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Analysis of structure formation stability in the centrifugal cast plate rolls of nickel-chromium cast iron when entering inoculant feedings

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Abstract
The paper presents an analysis of the influence of inoculating feedings Superseed® 75 (Sp) and Reseed® (Rd) Inoculant on the structure formation in the centrifugal cast rolls made from the nickel-chromium cast iron. It is shown that when increasing the share of the inoculant from 1 to 4 kg the top and bottom pinion rings have a similar structure of the graphite form as well as in the grain size and the ratio of the phases. Formation of a uniform structure along the length of roll pinion ring will enhance their service life and reduce the tendency to spalling.
Keywords: DOUBLE-LAYERED ROLLS, CAST IRON, INOCULATION, METAL STRUCTURE, SERVICE LIFE

In recent years, to improve the quality and depth stability of the working layer of double-layered rolls from nickel-chromium cast iron centrifugal casting method and inoculation of metal working layer by a new generation of mixtures such as Superseed®75 (Sp) and Reseed® (Rd) Inoculant [1-2] are used. This allows us to improve the metal quality and obtain the necessary operational properties of the rolls in their manufacture.

The work objective is carrying out the statistical analysis of the rolls quality of such performances to fix the stability of the metal structure formation with the determination of effective share of the inoculant of injected types is used.

To carry out the objective a sample of 19 rolls measuring of 675 × 1760 mm LPHNMd-71 and LPHNMd-73 versions of sheet mill 1700 were analyzed. The core of the rolls is a gray cast iron. The rolls were cast in the period from 2009 to 2012 at the State Enterprise» Lutugino Research & Production Roll Company."

The statistical rolls sample is characterized by the following chemical composition: 2.99 ±0.08% C; 0.92 ± 0.05% Si; 0.58 ± 0.05% Mn; 0.09 ± 0.01% P; 0.04 ± 0.004% S; 1.67 ±0.09% Cr; 4.25 ± 0.04% Ni; 0.25 ± 0.07% Mo; 0.02 ± 0.048% Al; 0.012 ± 0.006% Co; 0.068 ± 0.038% Cu; 0.019 ± 0.005% Nb; 0.01 ± 0.006% Ti; 0.15 ± 0.02% V; 0.027 ± 0.01% W; 0.002 ± 0.0004% Zr; 0.05 ± 0.026% B.

The chemical composition of the studied rolls corresponds to technical conditions of their production (TR U27.1-26524137-1291-2007) [3].

Analysis of the sample shows that the investigated rolls have close concentration of chemical elements and impurities.

The treatment of the alloyed metal in the amount of 2.1 to 2.5 tons intended for working layer in the ladle was carried out of total share of Superseed®75 (Sp) and Reseed® (Rd) Inoculant from 1kg to 4kg.

Paper studies the structure of the rolls after heat treatment - annealing at 600 °C for release of stresses.

Analysis of the structure of the rolls working layer treated with 1 kg of total weight of Superseed® 75 (Sp) and Reseed® (Rd) Inoculant showed that in the surface layer of top part of the roll body there were large nonmetallic inclusions in a large amount (indicated by the arrows, Fig. 1a). Graphite has a compact form. Uneven distribution of graphite, 5-7 pcs observed in view of the polished section, with the size of 45-60 microns.

Starting with a depth of 10 mm the formation of compacted and shortened graphite plates of 10-12 pieces is observed into view (Fig. 1, c).

With developing of depth the dimensions and the amount of graphite increases. Grain is formed in the iron working layer and has a different size. Metal is characterized by extended dendrites directed towards the removal of heat.

At the surface structure of the bottom of the roll body at a depth of 5mm graphite has a compact shape and compacted size of 45-60 microns. With developing of depth of the working layer the number of tight, compacted and shortened platelike inclusions increases and their size is reduced to 25-45mkm.

The microstructure of the metal is represented by martensite, bainite, troostite, ledeburite, cementite (up to 38%), graphite (Fig. 1b).

