Printed as manuscript

Tatiana Yu Gorokhova

COMPUTER MODELING AND DESIGNING OF A COMBINED CASTING-EXTRUSION PROCESS

Master's Program Metal and Alloys Forming under Pressure

The abstracts of the Master's Thesis

Krasnoyarsk 2017

The thesis work is done at the Department of "Metal Forming under Pressure" Federal State Autonomous Education Institution of Higher Professional Education "Siberian Federal University"

Scientific supervisor:

Professor, Doctor of Engineering, Sergey V. Belyaev

Peer Reviewer:

Head of the department of the workshop №19 OAO "Krastsvetmet", Candidate of Engineering, Evgeny A. Pavlov

Defense takes place on June 27, 2017 at FSAEI HPE "Siberian Federal University": 95, Krasnoyarsky rabochiy ave, 212 lecture room, Krasnoyarsk, 660025, Russia

Head of the Master's program:

Doctor of Engineering,

Professor  Sergey B. Sidelnikov

INTRODUCTION

Topicality of thesis: Many of modern fields of industrial production are aimed at the development of high-tech welding methods, which can significantly increase the efficiency of the production of aluminum details, for instance, waveguides. However, the development of welding technologies faces with difficulties in the production of high-quality welding aluminum wire (WAW) and ligature rods. The conventional technology of their manufacture consists of many stages of metal working and heat treatment operations, such as melting, casting, heat treatment, cutting, metal forming.

Nowadays the problem of increasing the efficiency of production of competitive products is one of the most important. It is especially topical for the production of long products from hard-to-deform non-ferrous metals and alloys. The solution to this problem is about reducing intermediate technological operations. It allows use the internal heat of the cast billets more efficiently, reduces metal losses during heat treatment and cutting billets. For this purpose it is necessary to improve the existing technological processes of production of long products and also create new technology, based on integrated and combined devices and units, that could reduce the number of stage, reduce the costs, time and energy consumption.

One of the effective methods for the production of WAW and ligature rods is the combined process of casting and extrusion. Previous research has developed some alternative technologies. One of them is continuous combined casting-extrusion technology – Conform, but this method has many disadvantages due to the horizontal axis of rotation.

As a result of research a complex of technological solutions was developed by members of the department of metal forming of "Siberian Federal University". According to them the disadvantages can be avoided by using a plant with the vertical axis of rotation. As the result Conform plant with the vertical axis of rotation was developed. But still there is the lack of scientific, methodological and software data of this combined process. Therefore further research in this area is timely and relevant.

Subject of the research: development of a computer model of the combined continuous extrusion process.

The aim of master's thesis: to design a computer model of the combined continuous extrusion process for the plant with the vertical axis of rotation; to do the technical and technological design of this process. Extra effort was made to model this process for Al–12%Si alloy.

Objectives of the research:

- to analyze existing methods for the production of WAW and ligature rods, to study software used for a computer modeling of metal working;
- to develop a computer model of the process using fundamental knowledge of the theory of metal forming under pressure;
- to design technological schemes of the combined continuous casting-extrusion process using the computer model;

- to produce pilot batches of WAW with the help of the designed technological schemes on the plant with the vertical axis of rotation.

Scientific novelty of work:

1. The initial stage of the casting process was studied using ProCast software. The temperature fields in the billet and crystallizer, the duration of a crystallization process were determined and then the rational speed of rotation was chosen.
2. The computer model of the Conform extrusion process was design using Deform-3D software. Stress distribution in the billet and strain rate in the crystallizer was obtained. It shows that the most uneven stress and deformation is observed in the zone of the shoe abutment. The maximum value of the strain rate of metal is near the die.

Practical importance of work:

1. The computer model of the Conform casting-extrusion process was design using ProCast and Deform-3D software.
2. It was conclude that a stable crystallization process starts from 15 seconds from the beginning of the process. Also the temperature of the crystallizer was increased by 40°C in a contact zone with the billet and about 20°C on a surface. Further, the feeding block should be installed in position that provides an angel with a shoe's entrance at least 145°. Besides, the rotation speed of the crystallizer should be at most 1.5 rpm.
3. According to results of the computer modeling the pilot plant for the combined process of continuous casting and extrusion was designed.

Personal contribution of the author: All results of research are received in a co-authorship with participation of the author, basic of which are as follows: the analysis of the scientific literature, the analysis of software, the computer modeling; processing; systematization and analysis of the results.

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

Work approbation: Basic provisions of the thesis are presented at the VII international congress "Non-ferrous metals and minerals 2015".

Publications: Results of the thesis are reflected in four printed works.

Volume and structure of the dissertation: The thesis consists of an introduction, three chapters and a conclusion. It contains __ typewritten pages, __ figures, __ tables, bibliography of __ positions and __ application.

