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The increase in efficiency of strips production process in foundry and rolling mill stand

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Abstract
In the article, new design of foundry and rolling mill stand is investigated. The beads, where crushed iron borings are poured, are pressed on rolls; it allows reliable holding of metal on the rolls. This technology makes it possible to increase the crystallization rate of liquid metal by 18 – 20% and to reduce the time of its cooling by 18 – 20%. It leads to increase in metal yield and processing rate.
Key words: CONTINUOUS CASTING, FOUNDRY AND ROLLING MILL STAND, SUSPENDED CASTING, METAL CRYSTALLIZATION, COOLING RATE, CRYSTALLIZATION

Introduction

Currently, rolling production technology both in Ukraine and abroad achieved significant positive results on increase in rolling mills productivity. It became possible due to development of Compact Strip Production. Production of section iron from continuous cast sections in comparison with rolling-mill products provides: metal economy, reduction of workers number, improvement of metal quality, opportunity of automation and mechanization, reduction payback periods when new enterprises building and decrease in energy costs of production. Therefore, improvement of foundry and rolling machines is relevant task, which solution will allow increasing of labor productivity and decreasing of production cost.

Analysis of latest studies and publications

Increase of requirements to rolling mills productivity, improvements of products quality and life have led to development of new technological processes, which reflect combination of casting and rolling [1, 2]. Continuous casting of steel together with rolling has provided creation of technological process with increase of rolled products output by 15%; it ensures improvement of products quality [1].

It is considered that Compact Strip Production (test sample), which was created in VNIIMETMASH and was put into operation in 1963, was first used for production of steel rod. It consisted of the radial continuous casting machine with casting mold of 38x45 mm section, universal planetary mill and finishing stands for rolling of rod with 6 mm diameter [2].

The arrangement diagram of basic equipment of Compact Strip Production, casting and rolling temperature conditions, and also section change when rolling are shown in Fig. 1[2].

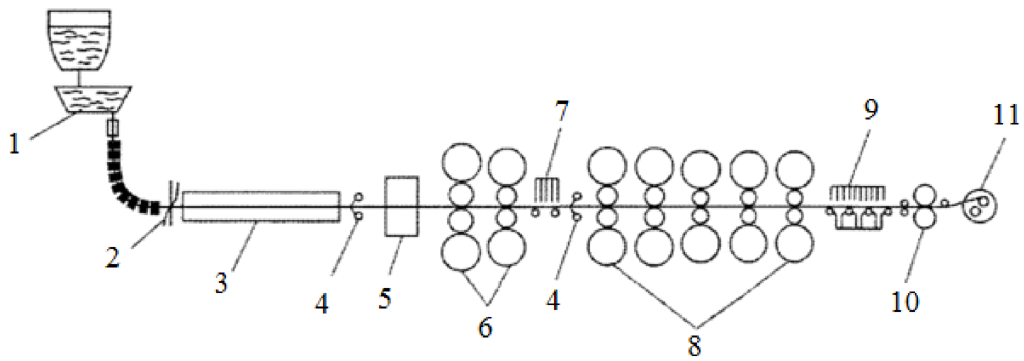

Figure 1. Diagram of DSP unit [2]:
1 – thin slab casting machine; 2 – pendulum-type shears; 3 – heating tunnel furnace; 4 – descaling system; 5 – edger mill; 6 – roughing stands; 7 – intercooling device; 8 – continuous finishing mill group; 9 – refrigerator; 10 – flying shears; 11 – strip-coiling apparatus

Currently, such foundry and rolling units have become widely used abroad [3, 4, 5]. In recent years, such complexes can be used under severe arctic conditions with the use of special steels [6]. During the whole period of the existence, the combined molding rolling processes were constantly improved. New units for sheet products manufacturing by cold rolling of aluminum and its alloys are suggested [7]. For increase in such machines productivity, it is suggested to increase the ladle capacity and to use double-strand plant [8]. The method of rolling of continuous cast section with improved calibers was proposed [9]. Recently, liquid steel is suggested to be casted directly into overhang rolls, which are casting molds [2], and also it is offered to reduce a metal overheat before casting and to form the additional centers of crystallization in steel volume [10].