Analysis of structure of the top roll body treated with 1.5 kg of total weight of Superseed® 75 (Sp) and Reseed® (Rd) Inoculant showed that working layer contained a small number of fine non-metallic inclusions (Fig. 2a). Graphite at the surface is compact and tight, the size is 15-30mkm, 5-8 pcs is in view of the section. From a depth of 10 mm compact graphite inclusions are observed (Fig. 2 c). For greater depth the amount and sizes of graphite increases. There is a very large dendritic crystallization. The microstructure of the top roll body includes martensite, bainite, ledeburite,cementite up to 35% (Fig. 2, b, d).

Analysis of the bottom structure of the roll body treated with1.5 kg of total weight of Superseed® 75 (Sp) and Reseed® (Rd) Inoculant showed that working layer also contained large (indicated by arrows) non-metallic inclusions (Fig. 2, e). Graphite at the surface has compact form with the size of inclusions 45-60mkm, 4-7 pcs into view of the section. From a depth of 10 mm the compact graphite colonies are observed (Fig, 2, g). From a depth of 25 mm flake graphite is formed. Grain is fine and with the depth increasing extended dendrites are crystallized. The microstructure of the bottom of the roll body includes

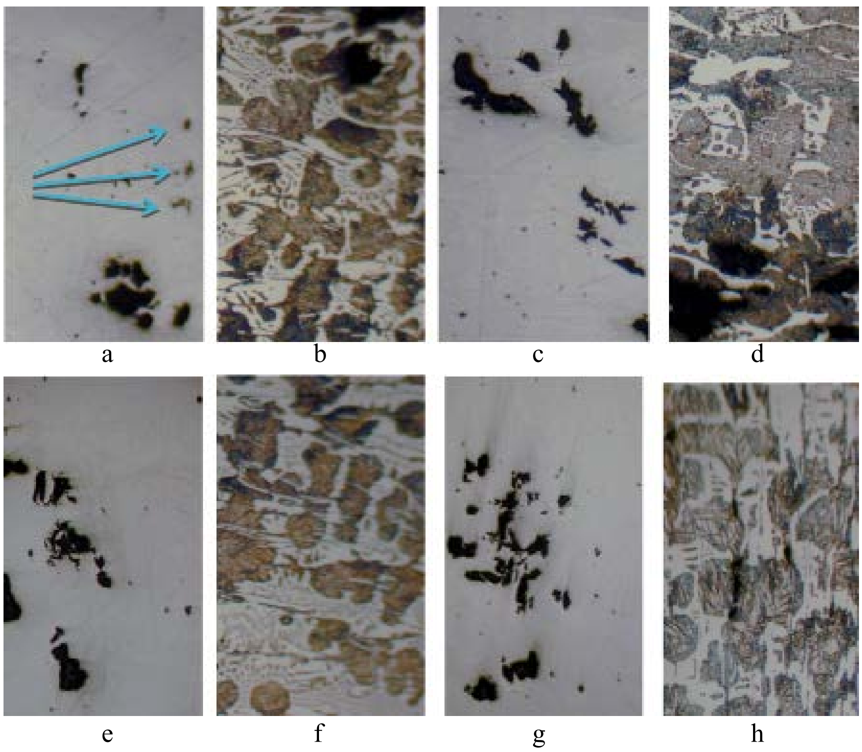

Figure 1. A typical microstructure of the rolls working layer treated with 1 kg of total weight of Superseed®75 (Sp) and Reseed® (Rd) Inoculant: a, b, c, d is the top part of the roll body; e, f, g, h - the lower part of the roll body; a, b, e, f, at the depth of 5 mm; c, d, g, h at the depth of 20mm, × 100