CONTENT OF WORK

In introduction the topicality of the subject is proved and the work purpose is formulated, novelty and practical importance are noted.

The first chapter examines principles used for metalworking technologies development, describes the basic methods of a computer modeling and presents an overview of computer programs.

The second chapter presents results and analysis of the computer modeling.

At the first step the initial stage of the casting process was studied using ProCast software. A parametric model of the crystallizer wheel, the matrix shoe, the roller clamp and a billet was designed using SolidWorks (fig.1).

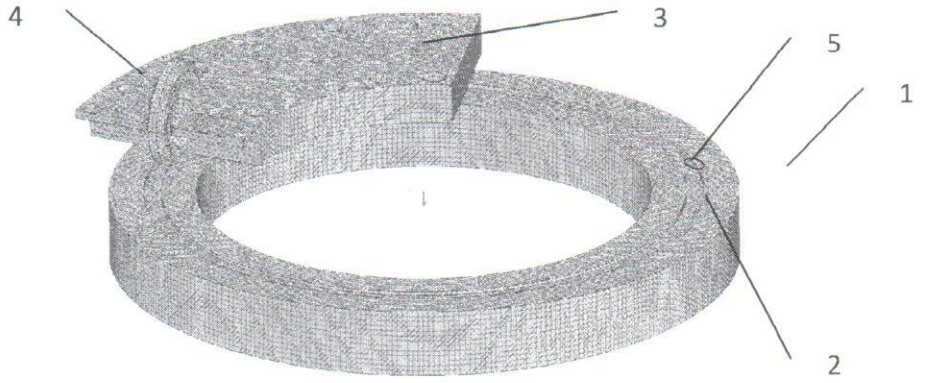
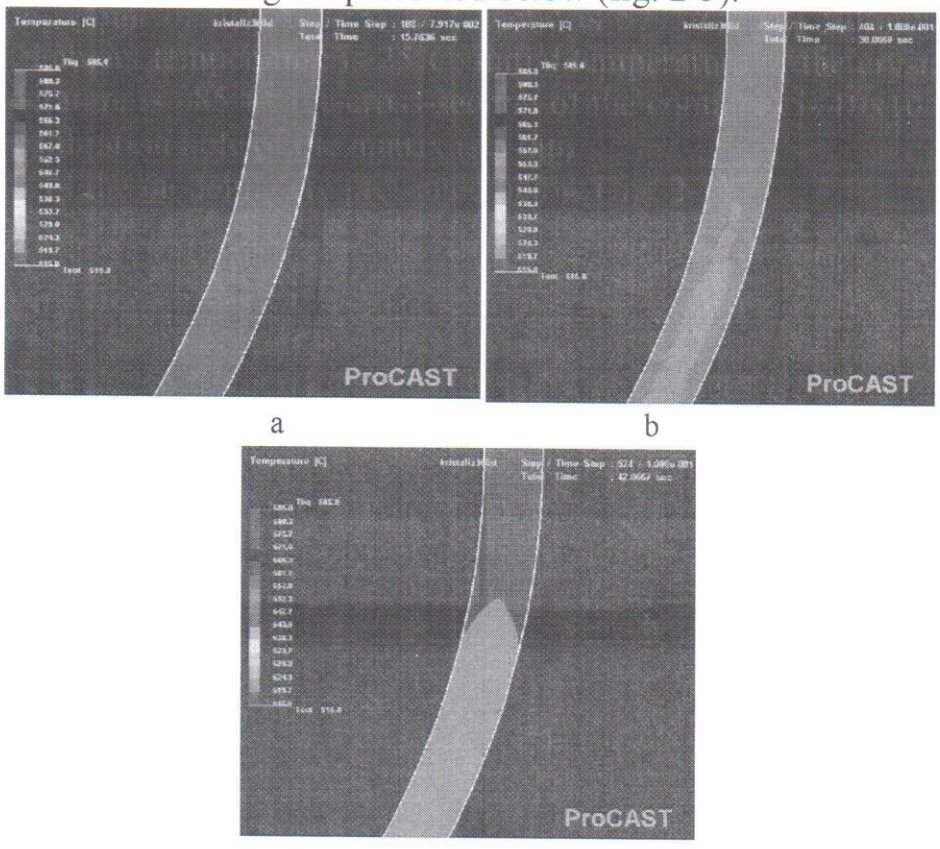


Figure 1 – The model of the plant: 1 – the crystallizer; 2 – the billet; 3 – the shoe; 4 – the roller clamp; 5 – the feeding place

