MATERIALS SCIENCE

DOI https://doi.org/10.30525/978-9934-26-340-8-5

IMPROVING THE PRODUCTION OF REINFORCING BARS OF STRENGTH CLASS 500-600 MPA WITH IMPROVED PERFORMANCE PROPERTIES ON THE EXAMPLE OF EUROPEAN STANDARDS

УДОСКОНАЛЕННЯ ВИРОБНИЦТВА АРМАТУРНОГО ПРОКАТУ КЛАСУ МІЦНОСТІ 500–600 МПА З ПІДВИЩЕНИМИ ЕКСПЛУАТАЦІЙНИМИ ВЛАСТИВОСТЯМИ НА ПРИКЛАДІ СТАНДАРТІВ ЄВРОПЕЙСЬКИХ КРАЇН

Ivchenko O. V.
Candidate of Technical Sciences, Senior Researcher,
Head of the Department of Intellectual Property
Ukrainian State University of Science and Technology
Dnipro, Ukraine

Zuiev O. V.
Postgraduate Student at the Department of Materials Science and Heat Treatment of Metals
Ukrainian State University of Science and Technology
Dnipro, Ukraine

Nurumgaliyev A. H.
Doctor of Technical Sciences, Professor,
Professor at the Department of Metallurgy and Materials Science
Karaganda Industrial University
Temirtau, Kazakhstan

Yerzhanov A. S.
PhD,
Head of the Department of Metallurgy and Materials Science
Karaganda Industrial University
Temirtau, Kazakhstan

Івченко О. В.
кандидат технічних наук, старший науковий співробітник,
завідувач відділу інтелектуальної власності
Український державний університет науки та технологій
м. Дніпро, Україна

Зуєв О. В.
аспірант кафедри матеріалознавства та термічної обробки металів
Український державний університет науки та технологій
м. Дніпро, Україна

Нурумгалієв А. Х.
доктор технічних наук, професор,
професор кафедри металургії та матеріалознавства
Карагандинський індустріальний університет
м. Теміртау, Казахстан

Єржанов А. С.
PhD,
завідувач кафедри металургії та матеріалознавства
Карагандинський індустріальний університет
м. Теміртау, Казахстан

Andryushkin A. V.
Master Student
Ukrainian State University of Science and Technology
Dnipro, Ukraine

Андрюшкін А. В.
магістрант
Український державний університет науки та технологій
м. Дніпро, Україна

The modern use of metal products in the construction of civil and industrial facilities, as well as special facilities (nuclear power plants, marine terminals, high-rise buildings, etc.) is focused on the use of reinforced bars (RB) with a wide range of high performance (consumer) properties. This is especially true when it comes to construction in regions with difficult climatic and seismic conditions. Therefore, in the standards of a number of European countries for RB [1; 2], several categories of plastic properties of finished products were specifically introduced. At the same time, the main criteria that determine the applicability of RB in construction are the characteristics of strength (yield point – σ_T or $\sigma_{0.2}$) and plasticity – relative uniform elongation (δ_p) or full relative elongation at maximum load (δ_{max}), as well as the ratio of temporary resistance to the yield point (σ_V/σ_T). Their level is normalized into three groups, which determines the applicability of RB for critical structures, depending on climatic and seismic conditions [1]. The higher are the characteristics of δ_{max} and σ_V/σ_T, the more reliable are the RB. Therefore, the constant tightening of requirements in the building constructions sets the task for metallurgists to create new cost-efficient steels for mass use. Products from these steels should have high performance properties such as controlled durability while maintaining plasticity in a wide temperature range, increased fatigue strength under static and dynamic loads, corrosion resistance, etc. Among some new performance properties of RB, that are yet to be reflected in the standards, are characteristics such as fire resistance and fire safety. The latter, as well-known events have shown, are especially relevant in countries where terrorist activity is observed (USA, New York, 2001) or in countries with a high probability of potential hostilities (for example, the war in Ukraine).

The purpose of this paper is to develop proposals for improving the production of RB of strength class 500-600 MPa with enhanced performance properties based on a comparative analysis of the requirements for mechanical properties for RB in the national standard of Ukraine [3] with similar requirements in the standards of some European countries [1; 2].

In the national standard of Ukraine [3] amended as of 2019, a number of changes were implemented for requirements for the chemical composition of steel and the magnitudes of mechanical properties. Some new indicators of properties were also introduced, which were absent in the 2006 standard edition. To produce weldable RB, the maximum allowable carbon content and carbon equivalent in steel were reduced. At the same time, the nitrogen content in steel is not limited when the content of aluminum and titanium is more than

0.020%. The last clarification will be used further in the development of an innovative proposal for improving the production of RB. The table below contains Ukraine's and European countries' standards to the minimum level of normalized mechanical properties of RB.

Table

Requirements for RB in the standards of European countries and Ukraine

Country, standard number	**Strength class**	**Mechanical properties indicators**				
		σ_T, Н/мм²	**σ_V, Н/мм²**	**σ_V/σ_T**	**δ_5, %**	**δ_{max}, %**
United Kingdom, BS4449:2005	B500A	500	525	1,05	12	2,5
	B500B	500	540	1,08	14	5,0
	B500C	500	575	1,15-1,35	-	7,5
Germany, DIN 488-1-2009	Bst500	500	550	1,08	18	5,0
	Bst600	600	670	1,08	15	5,0
Ukraine, DSTU 3760:2019	A500C	500	600	1,08	14	5,0
	A500E	500	-	1,15-1,35	-	7,5
	A600C	600	700	1,08	12	5,0

Previously, the main way to increase the strength properties of RB was by changing the chemical composition of steel (increase in alloying elements) and by the manufacturing technology (thermal hardening) of finished products. While at present, attention is paid to the formation of the internal structure of products to improve their performance properties by microalloying steel by implementing carbonitride hardening (CNH). Traditionally, CHN is carried out by introducing vanadium, niobium, molybdenum or other scarce elements into steel, which greatly increased the cost of RB.