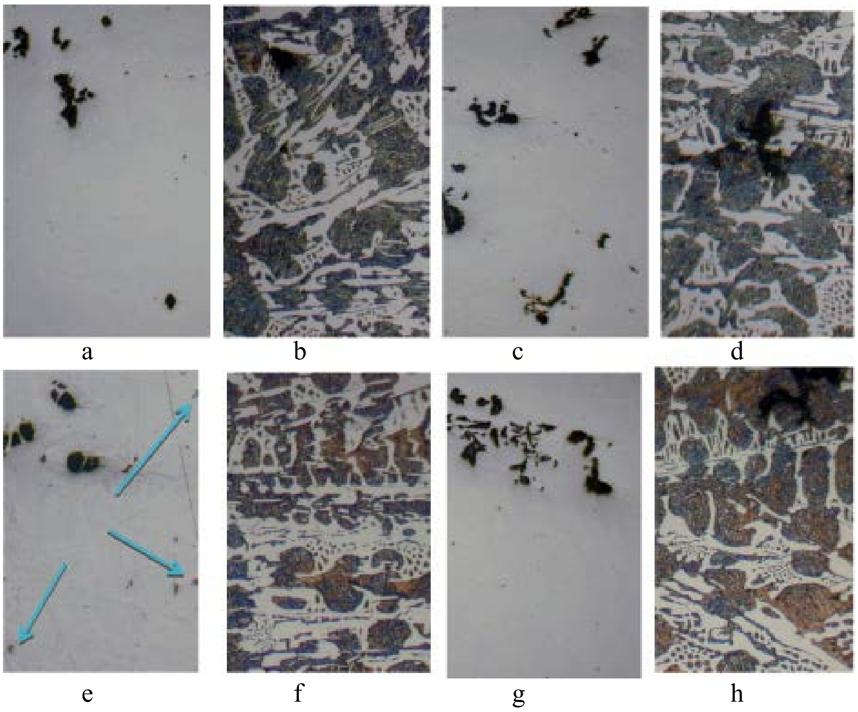

Figure 2. A typical microstructure of the working rolls layer treated with 1.5 kg of total weight of Superseed®75 (Sp) and Reseed® (Rd) Inoculant: a, b, c, d is the top part of the roll body; e, f, g, h - the lower part of the roll body; a, b, e, f, at the depth of 5 mm; c, d, g, h at the depth of 20mm, × 100

martensite, bainite (a small amount), ledeburite, cementite up to 37% (Fig. 2, f, h).

Analysis of the structure of the top roll body treated with 2 kg of total weight of Superseed® 75(Sp) and Reseed® (Rd) Inoculant has shown that the working layer also has large non-metallic inclusions (Fig. 3a). At the surface compact graphite inclusions are revealed with a size up to 45 microns. As the distance from the surface the compact graphite is formed, the size and number of inclusions is significantly increased (Fig. 3, c). Average grain increases with the depth. There is a rough dendritic structure

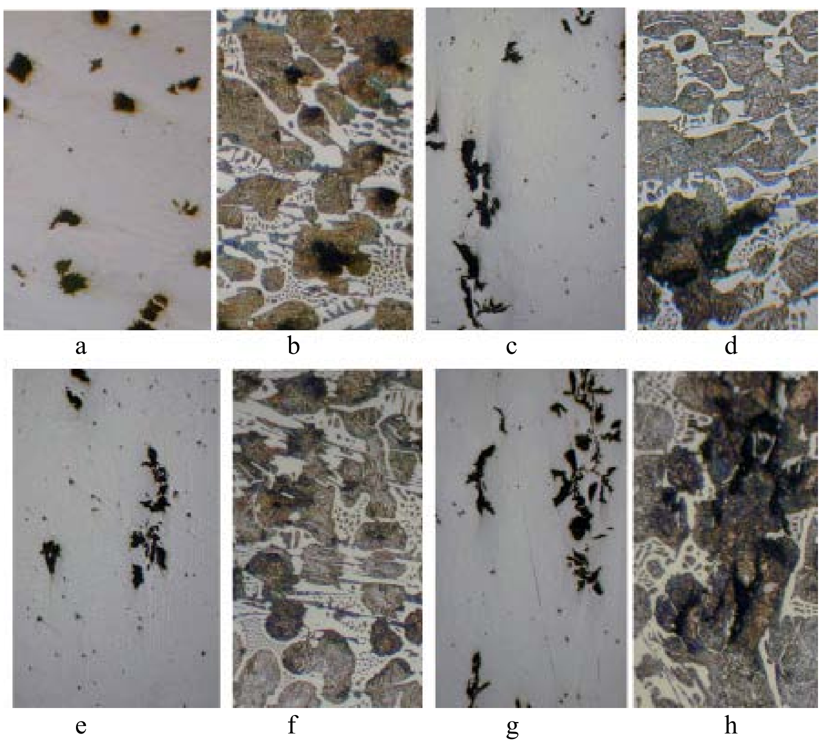

Figure 3. A typical microstructure of the rolls working layer treated with 2 kg of total weight of Superseed® 75(Sp) and Reseed® (Rd) Inoculant: a, b, c, d is the top part of the roll body; e, f, g, h - the lower part of the roll body; a, b, e, f, at the depth of 5 mm; c, d, g, h at the depth of 20mm × 100

on the surface. The microstructure of metal includes martensite, bainite areas troostite, ledeburite, cementite up to 37% (Fig. 3, b, d).

