Laminação
Rolling
49º Seminário de Laminação - Processos e Produtos Laminados e Revestidos
49th Rolling Seminar - Processes, Rolled and Coated Products
ISSN 1983-4764

DEVELOPMENT OF PLATE MILL ROLL GRADES[1]

Tommy Nylen[2]
Michael Brandner[3]
Alexander Mayr[4]

Abstract
Generally the roll grade development in Plate Mills has for many years followed the development from the Hot Strip Mill segment. New grades have been gradually introduced in the Plate Mills after being fully accepted in the Hot Strip Mills. Many Plate Mills around the world today are still using roll grades that were developed more than 30 years ago. Plate Mill roll grade development will be described in this paper in a historical sequence and major development steps going from old static cast rolls to modern advanced spun cast rolls will be elaborated. Reasoning for the choice of various roll grades will be discussed as well as some comparison of performance and surface aspects on both the roll surface and rolled products. The paper will also look into the near and far future regarding what could be possible or not with respect to roll manufacturing technologies as well as roll grade modifications.
Key words: Plate mill work roll development; Plate mill; Spun cast rolls.

[1] *Technical contribution to the 49th Rolling Seminar – Processes, Rolled and Coated Products, October, 22nd-25th, 2012, Vila Velha, ES, Brazil.*
[2] *Vice-President R&D. Eisenwerk Sulzau-Werfen*
[3] *Quality Manager. Eisenwerk Sulzau-Werfen*
[4] *R&D Engineer. Eisenwerk Sulzau-Werfen*

ISSN 1983-4764

1 INTRODUCTION

1.1 Plate Mills – Definition, Distribution in the World and Mill Builders

In the world today there are roughly around 191 active Plate mills out of which:
51 Light Plate Mills (barrel length < 3000mm)
51 Medium Plate Mills (barrel length 3000 – 4000 mm)
89 Heavy Plate mills (barrel length > 4000 mm)
The distribution of the Plate Mills per region in the world is shown in Figure 1.

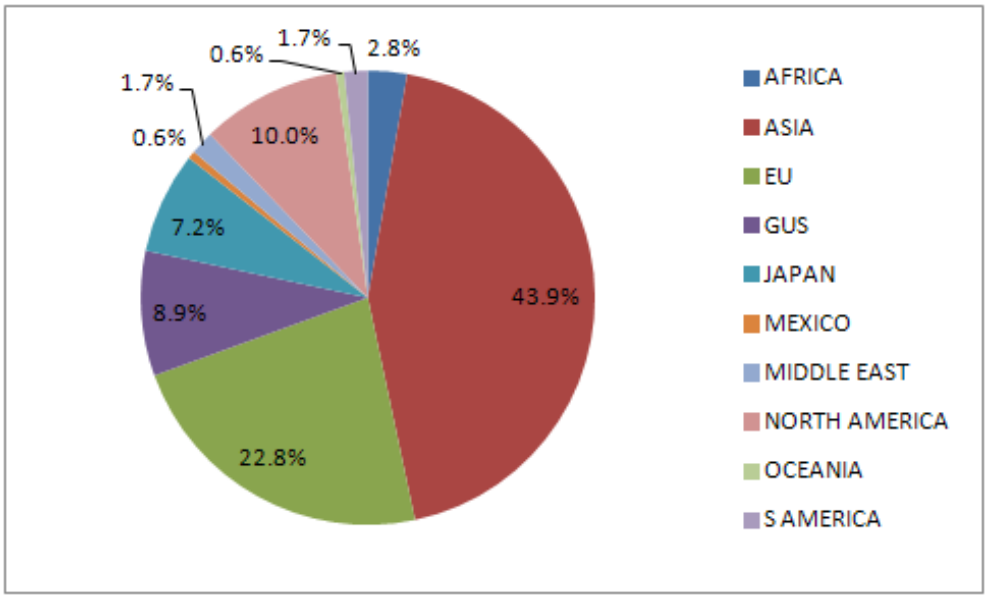

Figure 1. Distribution of Plate Mills per region.

As can be seen in figure 1 almost 50 % of the Plate Mills are located in ASIA and 75% of these mills are located in China.
Roughly 40% of the Plate Mills have 1 stand and 40 % of the mills have 2 stands and installed capacity is varying from <100 KTON per year up to just above 2 MTON per year.
In Plate Mills configured with 2 stands normally the first stand is used as a roughing stand and the second stand as a finishing stand. Since there are normally power restrictions in the mill in combination with the material strength of the rolled material the reduction has to be done in several passes normally 3-9.
Some different configurations of Plate Mills are mentioned and shown below:

- 2Hi roughing stand + 4Hi finishing stand
- 4Hi roughing stand + 4Hi finishing stand.
- 2Hi stand used for both finishing and roughing
- 4Hi stand used for both finishing and roughing.
- 4Hi roughing stand + 4Hi Steckel finishing stand
- 4Hi Steckel for both roughing and finishing.

