IMPROVEMENTS IN PLATE MILL WORK ROLLS (1)

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SUMMARY:

Big sized plate mill work rolls in conventional ICDP grades often show poor surface quality and low performance. The reason is coarse microstructure and graphite formation in the shell. Spun cast carbide enhanced grades can help to improve surface quality and performance at an even better cost – performance – ratio than conventional grades.

In high chromium rolls, carbide enhancement results in a higher surface hardness without changing the basic characteristics of the martensitic shell. Higher wear resistance can be reached without increase in heat crack sensitivity.

Roll production, differences in microstructure and performance comparison are discussed in detail.

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**CONVENTIONAL ICDP VS CARBIDE ENHANCED ICDP ROLLS**

Roll wear is a complex phenomenon. Apart from all the theories, the last years of roll application in plate mill rolling have shown a strategy to improve the wear resistance of work rolls by improvement of existing roll grades by carbide enhancement.

Indefinite chill rolls are widely being used for rolling plate. The shell material consists of:
- soft and tough martensite/bainite (c)
- a network of hard and wear resistant, brittle carbide (b)
- soft graphite inclusions (a), see illustration 1.

Illustration 1: main characteristics of Indefinite chill work rolls microstructure containing:
- a) graphite, b) cementite, c) martensite/Bainite

One of the typical features of ICDP rolls is the hardness drop from new diameter towards scrap diameter. This is due to the increasing amount of graphite and decreasing amount of carbide at decreasing diameter, see illustration 2.

In the transition zone between shell and core, the hardness drops from approx. 65 – 70 ShC to 36 – 44 ShC (core and neck hardness).

Illustration 2: main characteristics of Indefinite chill work rolls
- considerable hardness drop between new and scrap diameter
In case of too high graphite content of the roll surface close to scrap diameter or in case of lack of shell depth, the roll surface may become very rough and affect the surface quality of the rolled product – illustration 3.

Illustration 3: conventional ICDP roll near scrap diameter
- bad surface due to graphite segregation; plate mill work roll Ø950x3700mm

ESW has developed a special ICDP work roll grade that shows nearly no hardness drop between new diameter and scrap diameter. In illustration 4 on the left side the hardness measurement of conventional ICDP, on the right side the hardness measurement of “VIS” carbide enhanced special cast iron is shown.

Illustration 4: Improvement strategies for ICDP rolls - hardness drop of conventional ICDP (left) vs. carbide enhanced VIS (right)
In illustration 5 the difference in microstructure between conventional ICDP and the new carbide enhanced VIS grade is represented:

- the graphite form of conventional ICDP is flaky, whereas the new roll grade VIS shows round shaped graphite particles
- the new VIS rolls show smaller sized graphite particles than ICDP
- VIS rolls show special high hardness carbides in the martensitic – bainitic structure (b), which cannot be found in conventional ICDP.

Illustration 5: Improvement strategies for ICDP rolls - wear resistance
- a) globular graphite particles
- b) round-shaped high hardness special carbides

The high roughness and low tonnage performance of conventional ICDP close to scrap diameter is caused by the high amount and coarse particle size of graphite inclusions. VIS rolls show the same amount and particle size of graphite at new and scrap diameter – see illustration 6. The high amount of graphite of ICDP close to scrap size causes a lack of carbide, and low wear resistance. VIS rolls show high carbide content even at scrap diameter.

Illustration 6: Improvement strategies for ICDP rolls – segregations
distribution of carbides and graphite of ICDP vs. VIS work rolls
at new and at scrap diameter
It is also important to avoid the increase of graphite content in the inner parts of the shell, to avoid poor wear resistance in the second half of roll life. In fig. 7, the graphite formation throughout the 90 – mm shell thickness of a carbide enhanced plate mill work roll shows no difference from surface to scrap diameter. Such a uniform graphite distribution is completely unknown for conventional indefinite chill rolls and can only be obtained in certain types of spun cast carbide enhanced indefinite chill rolls.

Illustration 7: graphite formation in a VIS® plate mill work roll from 10mm to 90mm below as cast surface (Ø1150x3500mm)

High graphite content does not allow high performance because of poor wear resistance. Low graphite content does not allow high performance either, because the rolls will be prone to cracking. It is therefore important to measure the graphite content of the rolls and to find ways to influence it. Illustration 8 shows the big variation of graphite contents you can expect in case of conventional indefinite chill production compared with the small range of graphite contents that can be achieved in carbide enhanced rolls “VIS” by strict control of melting and melt treatment conditions.

