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IMPROVING THE EFFICIENCY OF THE ROLLING PROCESS OF 16 MM RIBBED BARS IN THE THREE-STRAND TECHNOLOGY

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The paper presents a modification of the slitting pass system for the three-strand rolling of 16 mm-diameter ribbed bars, which will reduce the wear of rolls, and thus increase the economic efficiency of the analysed process. The results of theoretical research were verified on the basis of the performed measurements of force and energy parameters during the rolling of ribbed bars according to the multi-strand technology in a D350 continuous rolling mill. The computer program Forge2011® was used for theoretical analysis of the rolling process with longitudinal strand separation.

Keywords: rolling, ribbed bars, roll pass design, numerical modelling, economical process efficiency

INTRODUCTION

In the era of constantly changing market factors, modern production companies are looking for opportunities to improve the efficiency of production processes in order to increase their competitive advantage. It is possible to achieve this by adapting production processes to the constantly changing market needs, e.g. by introducing new technologies, which will be characterized by lower energy consumption, savings in the use of raw materials and minimizing waste [1-3]. In addition, the subject of the production process improvement may be the entire process as well as individual sub-processes or operations, activities and even working movements performed within these processes.

In many research and development centres, research is carried out to develop new or modify existing rolling technologies in order to increase the efficiency of processes and reduce costs, e.g. by reducing the consumption of tools and utilities. Moreover, production companies should constantly strive to carry out innovative activities that will affect not only the economic aspect, but also the environmental one [4-6]. Because the pro-environmental approach of enterprises is associated with a new opportunity for their development, which is particularly important in such an energy-consuming industry as the metallurgical industry, for instance. Such enterprises should strive for rational energy management through comprehensive improvement of the production process.

The aim of the paper was to develop a new, highly efficient technology of three-strand rolling of 16 mm-diameter ribbed bars, ensuring a reduction in the consumption of tools and utilities, and thus an increase in economic efficiency.

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CHARACTERISTICS OF THE ROLLING PROCESS OF RIBBED BARS IN THE THREE-STRAND TECHNOLOGY

The experimental tests were carried out for the conditions of the D350 continuous rolling mill equipped with stands in a horizontal-vertical arrangement. Stands 16 and 18 can work both horizontally (H) and vertically (V).

The length of the roll barrels ranged from 500 mm (rolls in the finishing group) to 800 mm (rolls in the preliminary group), which made it is possible to arrange several passes along their width.

The rolling technologies used currently with longitudinal strand separation require the use of special rolling equipment in the form of non-driven separating rolls, which are located behind stand 16 – their task is to divide the band into individual strands [7].

In the current technology of multi-strand rolling of 16-mm diameter ribbed bars, 2 slitting passes are used: a pre-slitting pass in stand 15, and a slitting pass in stand 16. The use of such an arrangement of passes ensures a very quick reduction of the strand height in its characteristic areas, where bridges connecting individual strands are created, but it causes the knife parts of these passes to wear out quickly (Figure 1).

In order to reduce the wear of slitting passes, a new slitting pass system was developed with 3 slitting passes and a special edging pass, rounded at the bottom of the groove. The assumptions adopted for the modification of the system of slitting passes, boundary conditions and initial parameters together with the mathematical model were described in detail in previous papers [5,7-9].

Using the Forge2011® computer software numerical tests of the process of rolling 16 mm-diameter ribbed bars in the three-strand technology were performed. These tests demonstrated that the previously used pass system ensured the correct filling of individual passes in the group of finishing stands [10]. However, in order

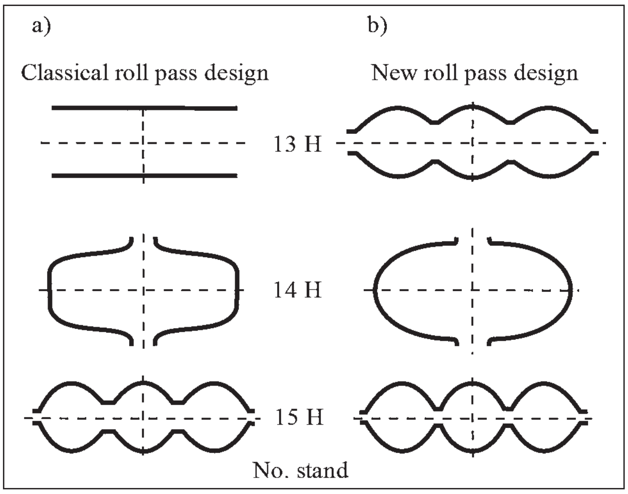

Figure 1 Roll pass design to three-strands rolling process of 16 mm ribbed bar: a) classical, b) new

to form bridges of an appropriate height in the multi-strand strand, i.e. such that will ensure its longitudinal separation by means of non-driven separating rolls, large reduction levels should be used in the slitting passes (stands 15 and 16).