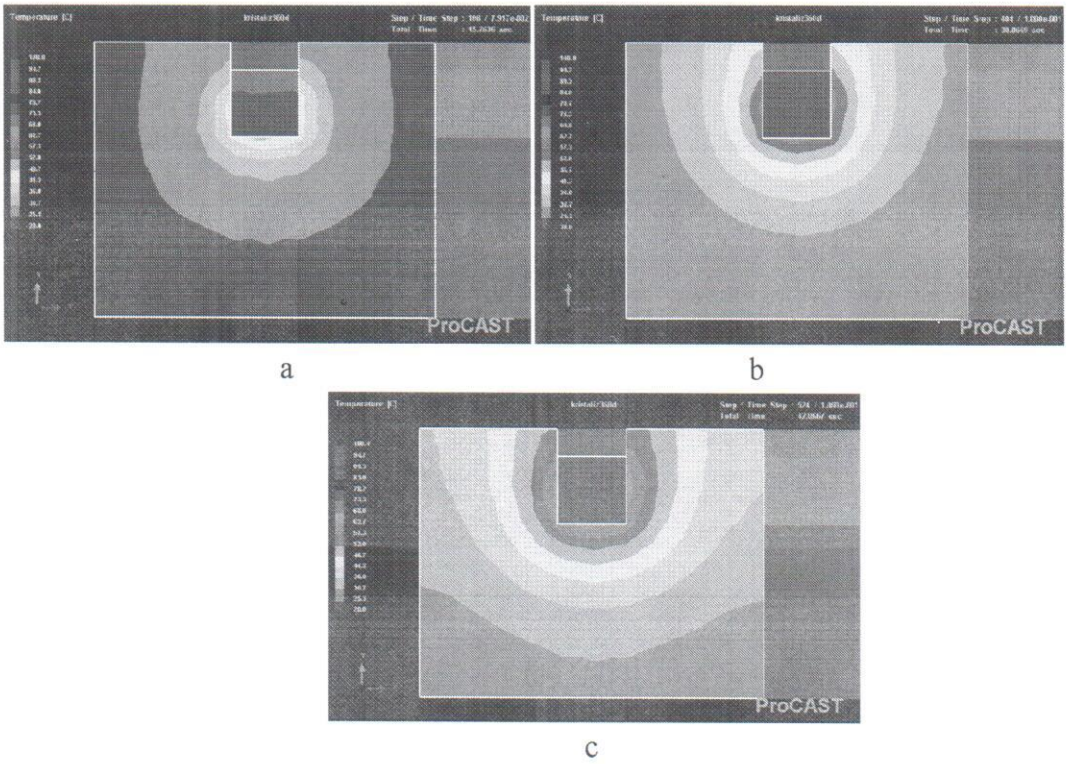
The melting point of the Al-12% Si eutectic is 577 °C. The following input data were used: ambient temperature is 25°C; initial temperature of the crystallizer is 25°C; melt temperature is 685°C; the cross-section of the container is 10x10 mm; the diameter of the calibration hole of the matrix is 3 mm.

The results of the modeling are presented below (fig. 2-3).



a b c

Figure 2 - Temperature field in a longitudinal section of the billet: a – after 15 sec.; b – after 30 sec.; c – after 42 sec.



a b

c

Figure 3 – Temperature field in a transverse section of the crystallizer near shoe's entrance:

a – after 15 sec.; b – after 30 sec.; c – after 42 sec.

It was conclude that a stable crystallization process starts from 15 seconds from the beginning of the process. Also the temperature of the crystallizer was increased by 40°C in a contact zone with the billet and about 20°C on a surface. Further, the feeding block should be installed in position that provides an angel with a shoe's entrance at least 145°. Besides, the rotation speed of the crystallizer should be at most 1.5 rpm.

At the second step the computer model of the Conform extrusion process was design using Deform-3D software. The results of the first step were used as input data.

The input date: initial temperature of the crystallizer is 50°C; temperature of the billet is 510°C; the rotation speed of the crystallizer 1.5 rpm.

The results of the modeling are presented below (fig. 4-5):

Figure 4 – Stress distribution in the billet

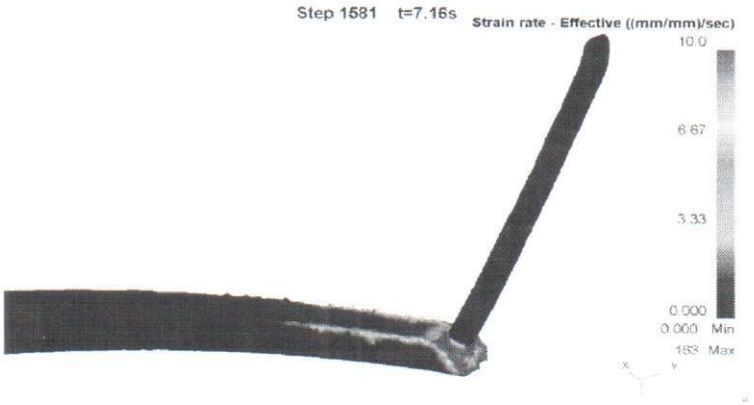


Figure 5 – Strain rate distribution in the billet

Output data show that the most uneven stress and deformation is observed in the zone of the shoe abutment. The maximum value of the strain rate of metal is near the die (10 mm/s).

