

## ABSTRACT

**for the dissertation of Jaxymbetova Makpal Adlikanovna on the topic: «Development of scientific and technical bases of production technology of long products combined deformation and heat treatment and assessment of quality compliance with international standards», prepared for obtaining a Doctor of Philosophy (PhD) degree in the specialty 6D073200 – «Standardization and certification»**

### **General work characteristics.**

The dissertation is devoted to improving the quality of rod reinforcement profiles by combined deformation and heat treatment, combining independent technological operations - hot rolling, heat treatment consisting of quenching and subsequent tempering.

### **Topic Relevance.**

The problem of improving the quality of steel products by deformation-thermal hardening directly in the technological line of the rolling mill is a new direction to ensure the quality performance of rolled products, because it provides (at lower costs) to obtain the required structures and physical and mechanical properties of the steel under study.

When manufacturing reinforced concrete structures, all metal (all reinforcement) is consumed irreversibly, i.e. it is not returned as scrap metal to steel plants. Hardening of reinforcement profiles contributes to the reduction of the metal intensity of reinforced concrete since it is made of strong reinforcement of smaller diameter than in the unstrengthened hot-rolled state, which ultimately leads to metal saving and resource-saving.

Taking into account that the cost and strength of low-alloy steel 35GS compared to low-carbon steel St5 is much higher, it is possible to replace it with cheaper carbon steels, but to achieve this task it is necessary to increase the strength of steel St5 to the level of strength of steel 35GS by thermal hardening according to the principle of «equal strength». At the same time, the replacement of low-alloy steel 35GS with hardened carbon steel provides a significant effect in rolling shops by reducing not only current costs, but also by saving expensive alloying elements.

### **Purpose of the work:**

- development of scientific and technical bases of production technology of long products (reinforcement sections), by combining hot rolling with heat treatment in the technological line of the rolling mill, in accordance with GOST 34028-2016 - Reinforcing rolled products for reinforced concrete constructions. Specifications, EN 10080-2011 Steel for the reinforcement of concrete. Weldable reinforcing steel. General.

**In order to achieve the purpose, the following main tasks were identified and solved:**

- improvement of cooling device for combined deformation and heat treatment of moving rolled products, by using countercurrent injection nozzles that intensify the cooling process of moving rolled products;

- investigation of parameters of the cooling device for deformation-thermal hardening: coolant flow rate and pressure, optimal values of geometrical dimensions of the nozzle and tubular cooling chamber depending on the diameter of the reinforcement profile from 10 mm to 25 mm (specifically 10, 12, 14 and 20, 25 mm);
- modification of the structure of the surface layer of reinforcing bars by combined deformation and heat treatment to improve their mechanical properties (strength and plastic characteristics and, consequently, quality);
- investigation of the influence of the main technological parameters of deformation-thermal hardening on the mechanical properties of reinforcing bars in accordance with GOST 34028-2016 – Reinforcing rolled products for reinforced concrete constructions. Specifications;
- estimation of the expected economic effect from the introduction of the technology of combined deformation and heat treatment of rolled products, taking into account the invested costs in the technological production process;
- development of a documented procedure for interlaboratory comparative testing of reinforcing bars.

**Scientific novelty** consists in modifying the structure of the surface layer of steel by creating an inhomogeneous gradient layered structure with unchanged chemical composition, physical and mechanical properties of the material in the inner layers of the treated steel in accordance with the requirements of GOST 34028-2016 - Reinforcing rolled products for reinforced concrete constructions. Specifications.

**Practical novelty of the work:**

- improvement of accelerated cooling unit for combined deformation and heat treatment of reinforcing bars in the technological process of production;
- documented procedure for interlaboratory comparative testing of reinforcing bars, which is implemented and applied at «AstanaSpecControl» LLP;
- together with «KazStandard» RSE sent to the parent organization a proposal to update paragraph 5.6 «Mechanical properties» of GOST 34028-2016 Reinforcing rolled products for reinforced concrete constructions. Specifications (Appendix A);
- sent Application for a patent of the Republic of Kazakhstan «Method of surface hardening of reinforcing bars combined deformation and heat treatment» (Appendix B).

**Practical significance of the work:**

- it is established that at deformation-thermal hardening of moving rolled products the main parameter determining strength characteristics of metal, hence qualitative indicators of rolled products, is the temperature of self-tempering, therefore it is recommended to regulate and control this very parameter of technology in the process of hardening.

It is noted that deformation-thermal hardening of reinforcing bars from cheap low-carbon steels St5 opens the prospect of replacing expensive low-alloy steels such as 35GS (on the basis of the principle of «equal strength») with more ductile and technological low-carbon steel, which will provide along with the reduction of current costs, saving expensive alloying elements (Mn, Si, Cr, etc.).

**Methodological basis and metrological support of research.**

The methodological basis of research is the central principle of applied materials science, according to which all properties of materials are determined by their real structure. Therefore, in this paper much attention is paid to the peculiarities of structure and property formation when plastic deformation and subsequent heat treatment are combined.

