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STUDY OF THE MECHANICAL PROPERTIES OF WIRE ROD FROM THE NEW ALUMINUM ALLOYS AL–TM AND AL–REM

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»

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Doctor of Engineering,
Professor Sergey. B. Sidelnikov

GENERAL DESCRIPTION OF THE THESIS WORK.

Significance of the work. The characteristic feature of the metallurgical enterprises development in the Krasnoyarsk region is the creation of powerful industrial centers for the manufacturing of bar stock profile production from aluminum alloys. The problems of press production mastering led to the studies development of the mechanical properties of deformed semi-finished products obtained by hot pressing of different aluminum alloys.

Aluminium and its alloys due to its unique technology performance characteristics occupy an important place in modern industry. Having such properties as electrical conductivity and high corrosion resistance in combination with low weight led to the fact that aluminum and alloys thereof have been widely used in engineering, electricity, truck, aircraft, etc.

Extruded semi finished products (profiles rods, tubes, plates, etc.)are made from aluminum alloys, the main ones are Al-Mn, Al-Mn (Mg), Al-Mg-Si (Avia), Al-Cu-Si (duralumin), Al-Si (silumins), Al-Zn-Mg, AL-Zn-Mg-Cu, Al-Cu-Mg-Ni-Fe, Al-Cu-Mg-Si, etc. In connection with this the area of study of the mechanical properties has considerably expanded and the necessity of the research of pressing production technologies goes without saying. We should consider very important the fact that there appeared the new developments in the field of press items manufacturing from such aluminum alloys as Al-Ti-B, Al-Zr, Al-Ce, Al-Li, etc., produced by means of casting, metal forming, pelletizing, and other processing techniques.

The technology of long items production from such alloys is characterized by high energy and labor intensity. Thus during various stages of the metal deformation defects can be formed; they cause a technological mode failure which in its turn does not allow to manufacture such deformed semi-finished products with high efficiency. However, the new alternative technologies of combined processing have now been proposed. Thus, the study of mechanical properties of semi-finished products produced by such methods of processing from new aluminum alloys is an important task of scientific research.

The subject of the research is processing modes of the new aluminum alloys of *AL–TM* and *AL–REM* systems.

The aim of master's thesis is improving the efficiency of wire rod production for electrical purposes from the new aluminum alloy of systems AL-TM and AL-REM.

Objectives of the research:

– to develop new technical solutions for creating devices for the combined processing of alloys of Al-REM and Al-TM;

– to conduct pilot studies on preparation of electro-rod from the alloys combined with methods of processing and to determine the mechanical properties of the metal at room temperature.

– to modernize the installation of torsion tool, to develop a useful model and to prepare it for the research;

– to plan and to conduct the research experiment of wire rod rheological properties from these alloys in a predetermined temperature range, the degree and rate of deformation.

– to obtain equations for the rheology of the alloys and to conduct metal deformation resistance depending on the temperature-speed processing parameters.

Scientific novelty of this work:

1. The technique for determining the rheological properties of metals and alloys by hot torsion has been improved.

2. The dependences of the mechanical properties on deformed semi-finished products from alloys *Al-TM* and *Al-REM* obtained by stretching were received.

3. Based on the experimental data, the dependences describing change of the resistance to deformation (σs) of new aluminum alloys of the Al-TM and Al-REM on the degree of (ε), velocity (ξ) and temperature (T) deformations were obtained.

Practical importance of the work:

1. There were obtained data on resistance deformation of new alloys *Al-TM* and *Al-REM*, used in calculations of power parameters and design of equipment for electrical wire rod at the Irkutsk aluminum smelter.

2. The tool was improved and a patent of the Russian Federation № 138590 on the device for continuous rolling and extrusion items of non-ferrous metals and alloys was received.

3. The equipment for obtaining the rheological properties of the metal by hot torsion was improved and a patent of the Russian Federation № 130708 was received.

4. Results of research have been implemented in the learning process and are used in the training of bachelors and specialists in the field of metal forming.

Personal contribution of the author.

All study results were obtained in collaboration with the personal involvement of the author, the main ones are: the development of a device for the continuous rolling and extrusion items of non-ferrous metals and obtaining experimental batches of rods of the alloys; modernization of installations for torsion testing; Pilot studies and getting dependencies characterizing the rheological properties of new aluminum alloys of *the Al-TM and Al-REM*.

