INDEFINITE CHILL CAST IRON ROLLS AND FUTURE POSSIBILITIES[1]

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Abstract

The roll grade of indefinite chill cast iron has a very long tradition. This grade is used in all types of Hot Strip Mills, Steckel Mills, Plate Mills and even in Cold Mills as Work Roll. In Skin Pass Mills and Temper Mills it can be used as Back Up Roll. From the original indefinite chill iron several modifications (enhanced grades) have been developed and introduced into the market. The standard grade is though still used in quite a number of mills. The enhanced versions of many different roll suppliers are on the other hand the "new" standard grade. Very high alloyed types have been designed and are applied in special mills. The very high alloyed types need very stable rolling conditions. Since the market has changed and the mills have to roll more and more difficult materials it is a question of time when the stability of the mill will be reduced. In this case it is necessary to find a solution for a grade with a high potential of wear resistance and at the same time enough resistance against incidents in the mill. The way of indefinite chill grade development from standard ICDP over the carbide enhanced VIS to the high alloyed VANIS and the new concept of VANIC will be explained

Key words: Work rolls development; Finishing mill; Indefinite chill cast iron.

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1 INTRODUCTION

1.1 Hot Strip Mill Conventional

The design of various HSM's is quite different. From Mills with 3 to 6 Roughing stands in continuous mode or 1 to 2 Roughing stands in reversing mode all is possible. The Finishing mill consists most of the time of 4 till 7 stands. In the last finishing stands the ICDP grades are used.

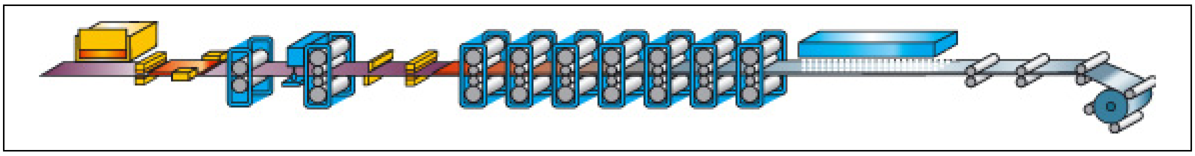

Figure 1: Typical Lay Out of a HSM.

1.2 Steckel Mill

A Steckel mill consist of either one Single stand or two stands or a combination of one Roughing stand and a single finishing stand. In the finishing stand the ICDP is still a standard roll material. Most Steckel Mills are producing Stainless Steel.

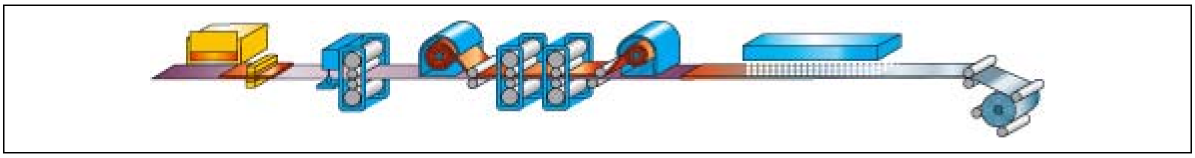

Figure 2: Possible Lay Out of a Steckel mill.

1.3 Hot Strip Mill with Strip Casting Facility

Different concepts of strip production came up in the recent years. The CSP (Continuous Strip Production) concept and various other concepts like ISP (Inline Strip Production) as well as DSP (Direct Strip Production) and finally the ESP (Endless Strip Production). All of them are using ICDP types in the finishing stands. All abbreviations are registered trademarks of the different producers.

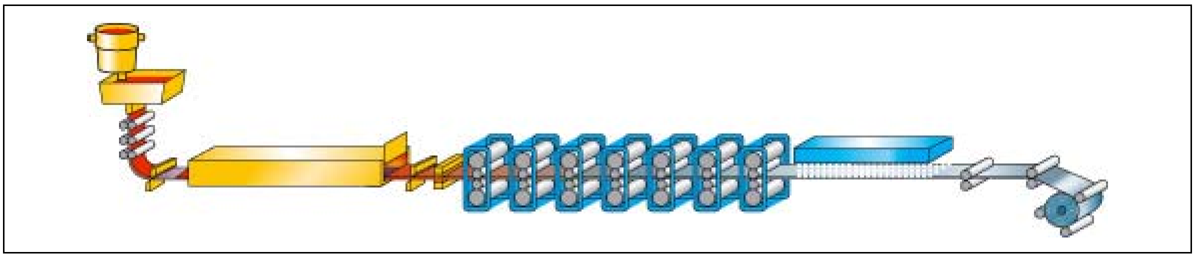

Figure 3: Example of a strip caster in combination with a finishing mill.

