104 lecture room, Krasnoyarsk 660025, Russia

Head of the Master's program:

Doctor of Engineering,
Professor



S. B. Sidelnikov

INTRODUCTION

The topicality of thesis. Nowadays white gold alloys, based on gold and palladium or nickel, with red gold alloys are becoming especially popular with the increasing demand for jewelry in 14-carat gold. They have a noble white color and luster, and are used as a substitute for expensive platinum. In this regard much attention is paid to the creation of new white gold alloys with improved mechanical and operating properties. Introduction of new materials into production, in its turn, requires multivariate calculations for improving existing or new production technology design for jewelry manufacturing. Such calculations are expedient to be carried out with automated design (CAD) systems.

Improvement of materials, processing technology, design and modeling of technological processes with the help of specialized software is an important task in the development of jewelry production and processing of non-ferrous metals in general.

This thesis has been carried out as a part of research commissioned by the Ministry of Education and Science of the Russian Federation on the topic T-7 "Creating of New Precious Metals Alloys with High Operational Characteristics and Research of their Properties".

Subject of investigation is improving of precious metals alloys and processing modes; development of software for long length deformed semi-finished production technologies support.

The purpose of thesis is competitiveness and efficiency improving for jewelry chains production in 14-carat gold alloys.

There are several **tasks** to reach this purpose:

- development of new compositions and preparation methods of 14-carat gold alloys;
- research of long length deformed semi-finished products technology for manufacturing of jewelry chains used in industrial environments;
- development of software for the analysis and design of technological processes of precious metal alloys wire production, as well as the design of the rolling tool calibration system;
- creation of a software module for the simulation of the rolling tool and its manufacturing on CNC machines;
- design of rational routes for new 14-carat gold alloys processing.

The scientific novelty

1. Based on the experimental data dependencies characterizing the change strength properties (tensile strength σ_b and yield strength σ_T) on the degree of deformation for new white and red 14-carat gold alloys were obtained.

2. Methods were improved and algorithms were developed to determine the deformation modes and power parameters of cold section rolling and drawing processes for precious metals and alloys.

The practical significance of thesis

1. A method of modifying of alloys based on 14-carat gold (RF patent number 2507284) and new red 14-carat gold alloy composition (RF patent number 2514898) were developed.

2. New modes of cold section rolling and drawing were proposed. They provide improved efficiency of production jewelry chains in 14-carat gold, the performance level of jewelry chains was increased.

3. Software to design precious metal alloys wire manufacturing processes and calibration as well as model of the rolling tool and its processing were developed. This program has no analogues in the design of cold processes for non-ferrous metals.

4. The results can be used in jewelry production and introduced in the educational process for the training of bachelors and specialists in the field of metal forming under pressure.

Personal contribution of the author

All research results were obtained in collaboration with the personal involvement of the author, the main ones are as follows: the development of algorithms and software for support of precious metals wire production technology; processing, systematization and analysis of the new 14-carat gold alloys properties research; getting dependences characterizing the properties of new alloys.

Place of thesis realization. Metal Forming Under Pressure Department of Institute of Nonferrous Metals and Materials, Federal State Autonomous Educational Institution of Higher Professional Education "Siberian Federal University".

Place of International internship. Delcam plc (Birmingham, United Kingdom).

Approbation of thesis results. Main ideas of work have been presented at the following conferences and congresses: Annual International Scientific Ural Workshop of metallurgists - young scientists (Ekaterinburg, 2011), the International Conference "Scientific research and its practical application. Current status and the development of '2012 '(Odessa, 2012), the annual International Congress «Non-Ferrous Metals" (Krasnoyarsk, 2012, 2013.), International Scientific and Technical Conference "Modern technologies of materials processing pressure: modeling, design, production "(Moscow, 2013), International scientific-practical conference "Scientific potential of the world" (Sofia, 2013), the International Scientific Conference "Applied Sciences and technologies in the United States and Europe: common challenges and scientific findings " (New York, 2013), Annual All-Russia Scientific Conference of Siberian Federal University with international participation "Youth and Science" (Krasnoyarsk, 2011-2014.); at the annual exhibition of innovative projects and scientific and technical developments within the citywide Assembly "Krasnoyarsk. Technologies of the Future "(Krasnoyarsk, 2014).

Published works. Results of thesis are presented in 17 publications, two of which were published in journals included in the list of recommended publications by the higher certifying commission, as well as 2 patents for inventions.

Volume and structure of thesis. The thesis consists of an introduction, three chapters and a conclusion. It contains 85 typewritten pages, 23 drawing, 17 tables, bibliography of 42 positions and 1 application.

CONTENTS OF THESIS

In Introduction the topicality of the project is grounded and the purpose of the work is formulated as well as its novelty and practical significance are noted.