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

Place of international internship. International Academy of Management and Technology «INTAMT» (Dusseldorf, Germany).

Work approbation:

Obtained results of dissertation and its separate parts were reported at:

- Annual International Congress «Non-Ferrous Metals" (Krasnoyarsk, 2012, 2013.)

- Annual All-Russian Scientific Conference of Siberian Federal University with international participation "Youth and Science" (Krasnoyarsk, 2012-2014 gg.)

- Annual exhibition of innovative projects and scientific and technical developments within the citywide Assembly "Krasnoyarsk. Technologies of the Future "(Krasnoyarsk, 2012-2013).

Publications. Results of the thesis are reflected in 5 printed works, as well as in 2 patents.

Volume and structure of the dissertation. The thesis consists of an introduction, three chapters and a conclusion. It contains 88 pages of typewritten text, 31 figures, 28 tables, bibliography of 75 titles.

CONTENTS OF WORK

Introduction. Relevance of dissertation work is proved, the purposes and research problems are formulated, objects and subjects of researches are defined.

Chapter 1 analyzes the available scientific and technical literature research results of the mechanical properties of aluminum alloys and discusses approaches of various authors to such issues as resistance to deformation of the metal depending on temperature range and deformation processing conditions. The equipment and the procedures in the study of mechanical properties of the metal by twisting and stretching are described.

The analysis of the structure formation and fast-graining aluminum-based alloys with rare earth and transition metals(used for the manufacture of wire for electrical purposes) properties was conducted. The features of long deformed semi-finished products manufacturing by means of the casting-rolling units (CRU), a combined rolling-pressing (CRP) and the combined casting and rolling, pressing (CCRP) were considered.

Chapter 2 represents the results of experimental research on the production of wire rod from alloys of *Al-TM and Al-REM* by combined method with the using an improved tool (Fig. 1) to produce long products of non-ferrous metals and alloys (patent number 138590).

Figure 1 - General view of the matrix for CRP

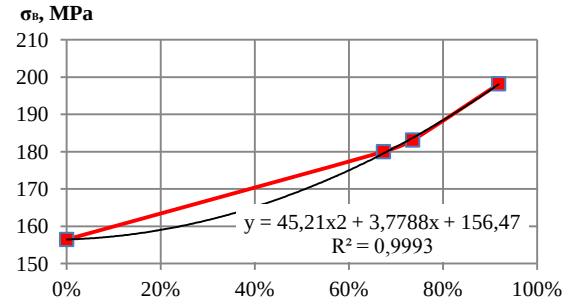
Methods of obtaining wire rod from the investigated alloys used for electrical products on continuous casting and combined metal forming equipment were described. There was presented the chemical composition of the alloys studied (Table

1) and the technical parameters of the equipment on which wire rod for research was obtained.

Table 1 - Chemical composition of the alloys

Alloy	Content, %				
	Al	Fe	Zr	REM	Si
Zr–1	Basis	0.273	0.2645	–	0.071
Zr–2	Basis	0.288	0.1980	–	0.067
REM –1	Basis	–	–	He > 0.5%	–
REM –2	Basis	0.6	–	7.0–9.0	0.3

The mechanical characteristics of the investigated by stretching alloys was analyzed. Equations are obtained that allow to calculate the temporary tensile strength of the metal (Fig. 2) and an elongation depending on the degree of deformation.



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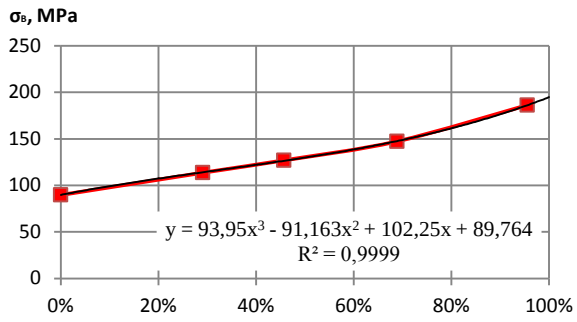

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Figure 2 - Plots of tensile strength on the degree of deformation for Zr-1 (a) and alloy REM -1 (b)

Chapter3 presents the experimental studies results of the new alloys rheological properties of the hot torsion method. There is given the composition for the retrofitted plant for hot torsion tests (patent number 130708), where the heating of the samples occurs in the molten salt, and it is described how it works.