1.4 Plate Mill

A plate mill is in many respects similar to a roughing mill. In more recent years the plate mills are also installed with a possibility to run as a Steckel Plate Mill. The difference between a Plate Mill and a Steckel Plate Mill is that for thinner gages (<15 mm) the plate is actually coiled. The wider strip is made in the Plate Mill without coil box. Thicker gages are just rolled in Plate Mills. Many Plate Mills are using ICDP rolls still today.

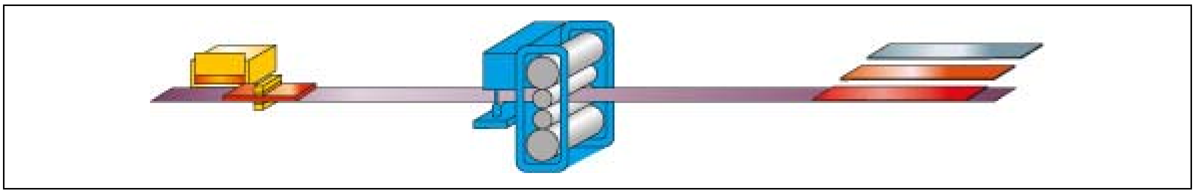

Figure 4: Plate Mill configuration.

1.5 Other Applications

ICDP rolls have also a minor share in other applications such as cold rolling of strip. Here the ICDP is an alternative to other alloys in case of work roll but also as back up roll. All together this are special cases such as Skin Pass or Galvanizing lines in case of BUR and special steel mills for ICDP work rolls in cold mills. In these cases ICDP is replacing cast steel or forged steel rolls. In all these cases the mechanical load has to be lower (compared to high reducing mills) since the ICDP roll material in combination with its core is not able to take higher loads due to strength limitations.

2 INDEFINITE CHILL CAST IRON

2.1 Description of ICDP

The ICDP material was the first step ahead after the clear chill material. The main difference between clear chill and indefinite chill was the graphite content in the full work zone. The graphite is believed to have few very helpful properties:

- It is very good to transport heat
- it can work as crack stopper and
- it is said the graphite has also a lubricating function.

At least all these characteristics mentioned above are very often mentioned in relation to the ICDP material and its benefits to other materials. On the other hand the graphite is a very soft component of the microstructure and this leads to higher wear in case of abrasion in the rolling gap. The amount of graphite was in the beginning difficult to control. Especially in cases of static cast double poured rolls. The core filling and flushing influenced the solidification of the shell and the amount of graphite varied in a wide range. Later when spin casting technology was developed the shell could solidify in a more continuous way and the graphite content was more a function of the alloy itself and the melting procedure in the foundry. Still the graphite content could vary in a wider range within one manufacturing specification. This normally ended up with not really satisfying results in various mills. The roll changes were quite frequent and the strip shape as flatness and thickness over the width were then suffering from that.
The main part of the microstructure consists of a martensitic-bainitic structure. The amount of carbides was influenced mainly by the chromium content. Higher alloyed versions sometimes appeared to be very brittle and micro spallings have been observed. In cases of low graphite content the fire crack resistance was poor. This lead to higher grind offs and the performance went down.
The basic consistency of ICDP shell material is shown in Figure 5 below

a) soft free graphite particles

b) a network of hard and wear resistant but brittle carbides
c) soft and tough Martensitic/Bainitic matrix

