CHEMICAL NON-UNIFORMITY OF THE ROLLING MILL METAL ROLL MADE OF 70Kh3GNMF STEEL

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Abstract. *The results of studies on the chemical composition of the rolling mill roll neck section, which corresponds to the upper part of the 48-ton 70Kh3GNMF steel ingot from which the roll was manufactured, are presented. It was determined that the carbon content across the entire cross-section of the roll exceeds the upper allowable limit (0.75 %) for 70Kh3GNMF steel.*

The highest content of carbon (about 1 wt.%), sulfur (up to 0.053 wt.%), and phosphorus (up to 0.023 wt.%) is observed at a distance of approximately 1/3 of the radius from the roll surface. Due to the resulting decrease in metal strength, this caused the formation of defects in the form of cracks in these areas during the ingot forging. The necessity of applying external influences to reduce segregation in the steel ingot, particularly heating and metal stirring, is noted.

Keywords**:** *steel ingots, chemical non-uniformity, segregation, metal defects.*

The service life of rolling mill rolls of modern high-performance cold rolling mills, in addition to the mechanical properties of the metal, largely depends on the quality of the ingots weighing tens of tons, from which they are manufactured. Complex processes occur during the solidification of large masses of metal, leading to the formation of various non-uniformities and defects in the ingot, including chemical macro-non-uniformity. This manifests as a difference in the content of alloying and impurity elements both in the ingot as a whole and in its separate zones, for example, in the form of the so-called A- and V-shaped segregation.

The chemical non-uniformity can be quite significant, as evidenced by the results shown in Fig. 1 and 2 concerning the content of carbon, sulfur, and phosphorus in a cold-rolled roll, manufactured at one of the Ukrainian enterprises from a 48-ton ingot of 70Kh3GNMF steel. Samples for the study were taken from the roll neck, which corresponds to the upper part of the ingot (Fig. 3).

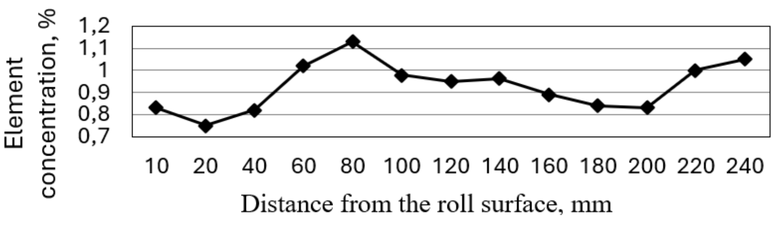

Fig. 1. Carbon distribution across the roll neck cross-section

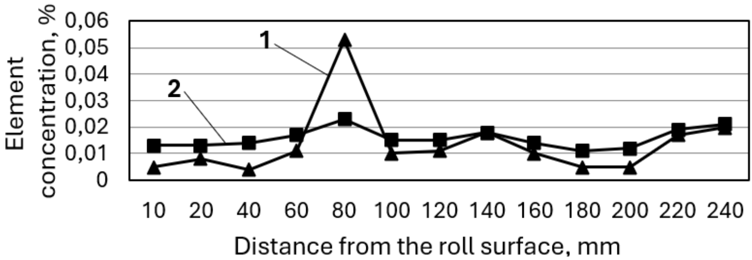

Fig. 2. Distribution of sulfur (1) and phosphorus (2) across the roll neck cross-section

The presented data show that the carbon content increases in the direction from the roll surface towards its axial part and exceeds the upper allowable limit (0.75 %) for 70Kh3GNMF steel (table). The highest content of carbon, as well as sulfur and phosphorus, is observed at a distance of approximately 1/3 of the radius from the roll surface and in its axial zones. This likely corresponds to the areas where the original ingot had sections with off-axial (A-shaped) and axial (V-shaped) segregations.

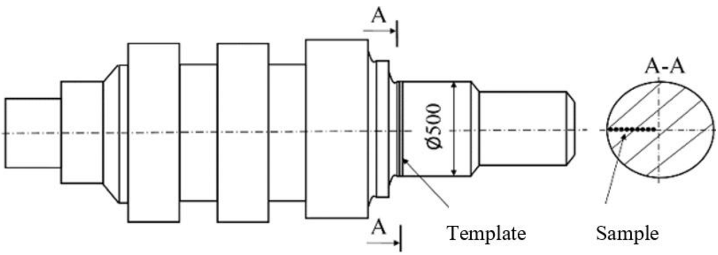

Fig. 3. Diagram of the roll from a 48-ton ingot of 70Kh3GNMF steel and the location of the template sampling for research.

