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Investigation of Rolling Rounds in the Blooming Mill

A.N. Tumko[1], O.A.Yaroshenko[1], F.A. Golubitskiy[1], V.N. Danchenko[2]

[1] PJSC "Dneprospetsstal"
[2]National Metallurgical Academy of Ukraine

Technology rolling rounds with diameter 265, 285, 300 and 330 mm of special steels in the blooming mill 950 (before reconstruction) and 1050 (after reconstruction) was developed and tested in conditions of PJSC "Dneprospetsstal ". The effect of the deformation modes on the rejection of rolled ingot on the axial porosity, which is not brewed under deformation, was researched. The stability of peals with an oval and rectangular cross-section during rolling in a round groove of the blooming mill rolls was studied. The recommendations on sizing rolls and technological parameters of rolling rounds from structural and corrosion-resistant steels in the blooming mill are developed.

Keywords: BLOOMING MILL, ROLLING, ROUND SECTION, THE MODE OF DEFORMATION, ROLL GROOVING

Introduction

Reconstruction of the steelworks, together with the implementation of out-of-furnace process usually involves the installation of continuous casting machine, which frees the power of blooming mills. Therefore, there is a need to load released capacity of blooming mills by manufacturing certain products, including rolling round sections of large diameter instead of press forging.

At PJSC "Dneprospetsstal" (Kiev) production of large diameter profiles up to 275 mm of carbon and alloy structural steels and the round sections up to 230 mm in diameter of hard austenitic steels was developed on billet mills 950 of the blooming-billet mill 1050/950 [1-3]. Production of rolled products with a diameter exceeding 275 mm of structural steels and diameter over 230 mm of stainless chromium-nickel steels in the mill 950 is not possible according to the strength and the energy-power parameters for the mill. This type of metal is traditionally produced by press forging, than is caused by its high cost. Forging is a low-performance energy-intensive process with large losses of metal in scale, lump and cutting waste.

The aim of this paper is to replace the expensive operation of press forging of round sections by rolling in the blooming mill at PJSC "Dneprospetsstal" to reduce costs and improve competitiveness of metal products.

Results and Discussion

For this purpose technology of rolling of high-quality round bars in the blooming made of special steel was developed and tested: blooming mill 950 - stand-rolled bars of diameter 285, blooming mill 1050 (after reconstruction of blooming mill 950) - bars of diameter 330, 300 and 265 mm of structural and austenitic stainless steels [4].

In order to roll a round section with diameter of 285 mm for the rolls of the mill 950 a special grooving (**Figure 1**) and rolling scheme, which provides 17 passes (**Table 1**), were developed.

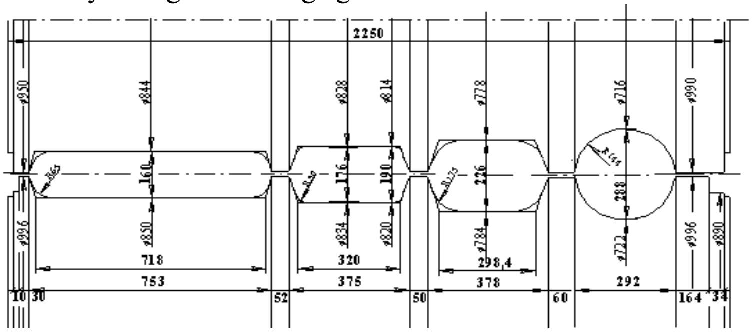

Figure 1. Grooving the blooming mill 950 rolls for rolling a round section of 285 mm

Table 1. Diagram of rolling a round section of 285 mm of structural steels (ingot weight 7.4 tons)

