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The improvement of the surface quality of workpieces by coating

The paper considers the coating of the work surface of the narrow walls of the mold using thermal spray coating way to improve the quality of produced billets. It was proved experimentally, that the coating leads to a decrease in the longitudinal, transverse and reticular cracks on the slab surface, which increases the yield in the subsequent rolling billets. Metallographic analysis of the billets carved from narrow edges of the slabs after latest melting, which were casted using normal and experimental mold, indicated, that reticular cracks occupied 0,1 and 6,6 % of billets, respectively. Experimental studies showed that thermal spray coating of the entire work surface of the narrow walls of the mold reduces the number of longitudinal, transverse and reticular cracks on the slab surface improving the metal yield. To improve the quality of the slab surface is advisable to make thermal spray coating of the work surface of the walls of CCM.

Key words: *thermal spray coating, mold, deterioration of the narrow walls, longitudinal cracks, transverse cracks, reticular cracks, quality of billets.*

One of the main ways to improve a surface quality of continuously casting slabs is to create conditions for monotonic cooling along length and width of a mold metal slab caster on continuous casting machine (CCM). Deterioration of the work surfaces of the mold walls is accompanied by increase of the air gap between them and continuously forming ingot, which leads to a deterioration in the cooling conditions and to a heating of the crystallizing metal surface and, in a pinch, — to a crust break of the ingot under the mold. Various coating of the work surface of the mold walls leads to a higher resistance, stability of the cooling conditions of the cast metal, and to a lower number of cracks on the slab surface [1].

The quality of the slab surface is determined by thermal state of the caster mold CCM, which largely depends on compliance the profile formed by the mold walls to the profile surface of continuously casting ingot, and by conditions of further secondary cooling of the ingot. The deformity of the slab surface caused by arachnid cracks is largely conditioned by it.

Furthermore, cracks may occur on the slabs during casting on curved CCM, when ingot bending and unbending occurs, that also leads to the slivers on its edges while sheets are rolling. Significant influence on the crack formation has a presence in the steel casted on CCM of nitrides and carbonitrides, which leads to a drastic reduction in its plasticity within a brittleness temperature range of 700–950 °C [2]. Active cooling of the edge zones of the continuous casting ingot leads to the fact that the temperature of the metal in these zones reaches the upper limit of the interval of brittleness before the ingot straightening zone is out of range, which significantly increases the probability of the formation and development of cracks.

In recent years to improve the quality of slabs there has been active reconstruction of CCM in Russia and in other countries, new machines equipped with thermal state control systems in the mold and crust break preventing system of the ingot have been constructed [3, 4].

A method of calculating the thermal state of the mold slab CCM allow you to choose the geometrical parameters and work surfaces material of the mold walls [5].

After calculating the shrinkage curves of the ingot in the mold, the authors [6] choose the desired profile of the mold wall, which ensures the most uniform deterioration of the copper along the length of the mold, and thereby uniform metal cooling in it. In conditions of JSC "Magnitogorsk Iron and Steel Works" kits with trimensional taper range adjustment on the narrow walls were tested, and in conditions of JSC "Severstal" kits with a complex parabolic profile were tested. These measures give a more uniform deterioration of the work surfaces of the narrow walls, and thereby uniform cast metal cooling. As a result, a reduction of destruction of the slab surface by cracks was recorded.

Currently the most promising direction of reducing the deterioration of the work surfaces of the narrow walls and of improving the surface quality of obtained slabs is considered a various coating of the mold wall [7, 8].

One of the first Russian metallurgical enterprises, where coating of the slab mold was used, was JSC "Severstal". Low mold cooling with drilling channels and loop cooling system could lead to the coating delamination. LLC "Korad" specialists developed a new mold design, which allows to use thin walls with slotted channels and direct-flow cooling system in old case. LLC "Korad" organized work on galvanic coating of old mold walls and carried out tests at JSC "Severstal" [9]. During the tests two types of coatings were used "KME Europa Metal AG" (Germany): AMC-HN20 — a coating of nickel with hardness 220 HV, and AMC-HN40 — a coating of an alloy of nickel with cobalt with hardness 400 HV. As a result, the number of slabs affected by sur-

Fig. 1. R-7 Mold after removal from the CCM on stand

Fig. 2. Narrow wall of the mold R-7 after its dismantling

face defects (about 6 times) decreased, and an increase in durability of mold walls was indicated. Tests have shown that the effect on the quality of two types of coating is the same. The work surface of the mold wall wasn`t fully coated with nickel, but only partly. Nevertheless, surface quality of arachnids (reticular) cracks meets the quality of billets prepared using casting mold with completely covered work surfaces.

However, galvanic coating is used only with thin-walled slotted mold CCM and isn`t used with thick-walled mold. To improve the surface quality of the slabs, which are produced using the metal casting by thick-walled mold, can help thermal spray coating.