When improving the production of RB with a strength class of 500-600 MPa by implementing CNH, in order to increase the nitrogen content in steel the authors proposed to carry out microalloying of steel with a set of nitrogen-titanium-aluminum. As a result, the production of RB is carried out of steel with a high nitrogen content at the following ratio of components, wt., %: carbon 0.14–0.28; silicon 0.05–0.90; manganese 0.50–1.60; aluminum 0.025–0.060; titanium 0.020–0.035; nitrogen 0.012–0.028; the rest is iron and inevitable impurities. This ratio is consistent with the requirements of the standard [3]. With this ratio of components, it is possible to form evenly distributed over the volume Ti(C,N) and AlN carbonitrides in size from 15–20 nm to 1–2 μm. Thus, it allows to achieve the level of the following operational properties: characteristics of deformability – $\delta_p \geq 5.0\%$ and $\sigma_V/\sigma_T \geq 1.15$; impact strength $KCV^{-60} \geq 30$ J/cm²; fire resistance and fire safety threshold of at least 500 °C (Application for utility model u2023 03571 dated July 24, 2023 (Ukraine). Ivchenko A. V., Nurumgaliev A.Kh., Zuiev O. V. and others: Production of reinforcing bars with improved performance properties for ferroconcrete structures).

Thus, the proposed improvement in the production of welded reinforcing bars for reinforced concrete structures with increased performance properties, such as deformability, cold resistance, fire resistance and fire safety from nitrogen micro alloyed steels, will significantly increase reliability of structures during construction in seismically active regions or with large temperature differences.

At the same time, it is more promising, rational and economically justified to carry out carbonitride hardening of reinforcing bars of strength class 500–600 MPa by modifying steel with the “nitrogen – titanium – aluminum” system.

Conclusion

1. A comparative analysis of the data presented in the table showed that the requirements for mechanical properties of RB of strength class 500-600 MPa according to the standards of European countries and Ukraine are almost the same.

2. Production in Ukraine of RB from steel additionally alloyed with nitrogen (via carbonitride hardening) will allow achieving a combination of both high strength and plastic characteristics of products at the level of requirements of European standards (BS 4449, DIN 488).

3. The production of RB with enhanced performance properties from steel that is micro alloyed with the nitrogen-titanium-aluminum set excludes the use of expensive carbide-forming elements (vanadium, niobium, molybdenum) and increases the competitiveness of products in the domestic and European markets.

4. The use of steel of specified composition makes it possible to produce RB of a strength class of 500-600 MPa, both in hot-rolled and in a thermos-mechanically strengthened state. The use of RB in the hot-rolled state, in comparison with the thermo-mechanically hardened state, guarantees increased weldability and less damage from corrosion.

Bibliography:

1. BS 4449:2005. Steel for the reinforcement of concrete. Weldable reinforcing steel. Bar coil and decoiled product. Specification. *British Standards*. 2005. – 36 p. 2.

2. EN 10080-2005. Steel for the reinforcement of concrete. Weldable reinforcing steel. General // CEN. 2005. 75 p. 3.

3. ДСТУ 3760:2019. Прокат арматурний для залізобетонних конструкцій (Національний стандарт України). Загальні технічні вимоги. Київ. ДП «УкрНДНЦ». 2019. – 21с . (ROLLED PRODUCTS FOR

REINFORCEMENT OF FERROCONCRETE STRUCTURES. General specification).

DOI https://doi.org/10.30525/978-9934-26-340-8-6

IMPROVING THE PRODUCTION OF COLD-FORMED REINFORCING BARS OF INCREASED PLASTICITY FOR CONSTRUCTION IN POST-WAR UKRAINE

УДОСКОНАЛЕННЯ ВИРОБНИЦТВА ХОЛОДНОДЕФОРМОВАНОГО АРМАТУРНОГО ПРОКАТУ ПІДВИЩЕНОЇ ПЛАСТИЧНОСТІ ДЛЯ БУДІВНИЦТВА У ПОВОЄННІЙ УКРАЇНІ

Perchun G. I.
Candidate of Technical Sciences, Associate Professor,
Associate Professor at the Department of Materials Science and Heat Treatment of Metals
Ukrainian State University of Science and Technology
Dnipro, Ukraine

Перчун Г. І.
кандидат технічних наук, доцент,
доцент кафедри матеріалознавства та термічної обробки металів
Український державний університет науки і технологій
м. Дніпро, Україна

Yakushev O. S.
Postgraduate Student at the Department of metal forming
Ukrainian State University of Science and Technology
Dnipro, Ukraine

Якушєв О. С.
аспірант кафедри обробки металів тиском,
Український державний університет науки і технологій,
м. Дніпро, Україна

Ivchenko A. O.
Postgraduate Student at the Department of Materials Science and Heat Treatment of Metals
Ukrainian State University of Science and Technology
Dnipro, Ukraine

Івченко А. О.
аспірант кафедри матеріалознавства та термічної обробки металів
Український державний університет науки і технологій
м. Дніпро, Україна

Для підвищення властивостей арматурного прокату (АП) для залізобетону використовується три найпоширеніших способи зміцнення продукції – легування сталі, термічна обробка і холодна деформація.