In the structure of the working layer of the roll's body bottom the compact graphite prevails (Figure 3, e, g). The inclusion size increases with the depth. The grain is slightly larger than at the top of the body. The microstructure is similar to the top of the roll body (Fig. 3, f, h).

Microstructure of the top roll body treated with 3 kg of total weight of Superseed® 75 (Sp) and Reseed® (Rd) Inoculant consists of martensite, bainite, troostite portions, ledeburite and contains cementite up to 30-32%. The structure of the top body also contains non-metallic inclusions. A considerable amount of graphite spots and compact structure (Fig. 4a) is revealed across the entire surface of the section. The grain size of the working layer is increased with depth developing. There is a pronounced coarse dendritic structure at the surface (Fig. 4b).

In the structure of the bottom roll body (Fig. 4, e, f) the proportion of graphite is increased and its inclusions are larger than the top part. The crystallizing of dendrites of different sizes from small to large is noted. Therefore, in these areas there identified the sections with different contents of cementite that characterizes different crystallization conditions of the identified zones. The microstructure shows bainite, martensite sections with an insignificant share of troostite and cementite (of 30-32%).

Analysis of rolls treated with 4 kg of total weight of Superseed® 75(Sp) and Reseed® (Rd) Inoculant (Figure 5) has shown that the structure contains a small amount of fine non-metallic inclusions. The graphite surface is compact, its dimensions are 15-25mkm and they are increased with the depth. At a depth of 30mm compacted graphite of flake form is

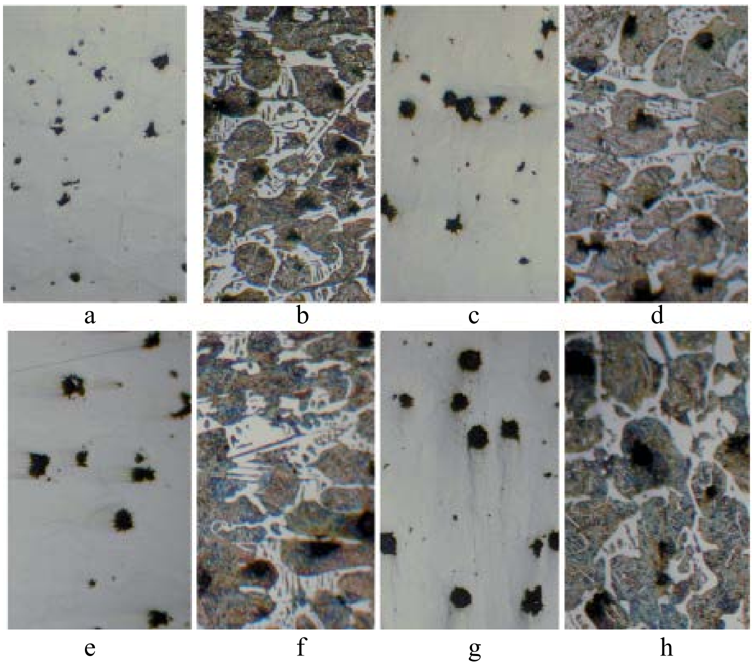

Figure 4. A typical microstructure of the rolls working layer treated with 3 kg of total weight of 75 Superseed® (Sp) and Reseed® (Rd) Inoculant: a, b, c, d is the top part of the roll body; e, f, g, h - the lower part of the roll body; a, b, e, f, at the depth of 5 mm; c, d, g, h at the depth of 20mm, × 100