In the first chapter modern trends of precious metal alloys jewelry chains production were examined, a patent search of technical solutions for the white 14-carat gold composition alloy, technology used in industrial environments, equipment and system calibration for section rolling were conducted. The review of existing CAD and programs for process modeling, analysis of research results for section rolling in rhombic caliber and methods of determination of metal forming and power parameters of the process were presented.

The analysis of scientific, technical and patent literature is followed by the conclusions:

1. One of the main trends in the development of the jewelry industry is the development and introduction in manufacturing new nickel-free white 14-carat gold alloys with improved mechanical properties and reduced finished jewelry cost.

2. Since the basic operations in the technology of long length deformed semi-finished products manufacturing for jewelry chains production are cold sheet, section rolling and drawing, it is necessary to develop rational routes of these processes.

3. Existing software products are unsuitable for the design of cold non-ferrous metals, particularly precious alloys, processing. This determines the relevance of CAD development for processes of cold sheet, section rolling and drawing, considering the specificity of the technological processes used in the production.

4. It is expedient to develop a program to simulate the rolling tool and its manufacturing on CNC machines.

The tasks of work were formulated based on the findings.

In the second chapter algorithms and methods of metal forming and power parameters calculation for cold section rolling and drawing, which became the basis of the developed "PROVOL" CAD, are presented. Program is realized in the Delphi programming environment and includes three basic modules for the processes design that can be used alone or in combination for the calculations in accordance with applicable in manufacturing technology. A view of "PROVOL" window for section rolling design is presented at figure 1.

Software database allows to work with a wide range of modern equipment and materials. Visualization modules may represent the results of calculations in the form of tables and graphs dependencies, generate reports in software product MS Excel.

The program allows to design calibers of section rolling, create drawings and export them in AutoCAD.

During the international internship CAD module for modeling of rolling tool and its manufacturing in Feature CAM system (Delcam plc development) was designed. Ready NC-code for making roll on turn-mill CNC equipment is generating automatically. The resulting 3D-model can be used for section rolling modeling, for example, in the DEFORM-3D software package.

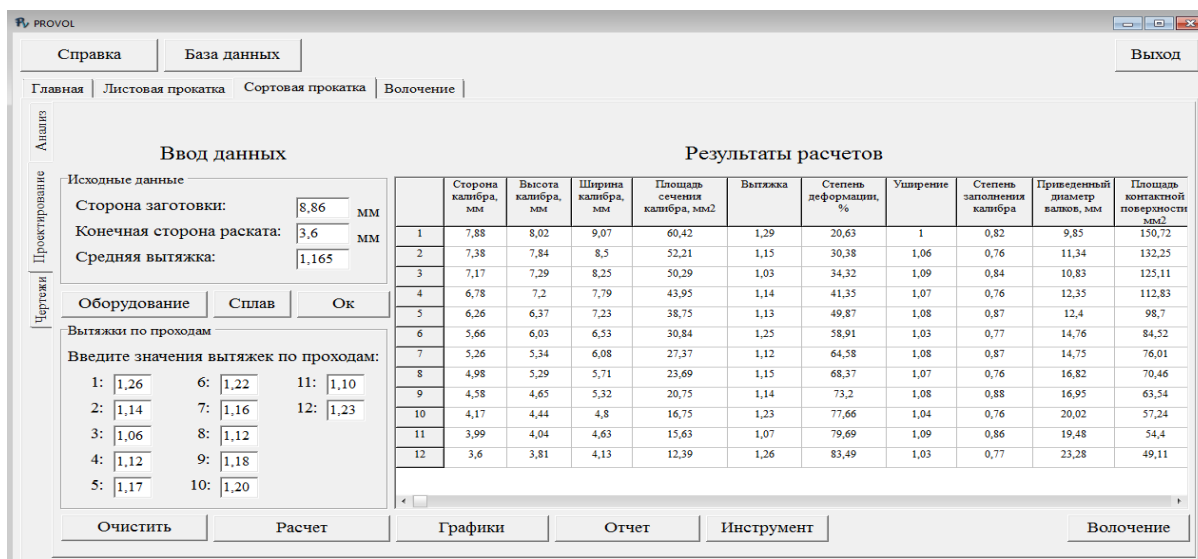


Figure 1 - The program window for section rolling design

Section rolling modes used in the manufacturing of semi-finished products in 14-carat gold have been analyzed by means of the "PROVOL" program, their irrationality was revealed, ways of improving were identified.

In the third chapter the results of pilot new 585 standard white gold alloys production testing in V.N. Gulidovs Krasnoyarsk Nonferrous Metals Plant (JSC "Krastsvetmet") are presented. The chemical composition and properties of new alloys (№2 and 3) and the known alloy (№ 1) are shown in Tables 1 and 2. The research showed that new alloys have high mechanical properties, fine grain structure and good processability which provide high consumer characteristics wire production.