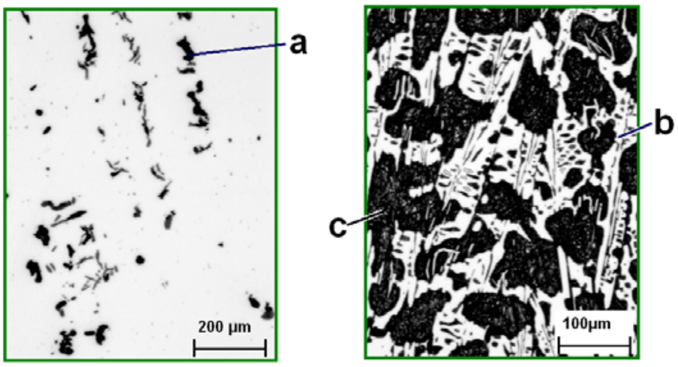

Figure 5: Main characteristics of Indefinite chill microstructure containing: a) graphite, b) cementite, c) Martensitic/Bainitic matrix.

One common characteristic of ICDP rolls is the hardness drop from the delivery Ø to the end Ø as described by Nylén, Brandner and Mayr.[(1)] This is normally due to the increase in the amount of graphite and at the same time decreasing amount of carbide at decreasing diameter (due to the effect of slower cooling rates). In the mixing zone between shell and core the hardness drops from approx. 65 – 70 ShC to 36 – 44 ShC (core and neck hardness), see Figure 6 below.

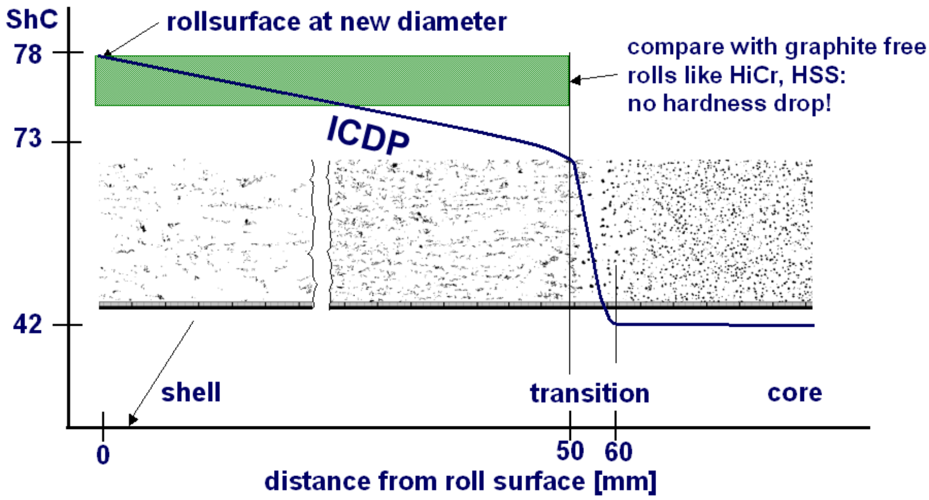

Figure 6: Characteristics of Indefinite chill work rolls considerable hardness drop between new and scrap diameter.

2.1 Development of VIS Grade

ESW has developed a special Enhanced ICDP (VIS) work roll grade that shows close to no hardness drop between deliveryØ and scrapØ as described by Schröder et al.[(2)] In Figure 7 below on the left side the hardness measurement of conventional ICDP, on the right side the hardness measurement of "VIS" Carbide Enhanced ICDP is shown.