The conducted researches [11] have allowed learning of development dynamics of Compact Strip Production in Ukraine and Russia from 2000 till 2013. This analysis gives the opportunity to determine shortcomings of such units development and to reveal the further line of research on metal overheat reduction when casting into rolls-molds.

Possibility of steel continuous casting intensification is limited mainly by the limited speed of continuously cast ingot hardening.

One of drawbacks of steel casting in rolls-molds is that it is difficult to hold liquid steel in the space between rolls, as it has considerable flowability in liquid state and is capable to pour out that causes finished products losses. Therefore, it is necessary to improve molds rolls design, which will prevent pouring out of liquid steel when casting, and also to provide measures for decrease in its overheat if it is in space between rolls. This is possible in case of additional centers of crystallization in rolls-molds within the metal.

Objectives and tasks of research:

The work objective is to find ways of increasing of steel cooling speed and to prevent the probability of steel pouring out between rolls-molds.

In order to achieve the objectives, the following tasks should be fulfilled:

1. To analyze possibilities of additional molds introduction and to apply an optimum mold for precipitation of liquid steel crystallization speed in rolls-molds;

2. To determine the way of prevention of steel pouring out between rolls–molds.

Research technique:

In course of studies, liquid steel (Steel 20) was poured from a ladle directly into rolling cylindrical rolls, which were rotating. In this case, working rolls serve as molds coolers as well as blooming tool, where processes of cooling and rolling are combined with drafting. Rolls are arranged horizontally as is shown in Fig. 2 and 3. Working rolls are made of copper with nickel coating. On the edge, the beads are put with tension (Fig. 2) [12]. The design of a separate roll is presented in Fig. 3 [12].

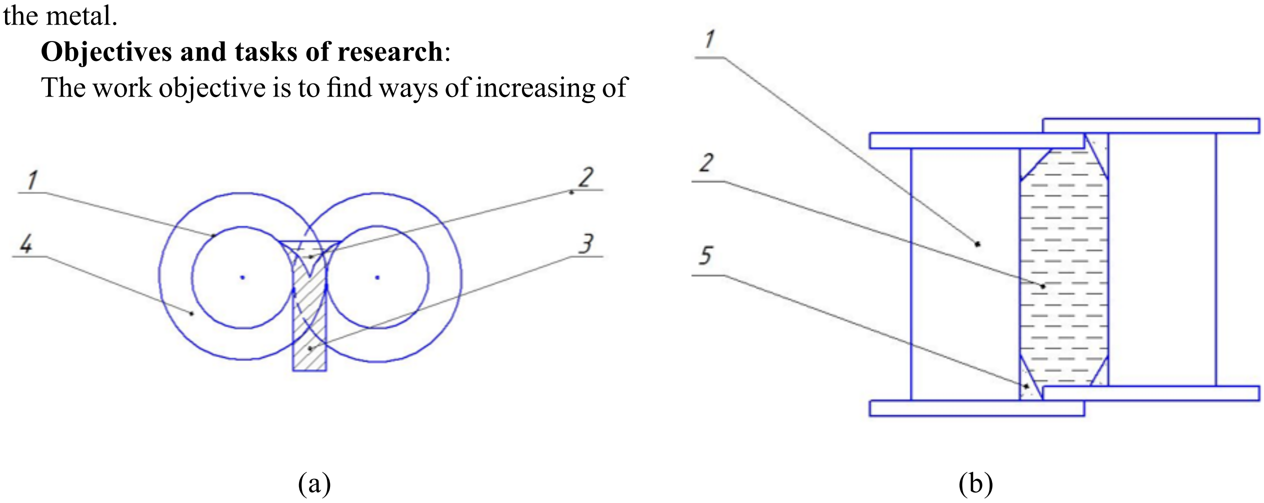

Figure 2. Foundry and rolling mill stand: a) side view, b) top view
1 –rolls-molds; 2 – liquid steel; 3 – dummy bar; 4 – pressed-on beads; 5 – the crushed boring.