Table 1 - Composition of white 14-carat gold alloys

Alloy marking	The chemical composition of the alloy, the mass fraction of component, %								Density, g / cm ³
	Au	Ag	Pd	Cu	Zn	Ni	In	Ru	
Alloy №1	58,5	-	-	25,0	4,0	12,5	-	-	12,70
Alloy №2	58,5	26,0	8,0	5,5	1,5	-	0,5	0,01	15,63
Alloy №3	58,5	21,6	10,0	8,4	1,5	-	-	0,01	15,63

Application of ruthenium as a modifier required a new method of its intrusion into the melt search, because the known methods of modifying don't provide enough solubility in gold because of the high melting temperature that leads to lower modifying effect. To improve the quality and grain refinement of the bars structure a new method of alloys modifying was developed and patented. It provides an accurate quantity determination of the ruthenium injected into the melt, complete assimilation of the modifier, in connection with what cast and deformed semi-finished products have a uniform fine-grained structure throughout the length and cross section of the bar (RF patent 2507284).

Table 2 - Mechanical properties of deformed white 14-carat gold alloys workpieces

Section rolling pass	Deformation scheme	Alloy №1		Alloy №2		Alloy №3	
		σ_B , MPa	δ , %	σ_B , MPa	δ , %	σ_B , MPa	δ , %
The first	$\varnothing 8 \rightarrow 3,7 \times 3,7$	814,7	0,6	942,4	3,6	940,1	4,0
The second	$3,7 \times 3,7 \rightarrow 2,1 \times 2,1$	1011,1	1,2	752,7	2,6	881,0	2,4
The third	$2,1 \times 2,1 \rightarrow 1,1 \times 1,1$	1014,5	2,7	660,5	1,9	819,9	1,5

Proposed and patented a new red 14-carat gold alloy composition having improved operational and strength characteristics (RF patent number 2514898).

Table 3 - Empirical formulas for determining of the strength characteristics of white 14-carat gold alloys

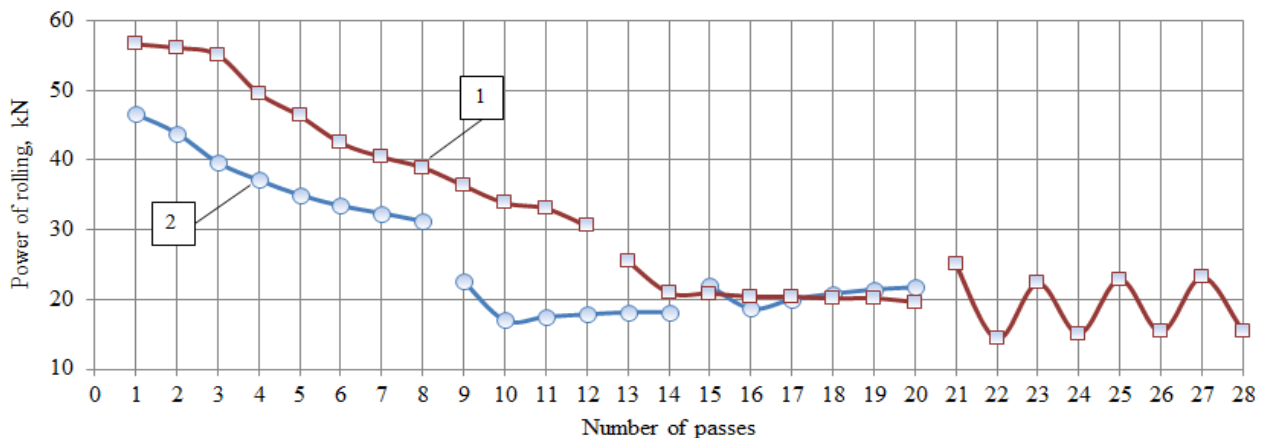
Alloy marking	Mechanical properties	Dimensionless coefficients		
		<i>a</i>	<i>b</i>	<i>c</i>
Alloy № 1	σ_B	0,096	-0,9212	438,5
	σ_T	0,092	-0,0452	269,5
Alloy № 2	σ_B	0,001	4,7385	516,5
	σ_T	0,021	1,6162	346,3
Alloy № 3	σ_B	0,009	3,0603	550,3
	σ_T	0,019	3,6589	388,0

In the results of test empirical dependences for calculating the ultimate tensile strength (σ_B) and yield point (σ_T) of the value of the accumulated deformation (ε) were obtained:

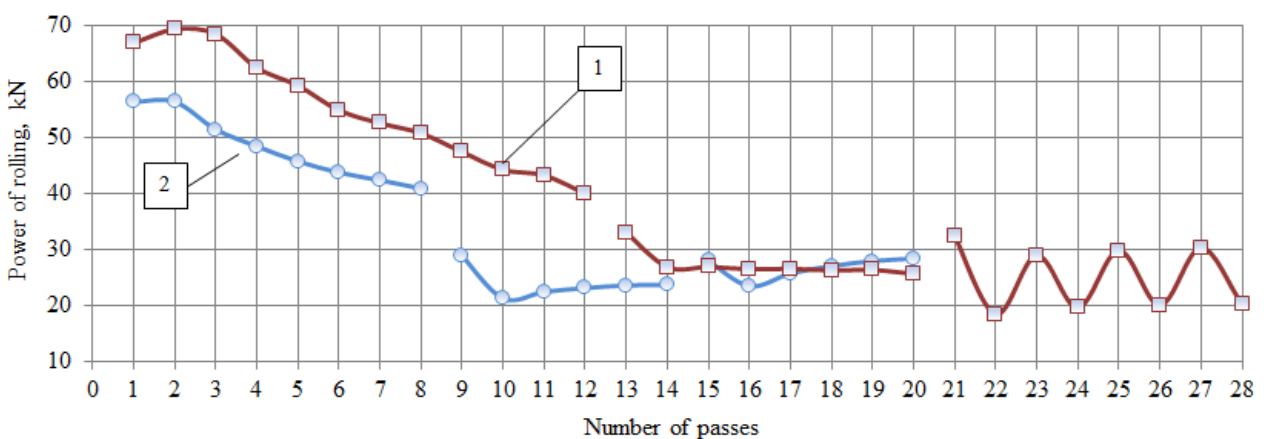
$$\sigma_B = a \cdot \varepsilon^2 + b \cdot \varepsilon + c, \quad (1)$$

$$\sigma_T = a \cdot \varepsilon^2 + b \cdot \varepsilon + c, \quad (2)$$

wherein *a*, *b* и *c* – dimensionless coefficients (Table 3).



a



b

Figure 2 – Changes of force on applied (1) and proposed (2) section rolling routes for new white 14-carat gold alloys: *a* - alloy №2, *b* - alloy №3

New section rolling routes are designed with help of developed "PROVOL" CAD for new 14-carat gold alloys (Figure 2). Their application allows to reduce the number of passes, align energy-power loading of equipment, ensure uniformity of workpiece deformation by passes, and thus, to improve the quality of the finished product.

In conclusion the main conclusions and results are presented.

CONCLUSION

1. A new method of gold alloys modifying (RF patent number 2507284), providing a precise definition of the amount of modifier injected into the melt, its complete assimilation, uniformly fine grain structure of semi-finished products, the high quality and effectiveness of modification, was developed and patented.

2. Proposed and patented a new red 14-carat gold alloy composition having improved operational and strength characteristics (RF patent number 2514898).

3. Experimental research of new white 14-carat gold alloy compositions were conducted, equations of their mechanical properties dependence on the deformation degree are defined. A database on the mechanical characteristics of materials is created.

4. Existing technology used in production is analyzed, its weaknesses and ways to improve are identified.

5. A "PROVOL" program allowing to design a complex of processes and based on the author's methodics of metal forming and power parameters determination for cold rolling and drawing is developed.

6. A software module for simulation of rolling tool and its manufacturing, that allows to go from section rolling and calibration design to the production process modeling and manufacturing of rolls is created.

7. By means of the developed program new modes of section rolling and drawing for new white and red 14-carat gold alloys, having increased technical and economic parameters, are designed.

Thus, results of thesis allow to improve the technology of new 14-carat gold alloys wire production for jewelry chains. The results can be recommended to introduction in the educational process and in the production with further expansion of precious metal alloys line and application of software for their processing modes calculation.

MAIN PROVISIONS OF THESIS ARE PUBLISHED IN THE FOLLOWING PAPERS:

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8. **Gaylis, Y. D. (Ditkovskaya, Y. D.)** Software for the technological parameters design for production of long semi-finished white 14-carat gold products / Y. D. Gaylis // Youth and Science: Materials of Conf.: 3 vol. / edited by O.A.Kraev. - Krasnoyarsk Sib.feder.un-t, 2013. - P.195 - 200.

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14. **Ditkovskaya, Y. D.** Tool simulation for section rolling of bars in precious metals and their alloys / Y.D.Ditkovskaya // Youth and Science: All-Russian conference with international participation [electronic resource]. - Krasnoyarsk Sib.feder.un-t, 2014. Mode of access: http://conf.sfu-kras.ru/sites/mn2014/pdf/d03/s10/s10_006.pdf. - Caps. from the screen.

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