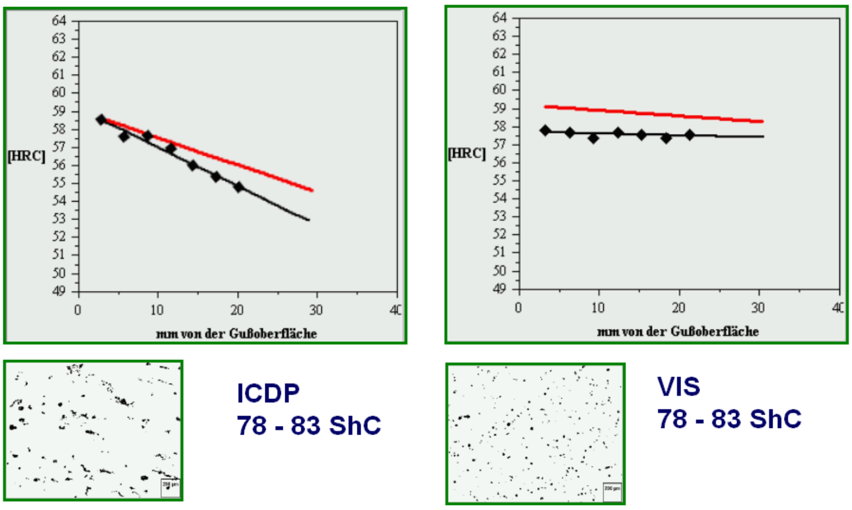

Figure 7: Improvement strategies for ICDP rolls - hardness drop of conventional ICDP (left) vs. Carbide Enhanced VIS (right).

In Figure 8 below the difference in microstructure between conventional ICDP and the new Carbide Enhanced VIS grade is shown. The most important differences are:

- VIS roll has round shaped graphite particles (a) whereas the graphite form of conventional ICDP is flaky
- VIS roll has smaller graphite particles than conventional ICDP
- VIS roll has special high hardness carbides in the martensitic/bainitic structure (b), which do not exist in conventional ICDP.

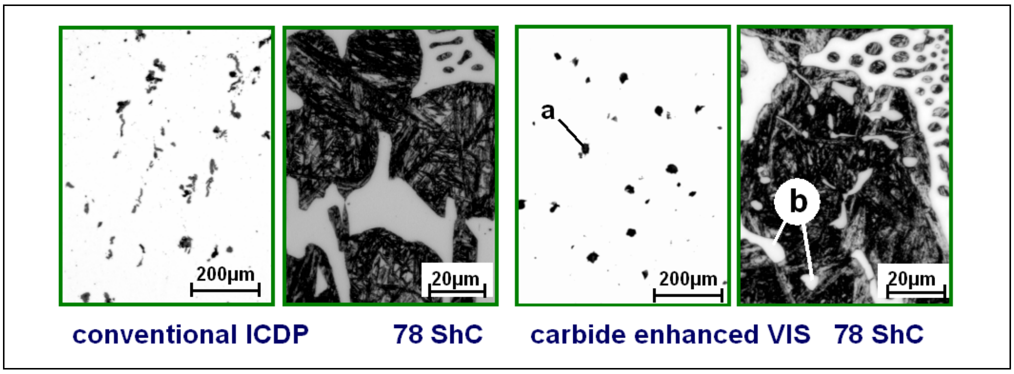

Figure 8. Improvement strategies for ICDP rolls - wear resistance: a) globular graphite particles; b) round-shaped high hardness special carbides.

The high roughness and lower tonnage performance of conventional ICDP close to scrap diameter is normally caused by a higher amount of coarser free graphite. VIS rolls have a more similar amount of graphite at new and scrap diameter, also the particle size is more regular – see Figure 9. The high amount of graphite in conventional ICDP rolls close to scrap size causes a lack of carbide, and low wear resistance. VIS rolls normally show high carbide content even at scrap diameter.

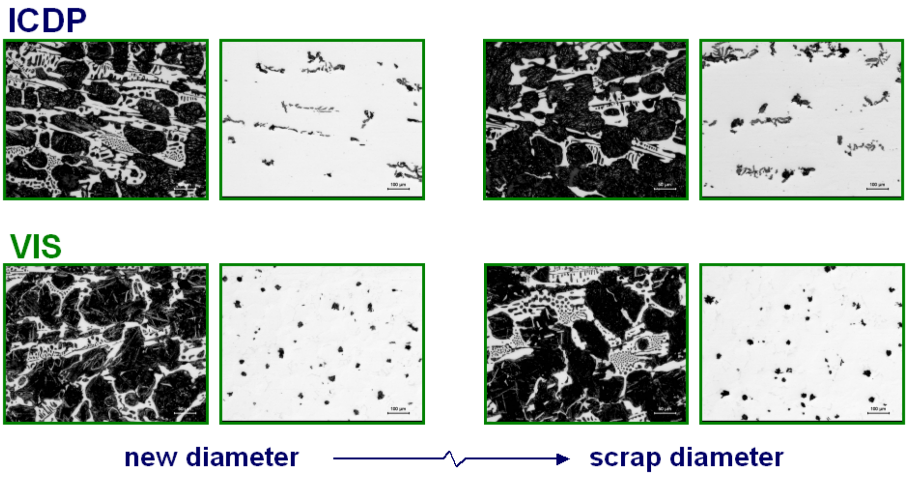

Figure 9. Improvement strategies for ICDP rolls – distribution of carbides and graphite of ICDP vs. VIS work rolls at new and at scrap diameter.

