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The Influence of Temperature and Size of the Cross Section on the Parameters of Rolling Casting-Rolling Mills for Bars and Rods

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The results of analytical studies of the effect size of the cross section and the temperature of billets at the finishing temperature of rolling and energy-power parameters of deformation in casting-rolling mills for bars and rods. The resulting pattern is recommended to use when choosing the size of the billets, composition and technological characteristics of the rolling mill equipment casting-rolling mills.

Keywords: CASTING-ROLLING MILLS FOR BARS AND RODS, THERMAL AND ENERGY-POWER PARAMETERS OF ROLLING

Introduction

One of the major purposes, facing on the metallurgists in Ukraine are reducing the energy intensity of rolled product of mass assignment. The main way of solving this problem is a shift to use continuous-moulded bar. The greatest savings in capital and operating costs is achieved by combining continuous casting and rolling in one complex – casting-rolling mill (CRM). Modern CRMs have different constructions and a temperature-speed rolling modes. However, there is not enough data in the scientific literature, which allows to define a rational section size of bars and temperature before rolling mill according to the range of products.

Statement of the task

There is a tendency of increasing the size of the cross-section of bars used in casting-rolling mills for bars and rods and complexes (CRC). It's explained by the desire to increase the performance of CRM and CRC with the same number of streams CC machine (CCM).

However, the increasing of cross-section of bars leads to the need of installing the additional stands, increases the spending of energy for the deformation. Now for light-section rolled products and rods usually used square bars from 125×125 to 165×165 mm [1-3].

The purpose of this work is the establishment of the influence of the size of the cross section of bars and its temperature before rolling mill on the total energy spendings (heating CCM and deformation), maximum power parameters defining the characteristics of the equipment, and the temperature of the end of the roll, as one of the main parameters, shaping the structure and mechanical properties of the finished product. An analytical studies of temperature, deformation and power parameters of rolling was being using mathematic models developed in the ISI NAS Ukraine [4, 5].

As a basic scheme of casting-rolling mill accepted a combined scheme based on the use of technological equipment of traditional construction (CCM, heating furnace, rolling mill) (**Figure 1**). Depending on the performance of CRM it's installed the CCM with the number of streams from one to five. The CCM bars after cutting to length passed through a heating unit are got to the rolling mill of traditional construction.

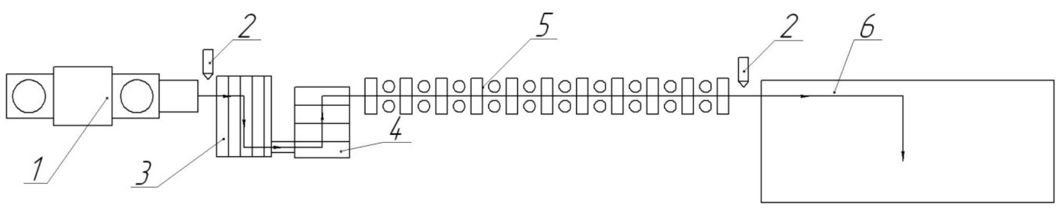


Figure 1. The accepted scheme of casting-rolling mill: 1 – CCM; 2 – scissors; 3 – drag-over unit; 4 – heating furnace; 5 – mill; 6 – fridge for finished product

The calculations are ready for three versions of CRM, which, depending on the type of rolling, differ on the number of working stands and rolling technology:

- CRM-1 for light-section rolled products and rods. Settlement profile – rod Ø5, 5 mm. Number of stands depending on the section bar 28-30;
- CRM-2 for light-section rolled products in one thread. Settlement profile – circle Ø12 mm. Number of stands depending on the section bar 22-24;
- CRM-3 for light-section rolled products with rolling division. Settlement profile -reinforcing steel № 12, produced by 4 stream-rolling division. Number of stands depending on the section bar 16-18.

For each CRM were adopted square CC-bars with-cross-section 125×125, 140×140 and 165×165 mm. The range of variation of speed rolling was determined from the following considerations. The maximum rolling speed (v1) is accepted, the corresponding stable achieved by casting-rolling mills for bars and rods for respective profiles. Minimum rolling speed (v2) is the maximum casting speed, which is achieved by modern CCM - 7.2, 6.5, and 6 m/min for bars with section 125×125, 140×140 and 165×165 mm, respectively [3, 6, 7]. Rolling speeds are shown in **Table 1**. For rods, rolled out CCM with section 165×165 mm, the values of the first and second rolling speed is almost the same.

