ANNOTATION
dissertation for the degree of doctor of philosophy (PhD) in the specialty 6D070900 – «Metallurgy»

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INCREASING THE QUALITY OF CONTINUOUS CAST BILLETS FROM PIPE STEEL GRADES

Relevance of the research topic. The technology for the production of steel continuously cast billets by continuous casting is a significant branch of the metallurgical industry. The tightening of the oil industry requirements for the quality and physical and mechanical properties of seamless pipes, due to the development of ultra-deep wells and the complexity of oil production processes, requires the development of new solutions to improve them. To ensure the required set of seamless pipes mechanical properties, it is necessary to obtain a high-quality billet at the initial stage of production with the maximum exclusion of chemical and structural heterogeneity.

The main solutions developed as a result of scientific research to improve the quality of steel billets are aimed at optimizing the technological parameters of the continuous casting process and improving equipment based on known patterns and production experience. Modernization of designs of continuous casting equipment units makes it possible to rationally increase the level of continuously cast billets quality characteristics.

The relevance of the research of this work lies in the development of solutions aimed at reducing the level of defects in the macrostructure of pipe billets. Improving the technology for producing continuously cast pipe billets, which ensures a decrease in the level of defects and an increase in the yield of good products, is an urgent issue that causes an increase in the competitiveness of domestic production and the resulting products.

The aim of the work is to improve the technology of casting pipe billets, providing an increase in its quality.

To achieve this goal, the following **tasks** were solved:

- research of the cast billet cross-sectional shape influence on the formation of its structure and mechanical properties;
- computer simulation of the hollow billet casting processes and its rolling;
- development of a methodology for determining the technological parameters of pipe billet casting;
- improvement of hollow steel billet casting technology;
- comparative analysis of technologies for the production of pipes from solid and hollow billets;
- economic justification of the proposed solutions.

Scientific novelty of the work:

- the expediency of using an improved technology for casting a hollow billet is substantiated, which ensures a decrease in the defectiveness of the macrostructure

compared to casting a solid billet: light stripes – from 0.68 to 0.35 points, edge point impurities – from 0.09 to 0.02 points, segregated stripes and cracks – from 0.63 to 0.31 points;

- a computer model of casting a hollow billet in LVM Flow was created, in which the formation of a non-shrinking structure and an improvement in the microporosity of the billet according to the Niyama criterion from 0.362-0.611 to 1.257-2.043 were predicted, and a computer model of billet rolling in Deform 3D, the results of which demonstrate a decrease in the difference in wall thickness from 7.8 up to 3.5% when changing from solid to hollow billet;

- a method for determining the technological parameters of casting a hollow steel billet for the production of oil and gas pipes based on similarity criteria – Fourier numbers;

- a method has been developed for steel continuous casting with two-sided cooling at the exit of the billet being formed from the mold, while determining the optimal ratio of the coolant consumption between the inner and outer surfaces, equal to 1.46. The novelty of the proposed method is confirmed by a utility model patent;

- experimentally confirmed the provision the required values of tensile strength (792-795 MPa), yield strength (635-640 MPa) and relative elongation (14.9-15.1%) of pipes obtained from a hollow cast billet according to the proposed technology, in accordance with GOST 633-80 standards and API 5CT for grades E and N80 respectively;

- the achievement of a more uniform structure and stability of the properties of hollow billets in relation to solid ones was revealed: the range of values for microhardness was reduced from ±14 to ±3.5 HV, the maximum value of the contamination index for non-metallic inclusions was reduced from $17 \cdot 10^{-4}$ to $11 \cdot 10^{-4}$ and significantly reduced the uneven distribution of segregating elements (for carbon – from $5 \cdot 10^{-3}$ to $2 \cdot 10^{-3}$%; for sulfur and phosphorus – from $2 \cdot 10^{-3}$ to 10^{-3} %).

Practical significance. The feasibility of applying the proposed solutions is economically justified by increasing the productivity of the pipe billet production technology by 16% and reducing the cost of additional deformation processes that affect the cost of manufacturing a seamless hot-rolled pipe. The results obtained can be implemented at the operating production of «KSP Steel» LLP. The reliability of the results is confirmed by a utility model patent.

In this work, the following **research methods** were used:

- micro- and macrostructural analyzes;
- uniaxial tension for mechanical properties and durometric analysis;
- analysis of computer simulation results in postprocessors of LVM Flow and Deform 3D programs;
- analysis of chemical heterogeneity and non-metallic inclusions.

Provisions submitted for defense:

- the research results of initial billet type influence in terms of geometry in cross section on the quality and properties of the pipe billet
- computer simulation results of the a hollow billet casting and its rolling processes;
- method for determining the parameters of casting a pipe billet;

- laboratory tests results of solid and hollow billets samples mechanical properties;

- research results of the non-metallic inclusions distribution, segregation heterogeneity and microstructures;

- economic evaluation of proposed solutions.

Approbation of work. The main results of the research were presented and discussed at international scientific conferences: at the international scientific-practical conference «Toraighyrov readings», Toraighyrov University, Pavlodar; at the international scientific-practical conference «Satpayev readings», Toraighyrov University, Pavlodar; at the international scientific and practical conference «Modern innovations in the field of science, technology and knowledge integration», Rudny Industrial Institute, Rudny; at the XX International Scientific and Technical Conference «Ural School of Young Metallurgists», Ural Federal University named after the first President of Russia B. N. Yeltsin, Yekaterinburg, Russia.

Publications. 10 papers were published on the topic of the dissertation, including 1 article in an international peer-reviewed scientific journal indexed in the Scopus database (46%), 4 articles in publications included in the List of scientific publications recommended for publishing the main results of scientific activity, approved by the authorized body, 4 articles in the materials of international scientific and practical conferences and 1 patent of the Republic of Kazakhstan for a utility model «Method of continuous casting of hollow billets».

Scope and structure of the dissertation. The dissertation work is presented on 95 printed pages and consists of an introduction, five sections, a conclusion, a list of references and applications. The work contains 31 figures, 17 tables, a list of references from 137 titles and 3 appendices.