High graphite content does not give a high performance because of poor wear resistance. On the other side too low graphite content does not give a good performance either because the rolls will be more prone to cracking. It is therefore extremely important to measure the graphite content in the rolls and to find reliable production methods to control it, Figure 10 below demonstrates this. The narrow range for VIS rolls are achieved by a strict control of melting and melt treatment conditions as mentioned by Brandner, Mayr and Nylén.[3]

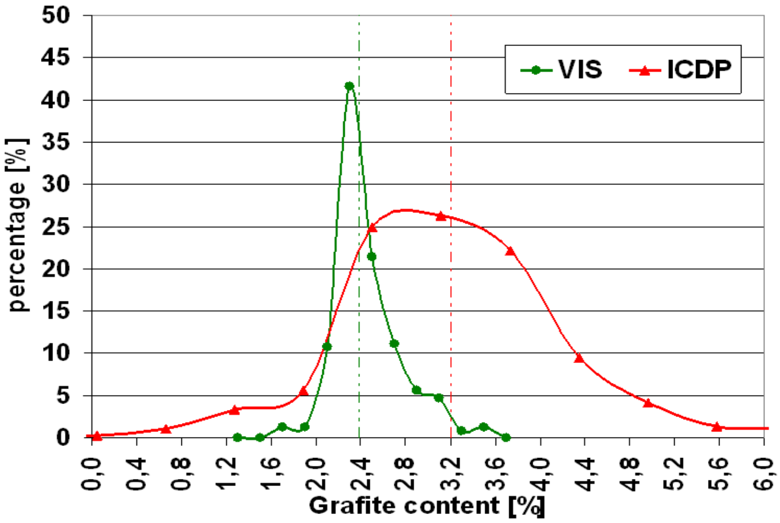

Figure 10. Distribution of graphite content of ICDP and VIS work rolls.

The comparison of wear measurements of conventional ICDP and VIS shows the superior wear resistance of the new grade VIS, see Figure 11. Although the campaign length had been increased by more than 50%, the measured wear was much smaller than in case of conventional ICDP.

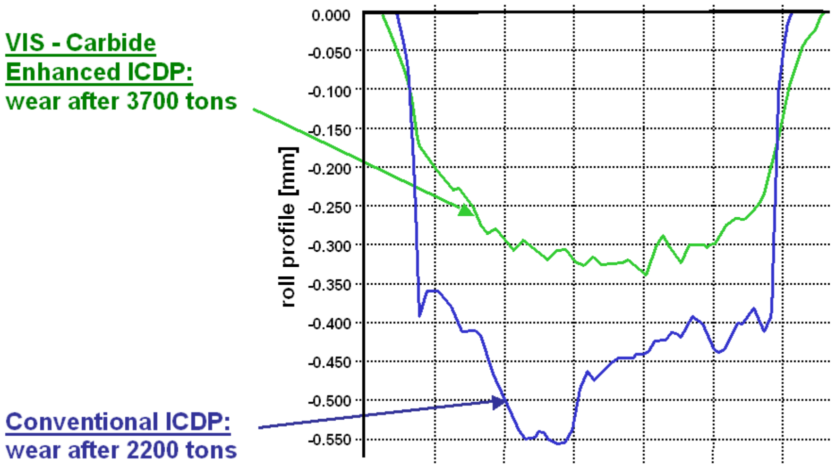

Figure 11. Wear profiles of conventional ICDP vs. Carbide Enhanced VIS Rolled product was stainless steel.

