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STABILITY OF THE ROLLING PROCESS OF RIBBED BARS BASED ON THE ANALYSIS OF STRENGTH PARAMETERS

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The article presents the results of the strength properties of 12 ÷ 24 mm ribbed bars used for concrete reinforcement. The strength properties and the ribbing geometry of the ribbed bars is a key factor in ensuring the safety of building structures. Therefore, the continuous analysis of the mechanical parameters of ribbed bars and the reasons for their change is essential for any rolling mill. This article aims to present an analysis of the strength properties of ribbed bars made of high ductility steel in 2021 in a selected production plant, and then, based on the obtained results, to perform an analysis aimed at verifying the stability of the rolling process.

Key words: steel, rolling process, ribbed bars, mechanical properties, process stability

INTRODUCTION

The demand for ribbed steel is growing all the time. Customers want to obtain a product characterized by appropriate parameters at the lowest possible price [1,2]. Therefore, metallurgical enterprises set themselves the goal of introducing systemic solutions influencing, inter alia, cost reduction, increased efficiency, timely execution of tasks, shortening the time between operations or reducing inventories [3-5]. However, in most cases, the priority action taken by steel companies is to improve the quality of the manufactured product. One of the factors that allow to verify the quality of the production process is the analysis of the parameters of the finished product. Construction steels with increased ductility are used, among others, in building structures such as: bridges or viaducts. The ductility of reinforcing steel is described as its ability to obtain significant deformations without a significant increase in stress after exceeding the yield point. This concept refers to the work of a structure in the plastic deformation phase, when the stresses exceed the maximum values and the strains increase non-linearly in relation to the stresses. Due to the critical role of ribbed steel with increased ductility in building structures, the subject of the production process stability in terms of obtained strength parameters of ribbed bars, and in particular the yield strength R_e [6].

The aim of this article is to present an analysis of the strength properties of ribbed bars made of high ductility steel in 2021 in a selected production plant, and then, based on the obtained results, to perform an analysis aimed at verifying the stability of the rolling process.

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CHARACTERISTICS OF PROPERTIES OF RIBBED BARS AND ROLLING PROCESS

Depending on the steel grade and the reference document against which the manufacturer declares the product's compliance, e.g. a harmonized national standard or the National Technical Assessment, it is necessary to carry out a series of strength tests for each production batch in order to confirm the compliance of the product with the reference document. In the case of ribbed bars made of high ductility steel, it is necessary to carry out tests in the scope of measuring, among others, the yield strength R_e, the ratio of the yield point to the tensile strength R_e R_m and elongation under the maximum load A_{gt}. The strength parameters in the scope of the requirements are presented in Table 1.

Table 1 **Strength requirements for ribbed bars with increased ductility**

	R_e / MPa	R_e/R_m	A_5 /%	A_{gt} /%
min.	500	1,15	16	8
max.	625	1,35	-	-

The result of the strength of ribbed bars depends, inter alia, on the chemical composition of the batch material and the parameters of the rolling process. The basic parameters of the rolling process influencing the strength properties of the finished product include, among others: charge temperature, rolling speed in the last stand, heat transfer coefficient between the material and rolls or the friction coefficient. In the case of the analyzed rolling process, the temperature range specified by the manufacturer was 1 080 ÷ 1 250 °C, while the rolling speed, in accordance with the established technological instructions, should remain in the range of 7,20 ÷ 9,90 m/s. The range of the parameter level in the technological assumption is to allow the rolling process to be carried out in a stable manner, the result of which is a finished product in the form of ribbed bars meeting the requirements of the reference document, i.e. Table 1.

DESCRIPTION OF THE TEST METHOD

In order to analyze the strength properties of ribbed bars with diameters of 12 ÷ 24 mm used for concrete reinforcement and to determine the stability of the production process in terms of repeatability of the obtained results, three stages of tests were performed:

Stage I - strength tests of ribbed bars - the aim of this stage was to obtain data confirming the fulfillment (or not) of the requirements of the reference document (Table 1) and the values of individual parameters.

Stage II - statistical analysis of strength parameters - the aim of this stage was to determine the average values of the strength properties of ribbed bars in the designated time intervals on 100 samples each month.

Stage III - comparison of the results obtained in selected time intervals and verification of the rolling process capability on the basis of the results of the R_e parameter strength tests (determination of the C and C index).

$$Cp = \frac{USL - LSL}{6 * \sigma} \quad (1)$$

$$Cpk = \min\left\{ \frac{USL - \overline{x}}{3 * \sigma} \middle| \frac{\overline{x} - LSL}{3 * \sigma} \right\} \quad (2)$$

Where:

C - potential capability index,
C - real capacity index,
LSL - lower specification limit,
USL - upper specification limit.