The proposed innovation, due to the introduction of the third pre-cutting pass in stand 13, enables to use smaller reduction levels in the knife areas of the pass in stand 15 and 16. The use of three passes, in which the bridges connecting the individual strands are formed, allows for the distribution of the total reduction level into three passages [8].

ECONOMIC EFFICIENCY OF THE RIBBED BAR THREE-STRAND ROLLING PROCESS

In the analysed process, the analysed elements of partial efficiency are the costs of: consumption of rolls, natural gas and electric energy.

Due to the fact that the modification of the passes regarded only stands 13÷16, for the analysis of the partial efficiency of the 16 mm-diameter ribbed bar rolling process in the three-strand technology, only those stands of the rolling mill train were taken into account.

The durability of rolls in the analysed stands (stands 13÷16) was determined on the basis of the methodology for determining the wear of rolls described in [4], as well as on the basis of the analysis of friction forces› unit work and performing the actual measurements of the wear of rolls during the experimental 16 mm-diameter ribbed bars rolling in the three-strand technology in the analysed continuous rolling mill. Moreover, it was assumed for the calculations that the average annual production of ribbed bars in the analysed diameter rolled in the three-strand technology is 90 thousand Mg (average production approximate to data from 3 years of production). On this basis, it was determined that the number of roll sets that were used to roll such a mass of bars in the pass system used so far is: in stand 13 – 1 set of rolls worn in 83 %, in stand 14 – 1 set of rolls worn in 83 %, in stand 15 – 1 set worn in 100 % and 2 worn in 41 % and in stand 16 – 2 sets of rolls worn in 100 % and 3rd set worn in 55 %, while in the new pass system it is: in stand 13 – 1 set of rolls worn in 94 %, in stand 14 – 1 set of rolls worn in 42 %, in stand 15 – 1 set of rolls worn in 100 % and 2nd one worn in 17 % and in stand 16 – 1 set of rolls worn in 100 % and 2nd one worn in 18 %. On this basis, it can be concluded that the proposed changes in the analysed pass system will affect the reduction in the wear of rolls in stands 14÷16, only in stand 13 the wear of rolls will slightly increase.

For the purposes of this paper, the cost of purchasing cast iron rolls, the maximum diameter of which in the analysed stands is 370 mm, and the weight of one cylinder is approx. 500 kg, was calculated. The cost of purchasing rolls consists of the raw roll cost and its machining. The price of 1 kg of cast iron rolls is EUR 3, which means that the purchase cost of a raw roll is EUR 1 500. The cost of machining depends on the type of rolls, i.e. a smooth roll is processed for approx. 4 hours, while a roll with passes is processed on average for approx. 12 hours. The machining man-hour costs on average EUR 25,7. On this basis, the cost of preparing a smooth roll was determined, which is approx. EUR 1 603 (the pass system currently used - stand 13), and the cost of preparing rolls with passes, which is EUR 1 808 (the pass system currently used - stands 14÷16 and the new pass system - stands 13÷16).

Table 1 shows the costs of rolls› consumption (taking the degree of their wear into account) for rolling 90 000 Mg of 16 mm-diameter ribbed bars for the pass system currently used and for the new pass system.

For the production of 90 000 Mg of 16 mm-diameter ribbed bars in the three-strand technology, using the currently used pass system, the cost of rolls› consumption will be approx. EUR 19 982, while the application of the proposed changes will reduce these costs to approx. EUR 13 419. This means that the use of a new pass system affects the reduction in the costs of rolls› wear by approx. 33 %.

In the process of multi-strand rolling of ribbed bars, another significant cost element is gas consumption in a walking beam furnace (necessary to heat the rolling charge). The use of the proposed innovation will allow for extending the rolls› service life, and thus reducing the frequency of roll replacement in individual stands, which will affect gas consumption savings. As each change of rolls interrupts the production process, it causes an extension of the working time of the furnace (the material is kept longer in the furnace) in relation to the mass of the rolled product, which increases the production costs. In addition, during each stoppage, the rolling mill also incurs fixed costs that are independent of the production volume (including administration fees, machine depreciation write-offs).

The data on the number of rolls that will be used for the annual production in both pass systems allows for stating that the use of the new pass system will result in

Table 1 **Cost of the rolls' consumption to produce 90,000 Mg of 16 mm-diameter ribbed bars in the current pass system and the new pass system EUR**

Rolling stands	13	14	15	16
The cost of rolls' consumption in the current pass system/EUR	2 661	3 001	5 099	9 221
The cost of rolls' consumption in the new pass system/EUR	3 399	1 519	4 231	4 267

a smaller number of stoppages related to the change of rolls, as they will be replaced only in stands 15 and 16 (2 stoppages). However, in the currently used pass system, the replacement takes place in stand 15 and twice in stand 16 (3 stoppages).