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

2.2 Next Improvement on Enhanced Carbide ICDP is VANIS

The next step ahead was an even higher alloyed version within the EC ICDP. Since we have the possibility to determine and predict the graphite content much more precisely, we could again go a step further. The leading force in the improvement was the calculation of the carbide equivalent CE.

$$CE = 2 * \%Cr + 5 * \%W + 10 * \%Mo + 40 * \%Nb + 70 * \%V$$

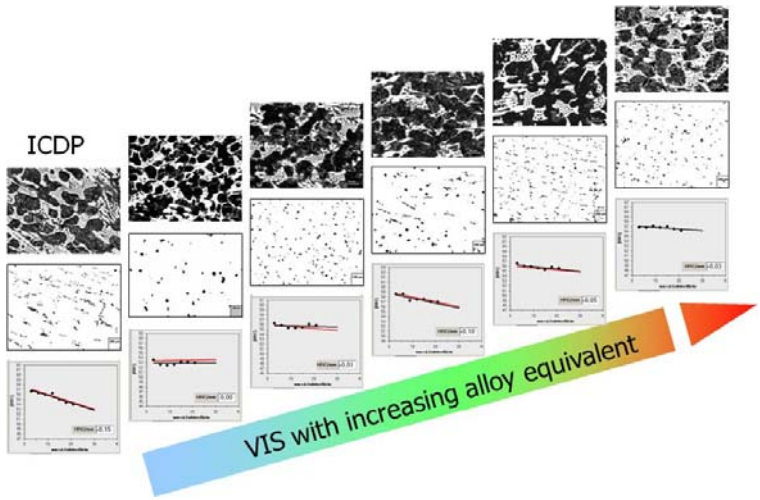

Figure 12. Steps of VIS generations with increasing CE.

The first VIS types have been in the range of CE 40 till 120 (Figure 12). The VANIS has a CE far over 200. The graphite shape is totally round and the planned graphite amount has to be achieved by strictly following the calculated inoculation. The distribution of graphite is very homogenous. In addition the amount of graphite particles per square mm is much higher in VANIS compared to the last generations as shown in Figure 13.

The microstructure is dominated by a very special equilibrium of special carbides and carbide precipitations in connection with the graphite particles. The graphite is the guarantee for the good behaviour in the mill. The microstructure has the basics in the near of a HSS.

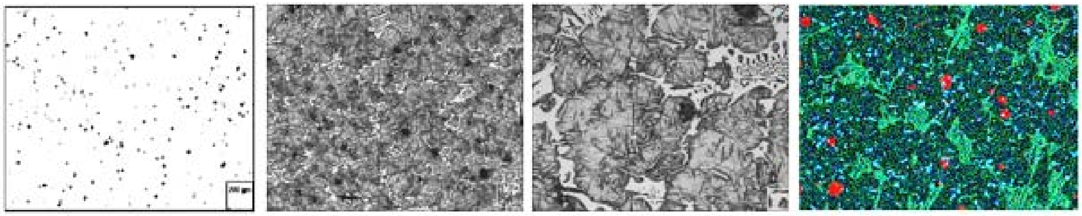

Figure 13. Graphite and microstructure of VANIS.

3 RESULTS

3.1 From VANIS to VANIC a Step Towards Easier Handling

The VANIS type of EC ICDP needs very smooth rolling operation on the one hand, and a very well equipped grinding shop and grinding management. In some cases this was not available and the great break through did not happen. The application of this roll type was still limited and needed a very close cooperation between supplier and producer. The high performance was given, but under changing rolling conditions the rolls needed additional grind offs. This lead to the idea to find a compromise between the high performance ability of the VANIS and the easier behavior of the lower alloyed enhanced carbide ICDP. The art to find the right solution was in the field of the mixture between the carbide content on the one hand and the free graphite on the other. Both should be embedded in a matrix which offers a higher fracture toughness to reduce the damaged area after an incident in the mill. Figure 14 shows the different parts of the microstructure.