Experimental studies were carried out under conditions of the productive capacity of the "NLMK" JSC, where the work surface of the narrow copper walls M1R with adjustable mold using thermal spray coating method were coated with a nickel-based alloy. The required purity grade of the work surface of the walls was ensured due to the mechanical processing. Using mold with coated walls (R-7) and without coating (R-3) cross-section 250×1850 mm in the converter shop № 2 at CCM № 5 11 heats of high manganese steel S355JR were casted, which often have multiple cracks on the billets.

Inspection of the casting mold R-7 after removal from the CCM on the stand without disassembly and narrow walls after the removal of mold showed, that the deterioration of the coating occurred only in the corners of the bottom wall. The rest of the work surface of the narrow walls on the mold coating remained unchanged (**Fig. 1** and **2**).

A comparative analysis of two parallel slab surfaces of streams № 9 and № 10 CCM № 5 with normal (R-3) and experimental (R-7) mold identified fewer longitudinal cracks on the meltings № 2, 3, 5, 9 and 11 using experimental mold. Furthermore, transverse cracks were found on slabs of melting № 3 casted using normal mold, whereas there were no such cracks on slabs casted using experimental mold.

Metallographic analysis of the billets carved from narrow edges of the slabs after latest melting, which were casted using normal and experimental mold, indicated, that reticular cracks occupied 0,1 and 6,6 % of billets, respectively (**Table 1**).

The results of the rolling of sheets from the obtained slabs are presented in the **Table 2**.

The table 2 illustrates that 1.2 % of sheets are sorted, which are made of slabs casted using mold (R-7) and 4.3 % using normal mold (R-3).

It may be that a significant improvement of the surface quality of the slab can be possible using simultaneous deposition on work surfaces of narrow and wide mold walls.

Table 1. Surface quality of the slabs analysis without (stream № 9) and with coating (stream № 10) on the narrow wall of the mold

Casted melting number	Mold	Number of cracks		Reticular cracks (% of the sample area)
		longitudinal	transverse	
2	R-3 R-7	9 7	– –	– –
3	R-3 R-7	14 13	5 –	– –
5	R-3 R-7	9 6	10 10	– –
9	R-3 R-7	9 7	10 10	– –
11	R-3 R-7	13 11	5 5	6,6 0,1

Table 2. The results of the rolling of the slab casted using experimental and normal mold

Stream number	Rolled, t	Sheets sorted, t				
		total	including defect			
			longi-tudinal cracks	trans-verse cracks along fold	trans-verse cracks	sliver
9	1737,8	74,8	28,2	33,5	13,1	0
10	1744,2	21,6	4,1	15	0	2,5

Conclusions

1.Experimental studies showed that thermal spray coating of the entire work surface of the narrow walls of the mold reduces the number of longitudinal, transverse and netlike cracks on the slab surface improving the metal yield.

2. To improve the quality of the slab surface is advisable to make thermal spray coating of the work surface of the walls of CCM.

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Putting into practice innovative potential in the universal radial-shear rolling process

Various mini-mill structures of new generation for implementation of multiple-purpose radial-shift rolling (RSR) are described. Deep compaction and metal structure development throughout all the levels of the metal-physical morphology take place during helicoidal metal outflow along the prescribed trajectories with deceleration of the outer layers of stock material and acceleration of the inner ones creates intensive shift displacements in the deformation zone. As for morphological structure, it is shown that the metal becomes a material of new quality after RSR. Principal improvement physical and mechanical metal properties are noted on the permanent base. The best results are reached in plastic and viscous performance properties as well as in those, which are correlation-associated with them. A number of highly-effective innovative technics of deformation processing of miscellaneous metals and alloys, such as deep metal structuring and improvement of its properties in elongated volumes by intensive plastic straining; creation of automatic complexes of thermo-mechanical processing; return to the economic circulation (recycling) of out-of-service rods and off-gage bar-profiled residual portions; production of stock materials of optimum diameter for piercing with improvement of the continuously-cast product structure and toughness, are presented.

Key words: *deformation impact, combining, plastic deformation, carbon wire, tension, compression, bending, twisting, ultrafine grain structure, mechanical properties.*

The present-day classification of metal forming processes defines the radial-shear rolling (RSR) as a special case of stationary screw rolling in the field of the big feed angles (15–18° and more) in rolls with special calibration for uniform cross-section solid billet working [1].

The RSR special-purpose designation is the effective production of round bars, rods, and rough workpieces mainly of alloyed metals and alloys; formation of unique metal structure by its deep structure processing in elongated volumes; RSR has opened essentially a new way to bar-rolling and tube production updating as well as solution of some actual problems concerning thermo-softening processing.