Groove	Pass #	Height H, mm	WeightB, mm	angle of nip α, rad	H/Dк	(α(6.88+α))/4	(α(6.88+α))/4 - H/Dк
I		720	720				
	1	655	725	0.392	0.853	0.714	-0.14
	2	595	730	0.377	0.776	0.684	-0.09
	Turning						
	3	660	610	0.407	0.865	0.742	-0.12
	4	590	620	0.407	0.782	0.742	-0.04
	5	520	630	0.407	0.699	0.742	0.04
	6	450	640	0.407	0.616	0.742	0.13
	7	385	650	0.392	0.533	0.714	0.18
	8	325	660	0.377	0.456	0.684	0.23
Turning							
II	9	570	340	0.470	0.811	0.864	0.05
	10	480	350	0.470	0.700	0.864	0.16
Turning							
I	11	320	490	0.267	0.415	0.476	0.06
	12	Dummy					
Turning							
II	13	410	335	0.443	0.602	0.812	0.21
	14	330	350	0.443	0.504	0.812	0.31
	15	Dummy					
oval	16	282	360	0.351	0.424	0.635	0.21
Turning							
circle	17	288	288	0.448	0.503	0.822	0.32
						Amount	1.51
						Average	0.09

For the straight bars eight melts of steel 18Г and one melt for steels 20 and 45, cast into ingots weighing 7.4 tons were rolled. Reduction coefficient in the padding part was 7.3, and the bottom 5.2. Single reductions on a smooth barrel were 50-70 mm, 40-55 mm on a box groove, on the polygonal (oval) 38 mm and 67 mm on the round one.

After turning round bars at 30 mm in diameter a satisfactory surface quality was obtained, but at UI 4.8% of the bottom rods and 41.5% had padding rods had the centerline porosity of the ingot not brewed during deformation.

Analysis of the pilot scheme rolling (**Table 1**) showed that during rolling in grooves and in the last five passes on the smooth part of the roll barrel, the axial zone of deformation under hydrostatic pressure and internal discontinuities must intensely brew. Analysis of the mode of deformation was carried out according to the formula

$$\frac{H}{Д_K} \le \frac{\alpha(6,88+\alpha)}{4}$$

where H – initial strip height, mm; Dк – effective roll diameter, mm; α - angle of nip, rad.

Condition (1) is obtained by transformation of the formula of V.M. Klimenko for the strip with the ratio of initial width to the initial height in the range from 0.8 to 1.6 [5]. The more positive the difference

$$\frac{\alpha(6,88+\alpha)}{4} - \frac{H}{Д_K}, \qquad (2)$$

the better "working-through" of the metal over the cross section and less probability of obtaining internal defects in the finished profile (see **Table 1**). As a comparison, by the same technique, rolling draft of ingots weighing 7.4 tons for the round section 300 mm in the blooming mill 1050 was asessed (see **Table 2**).

As shown by comparative analysis of the pilot schemes of rolling (see **Table 1, 2**), both of which provide the distribution of compressive stresses in the axial zone of the rolled sheet to obtain a dense macrostructure. At the same bars with a diameter of 300 mm have a lower rejection of the ingot centerline porosity (3.4%), despite the fact that the total drawing coefficient is less than 11%. Reducing the number of internal defects with an increase in diameter can be explained by an increase profile of individual rolling draft, riding an increase in diameter and a decrease in the rate of rolling. In addition, the sum of the differences, calculated by the formula (2), and the average value of the difference in a single pass for a circle with a diameter of 300 mm longer than the diameter of a circle 285 mm (see **Table 1, 2**).

Also rolling of ingots weighing 3.6 tons of ledeburite steel Х12МФ on bars with a diameter 285 mm was tested. Due to the high resistance to deformation and low technological plasticity [6] when rolling on the smooth part of the roll barrel and the box grooves single compression made it 30-35 mm, rolling oval profile (a flat oval) in a round groove was produced in two passes [1, 6]. At the same time oval-shaped roll in a round groove was deformed stably without dumped.

After the reconstruction of the blooming-billet mill with the replacement of blooming mill 950 for the mill with a diameter of 1050 mm rolls and an increase in engine power by 42%, technique of rolling round profiles with a diameter of 300 and 330 mm of carbon and low alloy steels and a diameter of 265 mm and 300 mm of corrosion-resistant chromium-nickel steels in the blooming was tested.