The plan of the experiment for the study of these alloys rheological properties at four various temperatures and speed parameters for extrusion processes were compiled. Varying levels and units of measurement process of factors deformations for the experimental alloys are presented in Table. 2.

Table 1 - levels Varying factors of the experiment

Factors	Units of	Varying factors

n	Name	Designation	measurement	1	2	3
1	The heating temperature of the preform	T	°C	320	400	550
2	Strain rate	ξ	c^{-1}	0,5	1,5	10

The studies results based on this plan of experiments is a graph of deformation resistance σ_s dependence on the degree of deformation ε at different strain rates ξ one of which is shown in Figure 2.

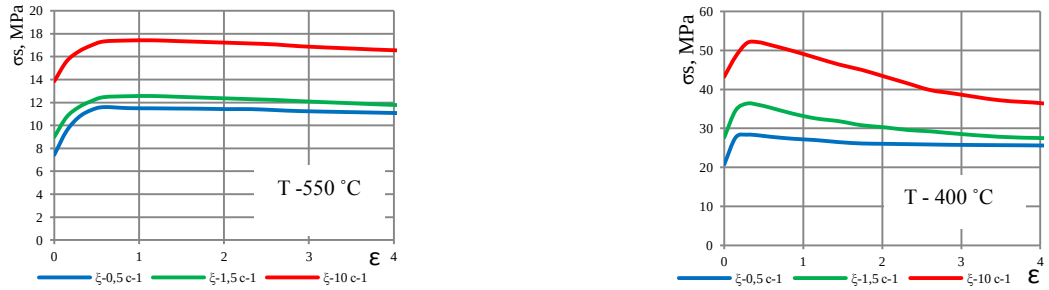

Figure 3 - Dependence of deformation resistance σ_s Zr-1 on the degree of deformation ε at different strain rates and temperatures ξ

Regression equations are given for calculating the deformation resistance for these alloys obtained from the experiments carried out on the hot rolling tool at different temperature and speed conditions. Data are presented in Table. 3.

Table 2 – Regression equations for determining the deformation resistance σ_s Zr–1 at different temperature and speed conditions

Measured variable	Spacing	Strain resistance
T, °C	320–400	$\sigma_s = 30{,}81 - 11{,}41\left(\frac{T-360}{40}\right) + 2{,}81\left(\frac{\xi-1}{0{,}5}\right) = 129{,}59 - 0{,}29T + 5{,}62\xi$
ξ, c^{-1}	0,5–1,5	
T, °C	400–550	$\sigma_s = 13{,}81 - 5{,}58\left(\frac{T-475}{75}\right) + 1{,}98\left(\frac{\xi-1}{0{,}5}\right) = 45{,}19 - 0{,}0744T + 5{,}94\xi$
ξ, c^{-1}	0,5–1,5	
T, °C	320–400	$\sigma_s = 38{,}2 - 11{,}88\left(\frac{T-360}{40}\right) + 4{,}58\left(\frac{\xi-5{,}75}{4{,}25}\right) = 138{,}9 - 0{,}3T + 1{,}1\xi$
ξ, c^{-1}	1,5–10	
T, °C	320–400	$\sigma_s = 18{,}3 - 8{,}025\left(\frac{T-470}{75}\right) + 2{,}5\left(\frac{\xi-5{,}75}{4{,}25}\right) = 65{,}745 - 0{,}107T + 0{,}588\xi$
ξ, c^{-1}	1,5–10	

A graphic description of the results calculated by the equations derived is presented as well.

MAIN RESULTS

Analyzing the results of the research the following conclusions can be made:

1. To increase the efficiency of long profiles production by means of combined rolling extrusion the equipment that outperforms the earlier design was developed and patented (patent number 138590 Russian Federation).

2. Experimental studies on obtaining electrical rod from alloys of Al-TM and Al-REM using combined methods of processing and defined mechanical properties of the metal at room temperature are conducted.