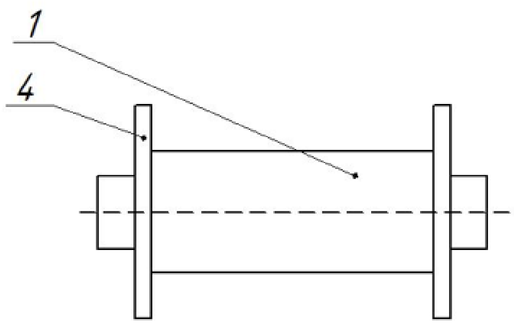

Figure 3. Foundry and rolling roll with beads

In experiments, suspended casting of steel was used. The crushed iron boring, which poured from the bunker on side walls of a roll mold, was added to liquid metal. Beams stabilized it in the form of triangular pyramid.

The experiments were conducted by the following technique: to pour a layer of the crushed iron boring (5) in the form of triangular pyramid on horizontal cylindrical rolls-molds (1). The beads are arranged on edge of rolls (4) for stabilization of this pyramid, the dummy bar is used (3) for maintenance of steel.

Researches results of efficiency increase of strips production process by continuous casting in foundry and rolling mill stands

The intensification method of hardening of continuous cast section is represented as advanced. This method consists in removal of superheating heat of liquid metal by means of internal heatdrains.

It will give the opportunity to increase the extraction rate continuous cast section. The liquid phase formation rate depends on overcooling value and proportionally total surface of area endo- and exogenous crystallization centers, which the liquid melt contains [10].

Side consolidation of a liquid bath is of great importance. Experiments have shown that when using of such consolidation, liquid steel is held properly by rolls: liquid metal interacts with iron boring, which is properly held on rolls due to beams and crystallizes on side surface faster; this prevents its pouring out in the space between rolls.

Experiments have shown that liquid steel when getting on a roll interacts with iron boring and is not poured out between rolls.

As a result of experiment, the strips of 2 - 4 mm in thickness were made. Their hardening rate was 50 - 70 m/min and time of hardening was 0.8 – 1.0 s. Results of experiments are presented in Table 1, where results without and with the use of suspension are compared.

Table 1. The researches results of rate and time of metal cooling in rolls-molds

No	. h ,	Without suspension		With suspension		Efficiency	
	mm	υ, m/min	.t, s	$υ_s$, m/min	.t_s, s	.υ%	t%
1	2	70	1,2	50	1,0	28,6	20,8
2	2,9	75	1,1	61	0,9	18,7	18,1
3	3	89	1	71	0,8	20,3	20

Designations in Table 1:

h – strip thickness;

υ – cooling rate;

t – hardening time.

Efficiency of hardening speed was calculated by a formula:

$$υ\% = \frac{υ - υ_s}{υ} 100$$

$$υ_1\% = \frac{70-50}{70} 100 = 28,6\ \%$$

$$υ_2\% = \frac{75-61}{75} 100 = 18,7\ \%$$

$$υ_3\% = \frac{89-71}{89} 100 = 20,3\ \%$$

efficiency of time was calculated by the following formula:

$$t\% = \frac{t - t_s}{t} 100$$

$$t_1\% = \frac{1,2-0,95}{1,2} 100 = 20,8\ \%$$

$$t_2\% = \frac{1,1-0,9}{1,1} 100 = 18,1\ \%$$

$$t_3\% = \frac{1-0,8}{1} 100 = 20\ \%$$

Results of experiments have shown that speed and time of metal cooling in rolls-molds depend on strip thickness: the thicker is strip, the slower will be cooling.

From results of research, it is seen that in each experiment, irrespective of the strip thickness, the speed of metal cooling increases by 18 – 20%, and time of metal cooling decreases by 18 – 20% when using of suspension (in our case, it is crushed iron boring) in comparison with the same experiment but without suspension. These experiments confirm that with the use of suspension, the metal extension increases by about 20%.

Experiments results have confirmed efficiency of steel continuous casing in rolls-molds, which have beads for holding of iron boring. This allows increasing of crystallization speed, reduction of cooling time of liquid metal, preventing of metal pouring out between rolls that increases metal yield, productivity of strip production process.

Conclusions

The possibility of introduction of additional molds was analyzed that allowed application of an optimum mold for increasing of crystallization speed of liquid steel in rolls-molds. Using the crushed iron boring as a mold, it is possible to increase the metal cooling speed by 18 - 20%, metal cooling time by 18 – 20%, to increase the extension by 20% that leads to increase in efficiency of strips production process by continuous casting in foundry and rolling mill stands.

The new design of rolls prevents metal from pouring out between rolls that allows increasing of metal yield.

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