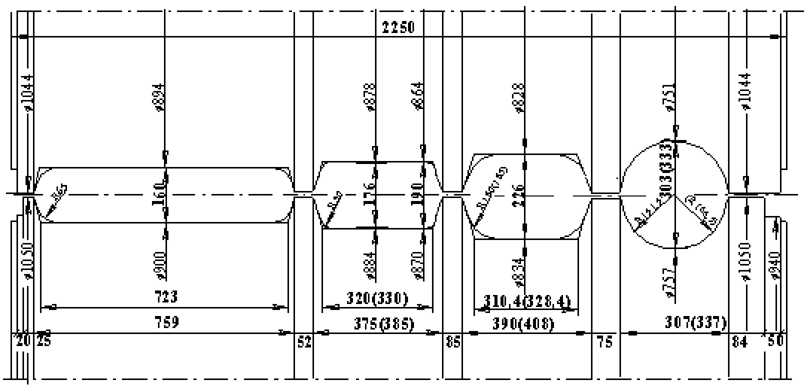

Figure 2. Grooving of the blooming mill 1050 rolls for rolling round profiles Ø300 mm (Ø330 mm)

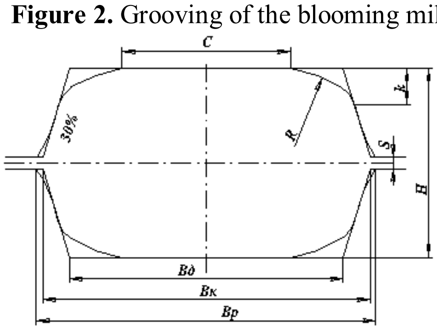

Figure 3. Flat oval for rolling round profiles

Rolling on the blooming mill 1050 of round profiles with a diameter of 300 and 330 mm of structural and stainless steels is satisfactory, oval roll in a round groove, held only by rulers of the manipulator, acted steadily. Reduction in the oval groove is 38-56 mm, 57-67 mm in the round. For rolling round profiles Ø265mm of corrosion resistant chromium-nickel steels, the experience of developing round profiles Ø300 and 330 mm, flat oval was constructed with the same aspect ratio (see **Figure 3, Table 3**).

Table 2. Diagram of rolling round sections of 300 mm of structural steels (ingot weight 7.4 tons)

Groove	Pass #	Height H, mm	WeightB, mm	angle of nip α, rad	H/Dк	(α(6.88+α))/4	(α(6.88+α))/4 - H/Dк
I		720	720				
	1	655	725	0.381	0.805	0.692	-0.11
	2	595	730	0.366	0.733	0.664	-0.07
	Turning						
	3	660	610	0.396	0.817	0.720	-0.10
	4	590	620	0.396	0.738	0.720	-0.02
	5	520	630	0.396	0.660	0.720	0.06
	6	455	640	0.381	0.582	0.692	0.11
	7	390	650	0.381	0.509	0.692	0.18
	8	325	660	0.381	0.436	0.692	0.26
Turning							
II	9	550	345	0.505	0.764	0.932	0.17
	10	445	365	0.493	0.637	0.909	0.27
Turning							
I	11	320	455	0.317	0.408	0.571	0.16
	12						
Turning							
II	13	350	340	0.493	0.527	0.909	0.38
	14	Dummy					
Turning							
oval	15	297	360	0.322	0.411	0.580	0.17
	16	Dummy					
Turning							
circle	17	303	303	0.390	0.479	0.708	0.23
						Amount	1.70
						Average	0.121

Table 3. Relations for the construction of flat ovals (**Figure 4**)

Вк	Вр	Вдн	С	R	к
(1.2-1.3)xD	Вк+16	(1.0-1.04)xD	(0.6-0.7)xD	(0.5-0.6)xD	(0.09-0.1)xD

Rolling ingots of structural steels in the range of Ø265 mm was satisfactory, but the rolling of stainless austenitic steels dumping occurred in peal oval round groove, which led to further trim of suitable metal, as well as the creation of an emergency on the mill1050.To prevent dumping of the oval strip in the round groove a variety of options for increasing stability have been tested:

- Rolling of forged billets 550x550 mm, assuming that the metal loses its stability due to the great length of the oval rolled sheet;
- Change of the size of the oval groove (depth, width, radii of curvature, the profile of the bottom of the groove).