Table 1. Rolling speed in the last working stand CRM

CRM	Type of rolling	Rolling speed (m/s) depending on section bar, mm		
		125×125	140×140	165×165
CRM-1	rod ∅5,5 мм	110/77,4	110/87,7	110
CRM-2	circle ∅12 мм	30/16,3	30/18,5	30/24,7
CRM-3	reinforcing steel №12	15/4,1	15/4,6	15/6,2

Note. On the left hand of the slash – the maximum speed reached by rolling (v1), on the right – the rolling speed, corresponding to the casting speed (v2)

Here is the process of endless rolling. Thus the speed v1 corresponds reconciliation multistrand CCM, flame heating furnace and rolling mill with installation welding bar butt. Speed v2 is for directly reconciliation monostrand CCM and rolling mill with pass-through induction heating unit.

As the rolling stock was accepted steel St3sp (killed steel). The range of variation of the temperature of bars on input mill is 1000-1200 ^{o}C.

For calculations, except for rolling temperature and power parameters of deformation, it's determined the degree of accumulated strain. The accumulated degree of deformation - is the strain in the last pass with the influence of the weakening of the metal part from the previous strains. It describes the stress-strain state of the metal after rolling and significantly affects on the structure and properties of the finished products.

Adopted calibration for rolling settlement profiles are max unified with each other. The basic system of calibers is adopted oval-circle (except for passages, intended to form multistrand peal and its division in the production of reinforcing steel №12 on the method of rolling-division). Besides, in all calibers for production of rolled bars 165×165 mm two additional first passages are made inbox-calibers.

Main results of study

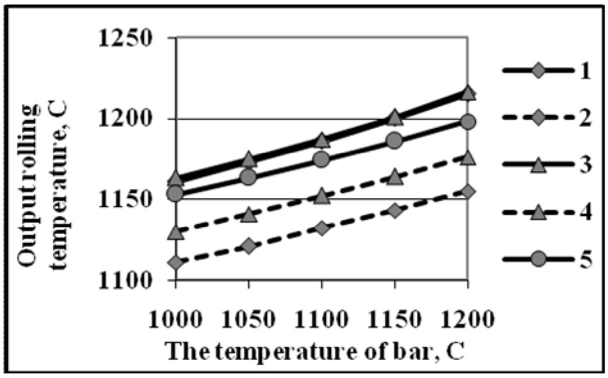
The estimated hourly production of casting-rolling mills at 100% charging of the rolling mill is presented in the **Table 2**. The rolling speed values are shown in **Table 1**.

Table 2. The estimated hourly production of casting-rolling mills

Products	The CRM production (t/h) depending on the speed rolling and section bar					
	Speed v_1			Speed v_2		
	Section bar, мм			Section bar, мм		
	125×125	140×140	165×165	125×125	140×140	165×165
Rod ∅5,5 мм	72	72	69	51	58	69
Circle ∅12 мм	94	94	94	51	58	73
Reinforcing steel № 12-4	188	188	188	51	58	73

Lower productivity of CRM for rod rolling with Ø5,5 mm from the bar 165×165 mm, compared with bars smaller section defined, that for maximum rolling speed of 110 m/s speed of the bar in the first rolling stand must be 5.62 m/min, which is below the maximum casting speed for bar 165×165 mm (6 m/min). Thus, using of bars larger than 160×160 mm in CRM, intended for the rolling of rod, will lead to a reduction in productivity.

Analysis of the results of calculation of temperature and power parameters of rolling has showed the following. Reducing the temperature of bars decreases output temperature of all rolling profiles, regardless of the section bar and the rolling speed (**Figure 2**). Reducing rolling speed leads to a significant drop of the output temperature of rolling. At most it is shown in the rolling of reinforcing steel in four threads, as in this case, the speed ratio v1/v2 is maximum.