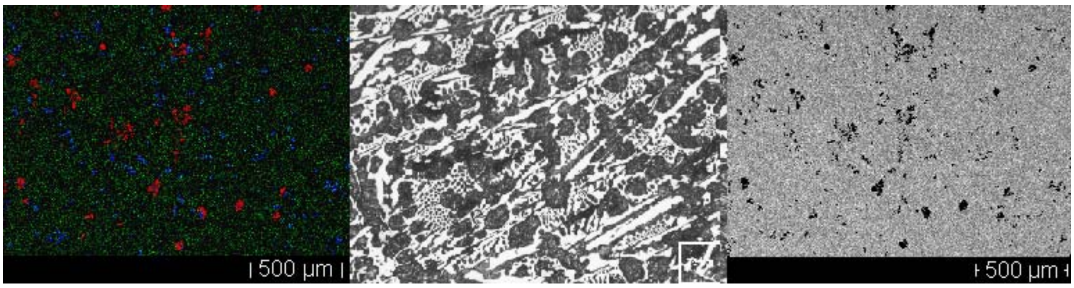

Figure 14. Graphite and microstructure of VANIC.

3.2 Results of VANIC

ESW has delivered more than 100 rolls to different customers and applications. In average we could achieve an increase of performance of about 15%. In some cases even 50 %. The biggest advantage of this type of ICDP roll is the broader field of application in different mills. We are facing more and more mills having very tough rolling schedules and difficult material to roll. This leads in more and more cases to incidents and changing rolling conditions. The testing facilities are not always in the best shape and then rolls suffer because of lost mm due to higher grindings. The VANIC is the ideal roll material to generate a good performance and less grindings in cases of incidents in the mill.

4 DISCUSSION

4.1 Future Perspectives for Materials in the Last Finishing Stands

There is still enough room to find other solutions for the last finishing stands. There are different trials ongoing and some of them look very promising. The questions to be answered are for example the following:

- Do we need graphite in the shell material?
- What materials are possible for the matrix?
- How do we influence the residual stress level?
- What core material is needed?
- How to perform an optimum heat treatment?

The question about graphite is a very old one and some claim that graphite is working as lubricant? Difficult to answer, but in case of roll gap lubrication most probably the graphite is not needed for rolling. Is it needed for the roll manufacturer? So far in the region of ICDP it is needed. If graphite is not available, the large amount of carbon will be found in the carbides. This makes the roll very brittle and it tends to crack even during roll production.

Materials for the matrix could be the chrome iron or even HSS? The question in both cases is, do we need the graphite? How do we get rid of the sticking problem in the mill. In any case the two examples above needed so far a high temperature cycle of heat treatment. With graphite present in the "as cast" condition this would then be difficult to control. Might it be possible to make such a roll (HiCr or HSS with graphite) just with low temperature heat treatment?

The question about the internal residual stress level will be a critical one. So far all Hi chrome and HSS rolls have a high level of stresses. This leads to quick crack propagation and less chances to survive if a high impact of cold material in the last stand will hit the roll. So how to achieve a low stress level with still enough hardness. Surely this cannot be achieved using the old way of shell and core combination.

Here the next question comes into the field. Is there a possibility to use a different material for the core? It should be easy to cast and not forming too much internal stress due to expansion or contraction during solidification or heat treatment. There are different alloying concepts to be thought about. Could the basis still be the nodular cast iron? Just different carbon and silicon contents or other elements to be added? Or is there another way in the direction of steel core such as graphitic steel? This would at least need a different setting of parameters for the casting itself. The heat treatment has also to be changed radically.

The last question concerns the heat treatment. So far all ICDP grades are low temperature heat treated. The other materials such as high chrome and HSS have all High temperature cycles. This will raise in any case the cost of the roll. If the roll performance will increase enough, this should be no problem. The essential question could be graphite yes or no. The graphite content and the precipitation during the high temperature cycle are not easy to control. The shell could suffer from this effect.

On the other hand depending on the alloy, it might create a different type of graphite shape in the shell material.

5 CONCLUSION

The field of enhanced ICDP rolls still offers numerous chances of improvements. The performance can be increased and the ability to tolerate incidents in the mill will increase. The alloying concepts are still offering possibilities. The new type VANIC was introduced to the market for testing and the results so far are very promising and the easier handling of this roll type is offering a wide field of applications on the market.

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