However, the above measures do not lead to positive results. In the rolling of stainless austenitic steels oval roll dumped in a round groove. To solve this problem, we developed a special grooving of rolls (**Figure 4**), the two schemes of rolling and a number of measures aimed at stabilizing the rolling process. Fundamentally the box groove # 2 was changed:

- The bottom of the groove is carried out without the convexity;
- Increased height of the groove from 190 to 254 mm;
- Radius of curvature of the groove bottom has been increased from 35 to 140 mm.

Prefinishing flat oval almost was not changed, this oval has previously been tested. There was also changed the design of the round groove:

- The height of the circle (280 mm) was made larger than the width (273 mm);
- At the bottom of the groove of the sector 74° were cut triangular groove with depth of 2.5 mm every 8 mm (**Figure 5**).

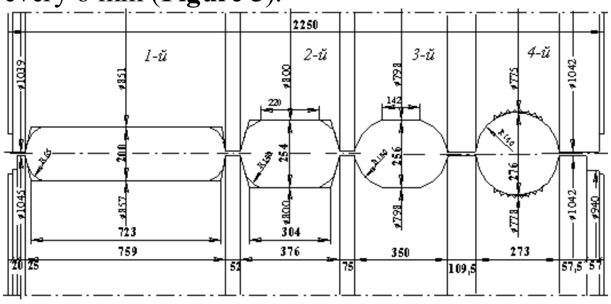

Figure 4. Calibration of rolls for rolling round profiles Ø265 mm

An elongated vertical circle and the presence of grooves on the bottom of the groove, presumably, should have increased the stability of the rolled sheet in a round-oval groove, avoid stalling of the rolled sheet. The depth of the grooves is chosen in such a way as not to affect the flow of metal during the subsequent stripping of rolled products: current technology for the allowance under the stripping of 15 mm at diameter (7.5 mm in radius).

The first scheme assumed rolling on already well-established pattern: smooth barrel →box → flat oval → circle. The size of the given oval is 254x340 mm. According to the second scheme the second box-groove was used: smooth barrel → box → circle. The size of rolled sheet from the box-groove is 260x300 mm.

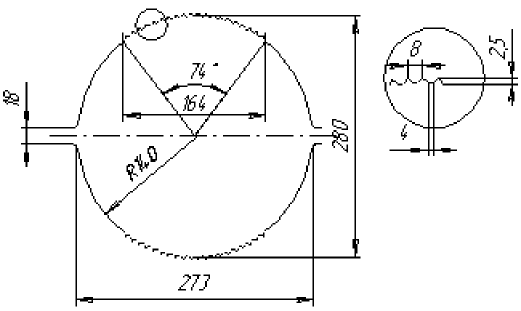

Figure 5. Round groove for rolling rods Ø265 mm

To test the stability of the incoming strip into the round groove were analyzed theoretically with the tested scheme of rolling circles with a diameter of 300 and 265 mm. The verification of the stability of the oval strip in a round groove were produced by two parameters:

1) according to the form of diagrams of the distribution coefficient of the high-altitude deformation $\eta = H / h$ (**Figure 6**);

2) according to the deformation C suggested by B.V.Merekin [7]

$$C = \frac{H}{B}\eta\beta,$$

where H, B - height and width of strip before rolling, mm; η - coefficient of high-rise deformation; β - coefficient of broadening.