Table 1

Chemical Composition of the Metal 70Kh3GNMF

Steel	Element Concentration, %								
70Kh3GNMF	C	Si	Mn	P	S	Cr	Ni	Mo	V
Ladle Sample	0,71	0,45	0,96	0,012	0,004	2,76	0,45	0,5	0,12
Grade Composition	0,65–0,75	0,40–0,60	0,90–1,30	≤0,015	≤0,015	2,70–3,30	0,35–0,50	0,50–0,70	0,10–0,30

According to numerous studies, the areas of the ingot where off-axial and axial segregation manifest, in addition to an increased concentration of segregating elements, usually also have increased porosity and other defects. This can cause premature failure or even destruction of the product manufactured from such an ingot [3, 4].

The performed macrostructure studies of the roll confirm this. After etching, cracks were detected on the transverse template along its circumference at a distance of 80–120 mm from the roll neck surface, and defects in the form of pores and metal discontinuities with a length of 5–15 mm were found in the central part of the template. That is, the defects are predominantly located where an increased content of carbon, sulfur, and phosphorus is observed (Fig. 4).

Additional studies have shown that the fracture along these defects exhibits signs of thermal oxidation and is characterized by a non-crystalline, rubbed (or 'ground'), and smoothed structural pattern.

Based on the results of the conducted research, it can be assumed that the formation of ruptures (cracks) occurs in the areas of zonal A-shaped segregation.

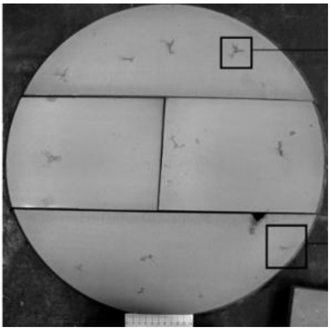

Fig. 4

In these zones, the metal, enriched with segregating impurities, has a lower melting point compared to the base metal. During the forging of the ingot to produce the roll at a temperature of 1150–1200 °C, these areas partially melt and soften, which causes their low strength and leads to failure during deformation. As a result, metal ruptures occur, which manifest as cracks on the transverse template. Such defects are unacceptable and require removal, as well as, at a minimum, the re-forging of the roll into a product of smaller mass.

The presented data demonstrate the danger of defects of segregation origin forming in a steel ingot and the necessity of developing measures aimed at their suppression. Such measures include the general reduction of undesirable impurities in the melted steel, primarily sulfur and phosphorus, as well as hydrogen by metal vacuum degassing (or "vacuum treatment of the metal").

To reduce the chemical non-uniformity of carbon during the production of large ingots, the method of successive pouring of steel from several ladles with gradually decreasing carbon concentration into the mold – the Multipouring (MP) process – is applied. However, these technological techniques do not allow for a radical impact on the processes that lead to element segregation.

More effective in terms of improving the quality of cast products can be methods of external influence that directly affect crystallization processes, such as modification, vibration treatment, metal stirring, and metal heating in the feeder head (hot top) [5]. For large steel ingots, the most effective of these are stirring the liquid core of the solidifying ingot and supplying additional heat and metal to the feeder head [6].

Studies conducted at the E.O. Paton Electric Welding Institute (EWI) using electroslag heating and metal stirring by argon blowing of its non-solidified core showed that such a combined external influence creates conditions for a significant reduction in the extent of the two-phase zone during metal crystallization and the unimpeded flow of liquid melt from the feeder head (hot top) of the ingot to the crystallization zones [7].

As a result, steel ingots produced using metal heating and stirring are free from gross defects of shrinkage origin in the form of closed shrinkage pipe and shrinkage cavities, and the axial porosity of the metal is also significantly reduced [8].

Considering that one of the main reasons for the formation of such a dangerous defect as A-segregation is the processes of element redistribution and their movement within the two-phase zone, it can be expected that reducing its size through metal heating and stirring will allow for a decrease in the degree of development of segregation defects in the ingot.

Currently, research is being conducted on the influence of the discussed method of external influence on the chemical non-uniformity of steel ingots made from roll steel grades.

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