3. The hot rolling equipment was improved (patent number 130708 Russian Federation),the utility model for this tool was developed and patented. The developed equipment complies with all the requirements for testing machines, it is equipped with modern registration resistance strain gauges, optical, thermometric equipment, easy to use and has a cost much lower than that of the modern equipment of foreign analogues.

4. Research analysis shows high accuracy of the results determining the rheological properties obtained on the torsion tool, used for the calculation of power parameters and designing of new equipment of combined processing at the Irkutsk aluminum smelter.

5. A series of studies of the rheological characteristics of the four new aluminum alloys were conducted, the graphs of the change in resistance of metal deformation in a given temperature range, the degree and rate of deformation characteristic of the pressing process are presented.

6. Regression formulas to describe the rheological properties of these alloys describing the obtained experimental depending with high accuracy are carried out.

7. Research results are applied in the training course in teaching students on the major 150400 "Metallurgy".

CONCLUSION

Thus, the new scientific knowledge needed to develop the technology of the new wire rod from aluminum alloys with transition and rare-earth metals were obtained. These alloys are actively used in recent years in the electrical industry for the production of electrical conductors. The results obtained were used for the calculation of power parameters and process parameters of combined processing equipment which currently being implemented at the Irkutsk aluminum smelter.

Fundamental principles of the thesis are rendered in publications:

1. **Samchuk, AP** Preparation of long semi-finished products from deformed alloys of Al-REM using continuous processing methods / Sidel'nikov SB, Dovzhenko NN, Voroshilov DS, Trifonenko LP Galiyev RI, Lopatin E.S ., Samchuk, AP / D 27 Non-ferrous metals 2012: Coll. Nauchn. Articles. - Krasnoyarsk: Verso, 2012. - 1044 p., P. 794-801

2. **Samchuk AP** Research complex to determine the rheological properties of deformed semi-finished non-ferrous metals / AP Samchuk / / M75 Youth and Science: compendium of IX All-Russian scientific and technical conference of students and young scientists with international participation, dedicated to 385 anniversary of the founding of the city of Krasnoyarsk [electronic resource], Br. Ed. O.A.Kraev - Krasnoyarsk: Sib. Fader. Univ., 2013

3. **Samchuk, AP** Investigation of receipt of long semi-finished products of aluminum alloys with different contents of rare earth metals. / NN Dovzhenko, SB Sidel'nikov, TN Drozdov, DS Voroshilov, SL Yakovlev, A.P.Samchuk / / Non-ferrous metals 2013: Coll. Nauchn. articles. - Krasnoyarsk: Verso, 2013.

4. **Samchuk, AP** Methodology of rheological properties of aluminum alloys and installation for their study / A.P.Samchuk Special engineering education - training of modern engineering personnel [electronic resource]: I theses regional scientific conference undergraduates November 19, 2013 / / Sib. a fed. Univ; Num. for MY. EA Shipilova. - Electron. text data. (PDF, 14,8 MB). - Krasnoyarsk: SFU, 2013.

5. **Samchuk, AP** Study of the rheological characteristics of the new deformed semi-finished aluminum alloys / AP Samchuk / / Youth and Science: All-Russian conference with international participation [electronic resource]. - Krasnoyarsk Sib.feder.un-t, 2014.

6. Patent of the Russian Federation № 138590, IPC V21S. Device for continuous rolling and extrusion products from nonferrous metals and alloys / Sidel'nikov SB, Bespalov VM, Dovzhenko NN Belyaev SV, SV Soldatov, Trifonenko AL, Samchuk AP Burlutskaya DM; applicant and patentee Federal State Autonomous Educational Institution of Higher Professional Education "Siberian Federal University."; appl. 20.11.2013; publ. 20.03.2014.

7. Patent of the Russian Federation № 130708, IPC G01N3/22. Equipment for torsion testing / Sidel'nikov SB, Dovzhenko NN Belyaev SV Grishchenko NA, Samchuk AP Gubanov IY, Lopatin ES Galiyev RI; applicant and patentee Federal State Autonomous Educational Institution of Higher Professional Education "Siberian Federal University."; appl. 07.03.2013; publ. 27.07.2013.