All experimental studies were carried out on certified equipment of the latest generation using modern physical and mechanical methods and techniques of analysis, and control and measuring devices have a high class of accuracy, verified in accredited laboratories by GOST ISO/IEC 17025-2019 General requirements for the competence of testing and calibration laboratories.

Scientific research was carried out on the basis of patent and information search, experimental work - in laboratory and pilot production scale.

**The object of research** is long products (reinforcing bars of periodic profile) for reinforced concrete structures.

**The subject of research** is the influence of combined deformation and heat treatment on the quality, structure and physical and mechanical properties of reinforcing bars of periodic profile.

**The validity and reliability** of the obtained results, conclusions and recommendations stated in the dissertation are confirmed:

- use of basic scientific provisions of theoretical and applied materials science;
- the results obtained using modern measurement tools and techniques; the reliability of the measurement was assessed by the confidence interval determining its accuracy ( $P=0,95$ ; level of significance  $q=0,05$ );

- correspondence of the obtained research results to the experimental results in the field of low-carbon and low-alloy steels and approbation at various scientific-practical conferences with publication in periodicals;

- application of the developed scientific and technical basis of the technology for the production of hardened long products in the experimental industrial laboratory «Metallurgy and flaw detection» of JSC «ArcelorMittal Temirtau».

**The connection of this work with other scientific research works.**

Together with the staff of RSE «Kazakhstan Institute of Standardization» developed 29 national standards (ST RK) and 4 interstate standards (GOST), including on the metallurgical industry, in accordance with the order of Acting Chairman of the Technical Regulation and Metrology Committee of the Ministry of Trade and Integration of the Republic of Kazakhstan from September 18, 2015 № 187-od «On Approval of State Standardization Plans for 2015-2017» under the Contract with RSE «Kazakhstan Institute of Standardization» CTRM MIID RK (2018-2021).

**The provisions submitted for the defense:**

- investigation of parameters of the cooling device for deformation-thermal hardening: coolant flow rate and pressure, optimal values of geometrical dimensions of the nozzle and tubular cooling chamber depending on the diameter of the reinforcement profile from 10 mm to 25 mm (specifically 10, 12, 14 and 20, 25 mm);

- investigation of the effect of the self-release temperature (the quality of rebar rolled products is determined by the self-release temperature) of steel with combined

deformation and thermal hardening of the moving rolled products on the quality and final physical and mechanical properties of steel;

- modification of the structure of the surface layer of reinforcing rolled steel to increase its mechanical properties (strength and plastic characteristics) with unchanged chemical composition, structure and material properties in the inner layers of the treated steel;

- determination of technological processing parameters affecting the mechanical properties of heat-hardened sections determining the quality of long products made of low-carbon steel in accordance with GOST 34028-2016 – Reinforcing rolled products for reinforced concrete constructions. Specifications;

- development of a documented procedure for interlaboratory comparative testing of long products;

- recommendation to make a proposal to update paragraph 5.6 «Mechanical properties» of GOST 34028-2016 Reinforcing rolled products for reinforced concrete constructions. Specifications.

On the subject of the dissertation published 21 scientific works, including 2 articles in scientific editions with a non-zero impact factor in Scopus scientometric base; 5 articles in journals recommended by CQAFSHE MSHE RK; 7 - in materials of international scientific-practical conferences; 4 - in the publications of the RINC database; 3 educational and methodological guidelines on the materials of the dissertation were published.

**Approbation of the work.** The main provisions and research results were reported and discussed at:

- The 3rd All-Russian scientific and Practical conference «Modern Metallurgy of the new Millennium» dedicated to the tenth anniversary of the Metallurgical Institute of LSTU. Structure and properties of bar reinforcing steel hardened by interrupted hardening method: report (Lipetsk, 2020 – October 21-22, Certificate received);

- The 12th International scientific and practical conference «Innovative Technologies and Engineering» dedicated to the 60th anniversary of Karaganda Industrial University. Features of the structure and properties of rebar rolled products with combined deformation and heat treatment: report (Temirtau, 2023 - December).

Methodological guidelines have been developed and introduced into the educational process for determining the mechanical characteristics of hardened and non-hardened metal materials, as well as methods of mathematical processing of experimental results, in particular, the detection and exclusion of systematic and random errors from measurement data (Appendix Г).

The documented procedure «Interlaboratory comparative tests» has been developed and implemented at the enterprise «AstanaSpecControl» LLP (Appendix D).

The recommendations «Production of thermally hardened core reinforcing steel of periodic profile» were developed and recommendations were received for its implementation in the experimental industrial laboratory «Metallography and flaw detection» of JSC «ArcelorMittal Temirtau» (Appendix E).

**Structure and scope of the dissertation:** the dissertation consists of an introduction, 5 sections, conclusion, list of used sources, appendices. The main text of

the work is set out on 120 pages of typewritten text, contains 41 figures, 19 tables, 20 formulas, the list of used literature consists of 114 sources, 8 appendices.