Illustration 8: distribution of graphite content of ICDP and VIS work rolls

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The roll surface of conventional ICDP after mill exposure shows the negative effect of big sized graphite inclusions on roughness. VIS rolls show very limited roughness due to the smaller size and equal distribution of its graphite particles – compare in illustration 9.

Illustration 9: work roll surfaces after exposure
A) conventional ICDP   B) carbide enhanced VIS

The comparison of wear measurements of conventional ICDP and VIS show the superior wear resistance of the new grade VIS (illustration 10). Although the campaign length had been increased by more than 50%, the measured wear was much smaller than in case of conventional ICDP.

Illustration 10: wear profiles of conventional ICDP vs. carbide enhanced VIS
- rolled product was stainless steel
Typical tonnage performance data of ESW’s Indefinite Chill plate mill work rolls in different plate mills are summarized in illustration 11. The tonnage performance varies in a wide range. The reason is differences in rolling program (thin gauge <6 mm and small strip width cause low tonnage performance of the rolls) and different roll dimensions, especially barrel length.

Illustration 11: Tonnage performance of conventional ICDP plate mill work rolls

Performance comparison of conventional ICDP work rolls and VIS carbide enhanced rolls. An increase of tonnage performance of 25 – 100% has been reported by our customers. The increase in tonnage performance by using VIS can be seen in carbon steel production, HSLA production and stainless steel production. Under favourable rolling conditions (plate >8mm thick) VIS may reach up to 6000 t/mm – see illustration 12.

Illustration 12: Tonnage performance
conventional ICDP vs. carbide enhanced VIS plate mill work rolls
HIGH CHROME STEEL AND CARBIDE ENHANCEMENT

In high chrome iron and steel shell materials, the chromium carbides have the highest impact on wear resistance. In the course of the years, a more or less uniform chemical composition of these rolls has been established worldwide.

High chrome iron and high chrome steel work rolls show a very uniform carbide formation from the as cast surface to scrap diameter, which gives the rolls nearly no hardness drop at all.

Illustration 15: Microstructure of High Chrome iron

In many cases, the high chrome iron quality turned out not to be the best solution for plate mill application. Compared to Indefinite Chill rolls, the wear resistance was much better due to the lack of free graphite and the higher hardness of the chromium based eutectic carbides. Unfortunately, the high amount of carbides gives low resistance against thermal fatigue and fire crack formation. The high chrome steel concept with lower total carbide content and, as a consequence, better resistance against thermal fatigue often has turned out to be the better solution. The change in microstructure moving from high chrome iron into the area of high chrome steel is shown in illustration 16.

Illustration 16: Decreasing content of chromium and carbon
To further increase the wear resistance of these rolls, additional carbide forming elements can be introduced which increase the hardness of the eutectic carbide network. These elements and their hardness can be seen in illustration 14. The higher hardness of these special carbides also allows to increase the overall hardness of the rolls without increasing the residual stress of the rolls. This has a major impact on the crack resistance of the rolls in operation.

Illustration 14: hardness of various carbide types

The carbide enhanced high chrome steel rolls have been tested in various plate mills with a big variety of work roll dimensions. Depending on the roll size, the rolling program and the rolling condition in general, the increase of roll performance turned out to be between 20 and 100%. The results of these tests can be seen in illustration 15.

Illustration 15: Performance [t/mm]
VYSG High chrome steel vs. VYS enhanced high chrome steel

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There have been no reports on any negative effects of carbide enhancement on roll behavior, surface roughness etc. We therefore expect that carbide enhanced high chrome steel rolls will have a good chance to replace standard high chrome rolls for plate mill application in the near future.

CONCLUSION

Both Indefinite chill and High Chrome rolls are currently used for plate mill rolling. Both grades are suitable and have their advantages. Carbide enhancement is an effective tool to increase the performance level of both roll grades without apparent negative effects on surface quality and operational safety. We therefore assume that carbide enhanced roll types will sooner or later completely replace conventional roll types.

REFERENCES