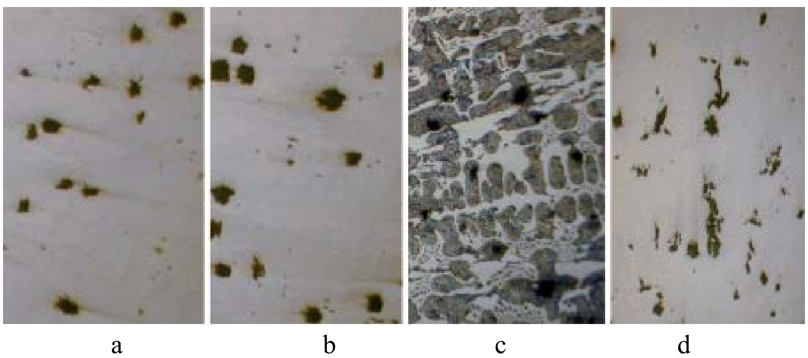

Figure 5. A typical microstructure of the rolls working layer treated with 4 kg of total weight of Superseed®75 (Sp) and Reseed® (Rd) Inoculant: a at the depth of 5mm; b, c, at the depth of 20mm; d at the depth of 30mm, × 100

observed. Grain has average size. The fine structure of the dendrites is formed. Direction is toward to the heat dissipation. Microstructure includes martensite, bainite, troostite, ledeburite, cementite up to 25-30%.

Based on the fact that the sample has been taken for a fairly long period of time, the obtained castings had different charge, i. e. they had different hereditary properties, impurity components (Al, Co, Pb, As, Zr), which can make some adjustments, form non-metallic inclusions and influence on the structure (the ratio of the phase composition, grain size) at the same parameters of the production process. The influence of these components on the rolls quality is covered in detail in [4].

The summarized data of the structure formation - the proportion of cementite and graphite grain size, which determine the level of hardness of the rolls produced with the processing of metal of their working layer with different total content of inoculants Superseed® 75 (Sp) and Reseed® (Rd) Inoculant are shown in Table 1.

Table 1. Content of high carbon phase in the structure of rolls made from a nickel-chromium iron.

The total weight content of Superseed® 75(Sp) and Reseed® (Rd) Inoculant when processing 2,1-2,5t of base metal	Investigated section of the roll body	The form of graphite inclusions		Graphite inclusions size, micron		The average area occupied by graphite%	The average area occupied by cementite%
		at a depth of 5 mm from the surface	at a depth of 10 mm from the surface	at a depth of 5 mm from the surface	at a depth of 10 mm from the surface		
1	Top	Compact	Compacted	45-60	25-60	3	36
	Bottom	Compact and compacted	Compacted	45-60	25-45	3	38
1,5	Top	Compact and compacted	Compacted	15-30	15-45	3	35
	Bottom	Compact	Compacted	45-60	25-45	3	37
2	Top	Compact	Compacted	30-45	30-60	4	37
	Bottom	Compacted	Compacted	15-30	30-45	4	35
3	Top	Poit-like and compact	Compact	up to 15	15-45	4	32
	Bottom	Compact	Compact	15-45	25-45	4	30
4	Top	Orbicular	Orbicular	15-30	25-30	5	27
	Bottom	Orbicular	Orbicular	15-30	25-30	5	30

Conclusion

Analysis of the rolls structure has shown that increasing the proportion of the inoculant from 1 to 4 kg promotes the formation of a finer structure of the matrix and it is significantly more uniform throughout up to the depth of the working layer.

The proportion of carbide phase is reduced by 5-10%, which does not significantly influence on the level of hardness of the rolls working layer and graphite acquires a compact form. Simultaneously it is found that with increasing the amounts of inoculant top and bottom of the roll body have a similar structure as the form of graphite, the grain size and the ratio of the phases. Formation of a uniform structure along the length of the roll body will enhance their service life and reduce the tendency to spalling.

References

1. Scoblo T. S., Sidashenko A. I., Alexandrov N. M. *Proizvodstvo i primenenie prokatnyih valkov* [Production and utilizing of rolls], Kharkiv, CD No 1, 2013, 572p.
2. Inoculants for furnace processing of iron and steel: NPP Company Website. Available at [http://www.npp.ru].
3. Rolls for rolling mills from cast iron, TR U 27.1-26524137-1291-2007.
4. Skoblo T. S., Avtukhov A. K., Sokolov R. G., Analysis of the operational stability of two-layered cast iron rolls(2015), *Steel No2*, p.p. 34-37.