Based on the data obtained from the analysed rolling mill, savings in gas consumption in a walking beam furnace can be calculated. The maximum roll change time in the stand is approx. 35 minutes, it means that the time during which the charge is in the walking beam furnace will be longer. During this time, 34 billets could be rolled. For the calculations, it was assumed that the weight of 1 billet was 1,976 Mg, and gas consumption in the walking beam furnace was approx. 29 m^3/Mg. The price of natural gas was determined on the basis of data obtained from the gas company and amounted to EUR 0,0294 per kWh (as of 01/02/2021).

The use of a new pass system will reduce gas consumption in a walking beam furnace by 1 948 m^3 (34 pcs. x 1,976 Mg x 29 m^3/ Mg), converted into 20 551,4 kWh. This means that the cost of gas consumption will decrease by approx. EUR 604.

Another factor that significantly affects the costs in the process of multi-strand rolling of ribbed bars is the cost of electric energy consumption. For its calculation, the following were used: data on the total rolling power in stands 13÷16, both in the currently used presses system (810 kW) and in the new presses system (727 kW), the time of rolling 1 billet, which is approx. 1 minute and the price for 1 kW of electric energy, which was determined on the basis of data obtained from the energy company and amounted to approx. EUR 0,10552 (as of 01/02/2021).

The electric energy necessary to roll 1 billet in stands 13÷16 for the currently used pass system is 13,1 kWh, and for the new pass system – 11,7 kWh. When calculating consumption of electric energy necessary to roll 1 billet in stands 13÷16, the mean error between the rolling power calculated by means of computer simulations and the rolling power recorded during industrial measurements in the analysed rolling stands was also taken into account – this error is 3,15 %. It can be assumed that the cost of electric energy necessary to roll 1 billet in the currently used pass system amounts to EUR 1,38 (13,1 kWh x 1 min. x EUR 0,10552), while for the new pass system - EUR 1,23 (11,7 kWh x 1 min. x EUR 0,10552). In order to calculate the savings in electric energy consumption for the production of 90000 Mg of ribbed bars, it was assumed that the yield in the analysed process amounts to approx. 96 % (yield from 1 billet – 1,897 Mg). This means that the cost of electric energy consumption for rolling 1 Mg in the currently used pass system will be approx. EUR 0,7 while the proposed innovation will reduce these costs to EUR 0,65. For the production of 90 000 Mg of ribbed bars in the currently used pass system, it will amount to approx. EUR 63 000, while in the new pass system it will be reduced to approx. EUR 58 500.

Table 2 **Partial efficiency of the process of rolling ribbed bars in the currently used and new pass system / EUR**

	Rolls' consumption costs	Electric energy consumption costs	Natural gas consumption cost
Currently used pass system / EUR	19 982	63 000	No data
New pass system / EUR	13 416	58 500	No data
Savings / EUR	6 566	4 500	604
Savings / %	32,56	7,14	-

Table 2 assesses the partial efficiency of the process of rolling ribbed bars in the currently used pass system and in the system in which the innovation was introduced. It can be observed that the use of the new pass system is characterized by a higher partial efficiency in relation to the use of the currently used pass system (Table 2).

When analysing the partial efficiency of the process of rolling ribbed bars in both pass systems, the main elements resulting directly from the introduced innovation were taken into account, without considering other possible factors, which should not, however, significantly affect the estimated calculations.

SUMMARY

Currently, industrial enterprises, by introducing innovative technological solutions, strive to achieve better economic effects, including by reducing and optimizing costs, improving the quality of work, increasing efficiency and productivity.

The process of rolling ribbed bars is a technology known for many years, but over the years it has been constantly improved. In recent years, the modernization of this process has been occurring by introducing minor changes (e.g. according to the Kaizen philosophy). The proposed innovation is such an element and leads to an increase in the efficiency of the process by reducing consumption of rolls and energy carriers (natural gas, electric energy). Constant improvement of the production process and identification of possible improvements should, in line with current trends, take the ecological aspect in addition to the economic aspect into account.

It is impossible to precisely define how the proposed innovation will contribute to the reduction of costs incurred due to the lack of comprehensive data (fixed costs, production, renovation, etc.). It is known that the benefits of implementing the presented innovation will not bring significant financial effects in relation to the total costs for the analysed company, nevertheless, any reduction in production costs is a desirable process.

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Note: The professional translator for English language is dogadamycie.pl Sp. z o.o. Agnieszka Chmielewska, Poland