Strength tests of ribbed bars performed at the first stage were carried out on a testing machine with a valid calibration certificate, by qualified personnel. The test results and parameters of the production process were archived as part of meeting the requirements of the Factory Production Control and were used to implement the research plan presented above. The analysis covered the period of one year divided into twelve months.

RESULTS AND THEIR ANALYSIS

As a result of the strength tests carried out in accordance with the requirements of the reference documents, the results were obtained. The analyzes show that the average of the obtained strength results of ribbed bars in individual months meets the requirements specified in Table 1.

The highest mean R_e parameter value was recorded in December and amounted to 587 MPa. In May, June and November, an average decrease in R_e was observed. The mean value of this parameter was 517 MPa, 522 MPa and 528 MPa, respectively. In each of the analysed months, the stability of the production process was tested in terms of repeatability of the obtained strength results (C and C) for the R_e parameter (Figure 1 and 2).

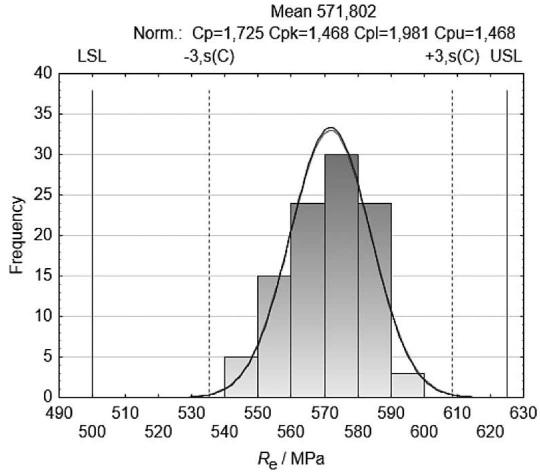

Figure 1 Stability of the production process for the month I (January)

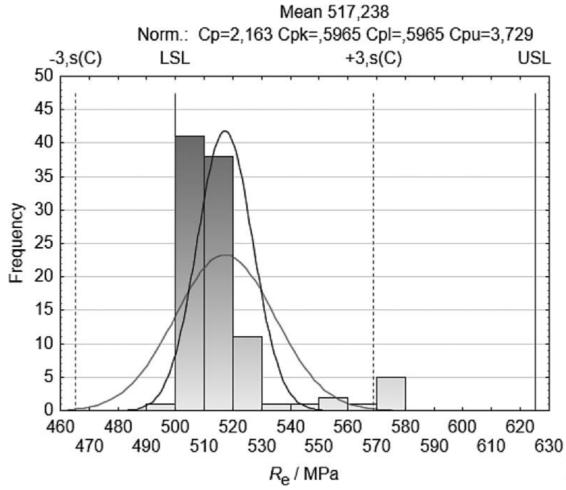

Figure 2 Stability of the production process in the month of V (May)

In January, the production process, in terms of the R_e results obtained, was characterized by the highest level of stability where the value of the C = 1,725 and C = 1,468. On the other hand, in May, the process stability level presented by means of the C and C indices indicated the lowest level of stability equal to 2,163 respectively and 0,5965.

As a result of the conducted analyses, a comparison of the basic factors influencing the level of the obtained strength results and process stability variability was made. No changes in the chemical composition of the charge material that could affect the obtained results were found. On the other hand, differences in the average values of the production process parameters in the analysed time periods were identified. In the case of January, the average rolling speed and batch temperature were respectively 8,2 m/s and 1 176 ^{o}C, while in the case of May, the average rolling speed was 7,4 m/s and the temperature was 1 110 °C. In June and July, when the production process was also characterized by a lower level of stability compared to January, the average rolling speed was in the range of 7,3 ÷ 7,6 m/s, while the rolling temperature was in the range of 1 105 ÷ 1 135 °C. The differences in the values of production parameters were considered to be the cause of discrepancies in the obtained results of strength parameters. It was found necessary to conduct further tests taking into account a smaller range of acceptable production parameters and to re-verify the stability of the process in terms of obtained strength parameters.

SUMMARY

The mechanical strength of ribbed bars with increased ductility is one of the most important factors necessary to verify in order to ensure adequate safety of building structures. The article analyzes the obtained strength parameters of ribbed bars over a period of twelve months. The analysis made it possible to determine the level of stability of the production process in terms of the repeatability of the obtained strength results. In the example described in the article, it was found that the rolling process took place in controlled conditions ensuring appropriate strength parameters. The occurring discrepancies did not pose a threat in terms of obtaining a product with strength parameters inconsistent with the guidelines. However, after analyzing the obtained results, it was found justified to conduct further analysis after reducing the ranges of acceptable strength parameters of ribbed bars after reducing the rolling parameters to the level of 1 150 ÷ 1 200 °C for the charge temperature and 8,10 ÷ 8,40 m/s for the rolling speed and then verification over time the level of any discrepancies in the strength of ribbed bars.

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Note: Sz. Pawlak is responsible for English language