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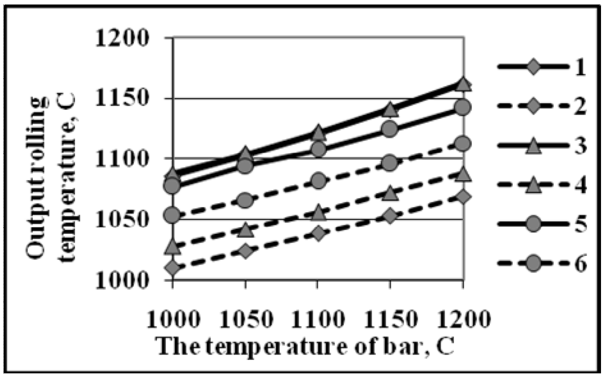

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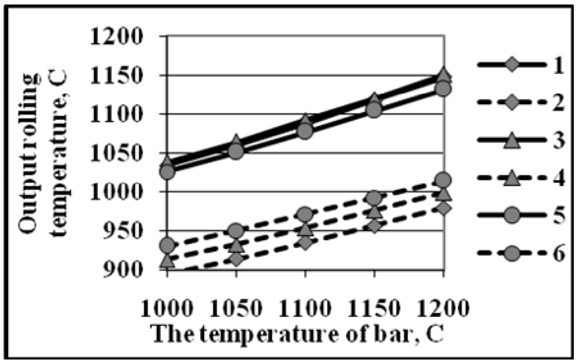

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The bar size 125×125 (1 and 2), 140×140 (3 and 4) and 165×165 mm (5 and 6).

The rolling speed v1 (1, 3, 5) and v2 (2, 4, 6):

a – rod Ø5,5 mm;

b – circle Ø12 mm;

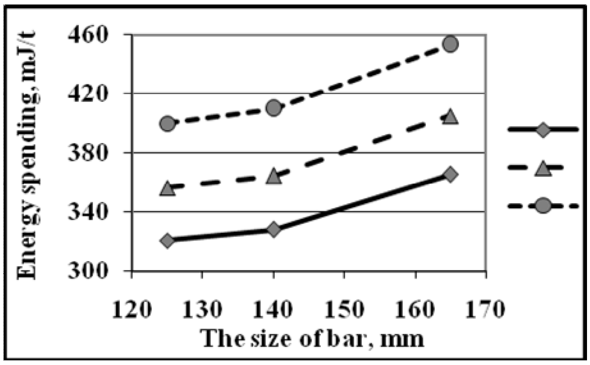
c – rein for cement № 12-4

Figure 2. Dependence of the output rolling temperature on temperature and size of the square bar

The influence of size section bar on the output rolling temperature is more complex. When the rolling speed v2 with increasing cross section size of the bar the end rolling temperature decreases. However, the rolling speed v1 and section size pieces 125×125 and 140×140 mm end rolling temperatures at the same heat are close. For a section 165x165 mm end rolling temperature decreases.

During the reducing temperature of heating the bars from 1200 to 1000 °C, power parameters of rolling (power and moment) are increased by 50-60% in the first stands and by 2-35% in the last stands of the rolling mill. Increasing the value of power parameters in the last stands is most significant in the case of reinforcing steel rolling № 12-4 (25-35%) and the least significant in the case of rod rolling Ø5,5 mm (2-15%). The effect of increasing the size of the cross section bar in the investigated interval increases power parameters values by no more than 10%.

The calculations also showed that the accumulative degree of deformation in the studied range of varying parameters of rolling is changed slightly and value for rod is Ø5,5 mm 0,36-0,37; for the circle Ø12 mm 0,38-0,40; for reinforcing rolled products № 12 0,26-0,33.



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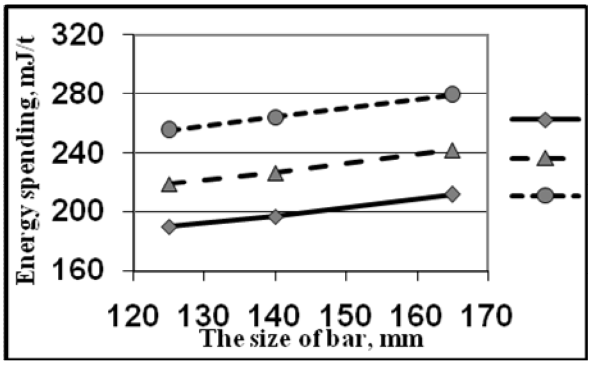

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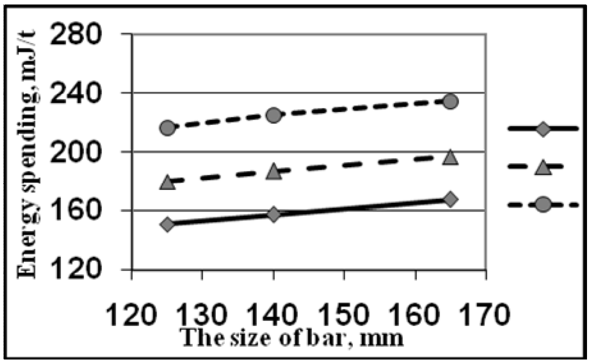