In this present case, when h = b, we can write

$$C = \frac{H}{B}\frac{H}{h}\frac{b}{B} = \frac{H^2}{B^2}.$$

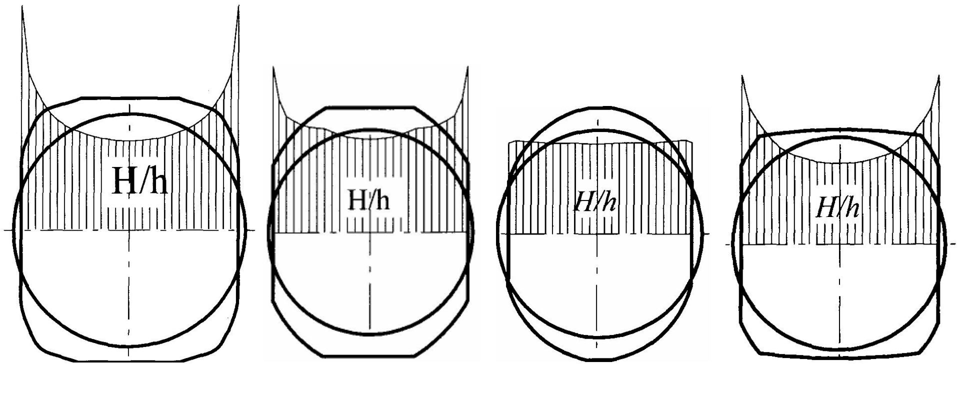

Figure 6. Reduction of strips with oval cross sections in the round groove

Table 4. Results of experimental rolls of various oval strips in the round groove on the blooming mill

Reduction scheme	Circle diameter, mm	Stability coefficient C	Steel	Behavior of rolled sheet in a round groove
Figure 6a	300	1.48	Structural stainless	not dumped not dumped
Figure 6b	265	1.65	Structural stainless	not dumped dumped
Figure 6c	265	1.78	Structural stainless	dumped
Figure 6d	265	1.32	Structural stainless	not dumped not dumped

The results of experimental rolls of oval strips in the round groove for different schemes (**Figure 6**) are shown in **Table 4.**

The analysis of diagrams and coefficients of deformation showed that the largest reserve of stability of strip rolls was in a scheme of rolling circle diameter of 265 mm, for which C = 1.32 (**Figure 6d**), and the smallest - the scheme rolling circle diameter of 265 mm, for which C = 1.78 (**Figure 6c**). In a pilot rolling according to the scheme of rolling oval groove (**Figure 6c**) the rolled sheet for both of low alloy and stainless steel was dumped.

When testing rolling which provides receipt of a circle from a box-groove # 2 (**Figure 6d**), has a positive result, rolling circle Ø265mm was held steady without dumping strips. According to this scheme more than 120 bars of stainless steel austenitic class were rolled.

Conclusions

1. To ensure the required stability of the strip in the round groove of the blooming mill rolled sheet aspect ratio B / H, defined in a round groove, should not exceed 1.15, a form of rolled sheet should be rectangular, with a radius of rounded corners on the bottom of the groove equal to (0.5-0.6) the diameter of the circle rolled; indicator of deformation C should be minimized, distribution diagram of altitude should have maximum values at the edges, the temperature of the rolling and roll speed should be as maximum as possible to reduce the broadening.

2. Lowering of the rolling temperature, reducing the rotational speed of the rolls below 40 rpm contribute to an increase in the broadening of chromium-nickel stainless steel, round groove overflow, loss of stability of the oval rolled sheet and its dumping in a round groove.

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Исследование прокатки круглых профилей на обжимном стане

Тумко А.Н., Ярошенко О.А., Голубицкий Ф.А., Данченко В.Н.

Разработана и опробована в условиях ПАО «Днепроспецсталь» технология прокатки круглых профилей диаметром 265, 285, 300 и 330 мм из специальных сталей на блюмингах 950 (до реконструкции) и 1050 (после реконструкции). Исследовано влияние режимов деформации на отбраковку проката по осевой пористости слитка, которая не заварилась при деформации. Исследована стойкость раскатов с овальным и прямоугольным сечением во время прокатки в круглом калибре валков блюминга. Разработаны рекомендации по калибровке валков и технологических параметров прокатки круглых профилей из конструкционных и коррозионностойких сталей на обжимном стане.