The third chapter presents the result of the tests of the pilot plant for the combined process of continuous casting and extrusion (fig. 6).

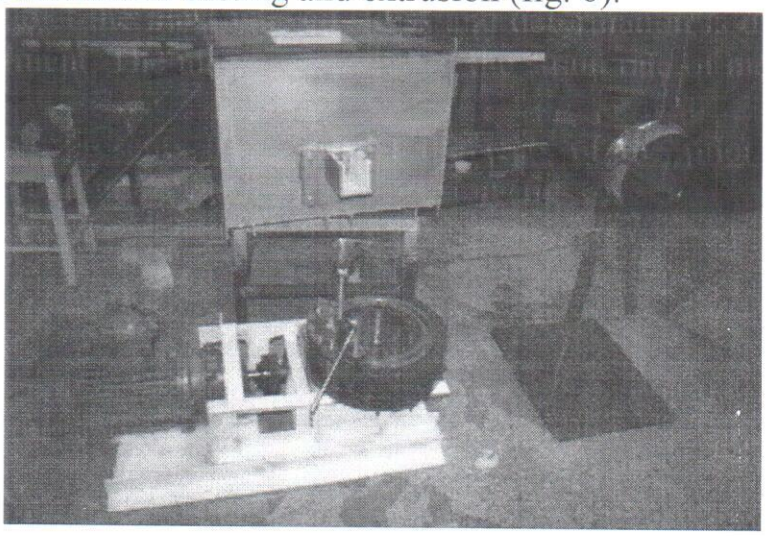


Figure 6 - The laboratory plant for Conform continuous casting-extrusion process

The efficiency of the laboratory plant was confirmed by the positive results of experiments. After that the plant was used to produce billets for WAW. Two batches of the rod billets were produced (Al-12%Si with 10% and 15% Zn). The output temperature of metal was in the range 490÷520°C, therefore the computer model is reliable. The wire with 1.1x1.3 dimension was produced from these billets.

The positive results of testing the elements of aluminum waveguides welded with the obtained wire show the advisability of manufacturing a billet for a wire by the continuous combined casting-extrusion process.

Conclusion presents the main developments and results.

MAIN RESULTS AND CONCLUSIONS

One of the effective methods for manufacturing complex designs from non-ferrous metals is the welding technology. Wires that are used for this purpose should provide high properties of the final product. The main requirements for quality are parameters, such as near-net-shape, homogeneity of the crystal structure, grain size and absence of contaminants. Therefore, the organization of production of WAW and other special aluminum alloys in Russia is an actual scientific and technical problem.

The main objectives of this work were achieved; the computer model of the combined continuous extrusion process for the plant with the vertical axis of rotation for special aluminum alloys was design. Also the laboratory plant was tested using output data; two batches of the billets for WAW were produced. Manufactured waveguides that were produced from these billets have been tested by staff of "ISS" named after Academician M.F. Reshetnev and showed the high quality.

The results of the work could be useful for students in the field of "Metallurgy" and profile specialties "Metal Forming under Pressure" and "Foundry Production" of the Siberian Federal University.

MAIN PROVISIONS OF DISSERTATION PUBLISHED IN THE FOLLOWING

1. **Gorokhova T.Yu.** Application of combined die-casting process in the manufacture of aluminum wire for waveguide soldering / Gorokhov Yu.V., Belyaev S.V., Uskov I.V., Konstantinov I.L., Gubanov I.Yu., Khramtsov P.A. // Universities proceedings. Non-ferrous metallurgy, 2016. – №6 – P. 65–70.
2. **Gorokhova T.Yu.** Deform-3D modeling in continuous extrusion of copper Busbars for installation Conform with the pre-chamber matrix / Gorokhov Yu.V., Belyaev S.V., Mochalin I. V., Uskov I. V., Gubanov I. Yu., Hramtsov P.A. //Journal of Siberian Federal University. Engineering & Technologies, 2016. – 9(6) – P. 821-829.
3. **Gorokhova T.Yu** Manufacturing technology research Al-Sr ligature rods for modification of aluminium alloys / Gorokhov Yu.V., Belyaev S.V., Uskov I.V., Gubanov I.Yu. // Vestnik of Nosov Magnitogorsk State Technical University, 2016. – V.14, №3. – P. 146–152.
4. **Gorokhova T.Yu** Modeling in Deform-3D process continuous pressing cooper bars for the installation Conform prechamber / Gorokhov Yu.V., Mochalin I.V., Gubanov I.Yu., Uskov I.V., Tserna V.V., Hramtsov P.A. // The source book of the VII international congress "Non-ferrous metals and minerals 2015". – Krasnoyarsk, 2015. – P. 440- 441.