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The temperature of bar 1200 (1), 1100 (2) and 1000 °C (3):
a – rod Ø5,5 mm;
b – circle Ø12 mm;
c – rein for cement № 12-4
The rolling speed v1

Figure 3. The dependence of the specific energy consumption on the deformation of the metal on the temperature and size of the square bar

Reducing the temperature of bar leads to an increase in energy consumption on the deformation (**Figure 3**). However, the increase of energy consumption is not the same for the profiles with various sections. For example, if the reduction of the temperature of the bar from 1200 to 1000 ^{o}C with rolling reinforcement № 12-4 leads to increase power consumption in 1,41-1,46 times, so for rolling rod Ø5,5 mm power consumption increases by 1.25 times . This is due to the influence of strain heating in the later passes on the stress of steel.

As the size of the cross-section of the original bar power the consumption increases during rolling any profiles. However, if the rolling rod Ø5, 5 mm the intensity of energy consumption increases, then the rolling circle Ø12 mm practically isn't changed, and the rolling reinforcement № 12-4 the intensity of energy consumption decreases.

Reducing the rolling speed to a value, corresponding to the casting speed, leads to some increase in energy consumption during rolling of all the above profiles by 2-3%. Therefore, the combination of a multistrand CCM with rolling mill is use full not only from the standpoint of improving charge mill, but also from the standpoint of energy savings for the deformation.

Decrease bar heating temperature, despite the increase in consumption of energy for the deformation of the metal, is still beneficial from the standpoint of the total energy savings for heating and deformation of the metal. This is confirmed by the calculated data presented in **Table 3**. In the calculations, the average temperature of the bar at the input to the heating device is 850 ^{o}C, the efficiency of the heating device is 0.6;bar heating temperature in the base case 1200 ^{o}C.

From the **Table 3** the energy savings due to reduced heating temperature bar with decreasing cross-sectional area of final products and the increase of the cross-sectional area of the bar. Thus, for the CRM and CRC it's right to reduce heating temperature at 100-200 ^{o}C, which is confirmed by the practice of designing CRM and CRC [3, 8]. The temperature of the heating of the bar must be chosen depending on the grade of steel and required temperature of the end of rolling.

Table 3. Reduction of the total power consumption when the temperature of bar heating decreases from 1200 °C

Products	The size of bar, mm	Reduction of the total power consumption to heating and deformation in CRM (%) at bar heating temperature, °C			
		1150	1100	1050	1000
Rod ∅5,5 mm	125×125	4,9	9,5	13,8	17,7
	140×140	4,7	9,2	13,4	17,2
	165×165	4,3	8,3	12,1	15,5
Circle ∅12 mm	125×125	6,7	13,0	19,0	24,6
	140×140	6,5	12,7	18,5	23,9
	165×165	6,3	12,3	18,0	23,3
Rein for cement №12-4	125×125	7,2	14,0	20,4	26,4
	140×140	7,0	13,7	19,9	25,7
	165×165	6,8	13,5	19,6	25,3

Conclusions

Based on analysis of the calculated temperature and power parameters of rolling in casting-rolling mills and complexes, there are the following conclusions:

- increase the size of the original bar size increases specific energy consumption on deformation, but also increases the productivity of a single stream CCM, thanks to it, it's possible to reduce the number of streams CCM up to one;
- for rod Ø5,5 mm it's useless to take bars larger than 160×160 mm in CRM, as it will lead to a decrease in productivity;
- reducing the temperature of bars heating provides decreasing of total energy consumption for heating and deformation of the metal, but increases the power, moment and rolling capacity. Depending on the rolled product, the rational temperature is 1000-1100 °C;
- combination with multistrand CCM with rolling mill for the production of profiles section of more than 50-100 mm^2 is benefit for both increased charge of the mill and the standpoint of energy savings for the deformation.

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Влияния температуры и размера сечения заготовок на параметры прокатки в сортовых литейно-прокатных агрегатах

Бадюк С. И., Воробей С. А.

Приведены результаты аналитических исследований влияния размера сечения и температуры непрерывнолитых заготовок на температуру конца прокатки и энергосиловые параметры деформации в сортовых ЛПА. Полученные закономерности рекомендуется использовать при выборе размеров заготовки, состава и технологических характеристик оборудования прокатного стана ЛПА.