Given the high demand especially for heavy plate worldwide, capacities for plate production are currently (or at least just currently) greatly extended. Since the year 2000 new plants with an additional output of approximately 8.5 M tons have started operation and by 2011 more than 20 M tons was planned to be added to this capacity. The typical heavy plate mill remains the prevailing type of plant as it

ISSN 1983-4764

combines High productivity with an excellent product quality and a large range of steel grades and dimensions.
As for all rolling mills the layout mainly depends on the production specifications of the customer and the site premises which is why the arrangement of the various plant sections often (always) differs greatly.
The mill building leaders in this segment are SMS Siemag and SIEMENS VAI who have more than 60% of the market share in the heavy plate segment.

Plate products

Steel plates play a key role as a basic material supporting the industrial infrastructure such as shipbuilding, building construction, bridges and various types of heavy industrial machinery. Without any doubt the demands on steel plates has been changing dramatically in the recent years especially due to the strong growth of the Asian economies led of course by China. This in turn has needless to say also increased the demand on the plate mill work rolls both in numbers but also in quality and technical specifications.

ESW Plate Mill roll deliveries

ESW has over time been delivering rolls to around 60% of the Plate Mills in the world. For the year 2011 the delivery distribution per mill application was as per figure 2 below.

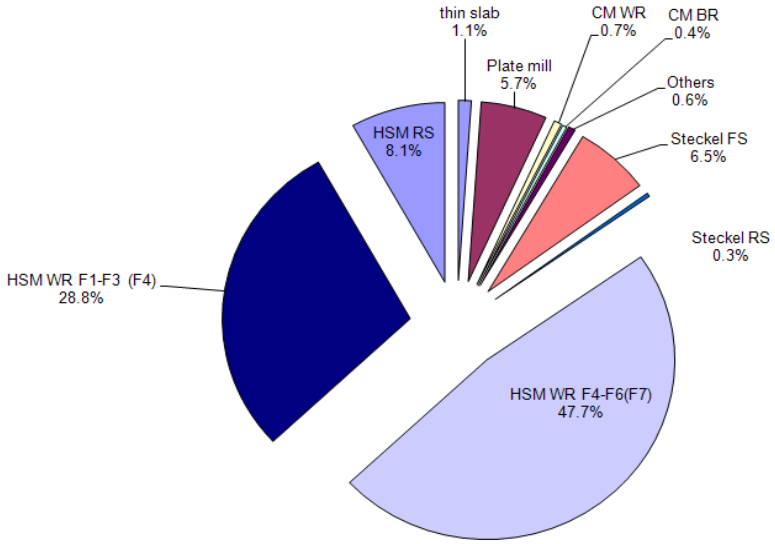

Figure 2. Delivery distribution per application ESW the year 2011.

As can be seen in Figure 2 the delivery to Plate Mills corresponds to 5.7% (as number of rolls) of the total delivery.
The various grades delivered for the Plate Mills can be seen in figure 3 below, where there is an even split between delivered grades Indefinite Chill (VI) (or Enhanced Indefinite Chill = VIS) and Hi Cr steel (or Enhanced Hi Cr Steel CE HiCr Steel). Notable is that ESW does not deliver any High Chromium iron rolls for the usage in Plate Mills.

ISSN 1983-4764

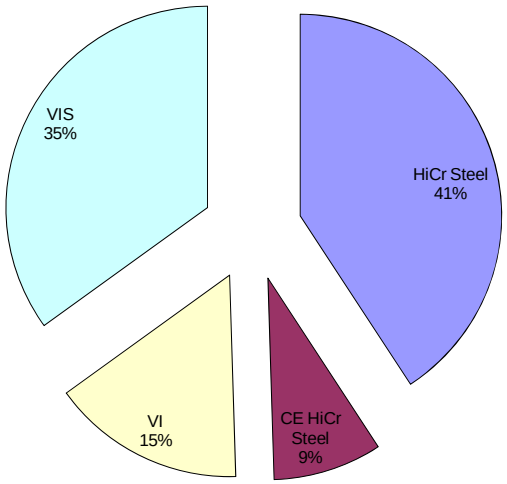

Figure 3. Roll grade distribution for Plate Mills at ESW the year 2011.

2 PLATE MILL ROLL GRADE DEVELOPMENTS

2.1 Introduction Roll Grade Development

The historical development of work rolls for the Plate Mill follows to a large extent the development in the HSM (especially the Roughing Stand developments (1)).
Accordingly the list of materials used as work rolls for Plate Mills over time could be:

- Adamite monobloc rolls
- Indefinite Chill static compound rolls
- Indefinite Chill spun cast rolls
- Enhanced Indefinite Chill spun cast rolls
- High Chromium rolls static compound rolls
- High Chromium spun cast rolls
- Enhanced High Chromium spun cast rolls
- Chrome Steel spun cast rolls
- Enhanced Chrome Steel spun cast rolls

Big sized plate mill work rolls in conventional ICDP grades could often show poor surface quality and/or low performance. The reason is often to be found due to the coarse microstructure and the presence of free graphite in the roll surface. This is regularly more so for Static Compound ICDP rolls.
Spun cast Carbide Enhanced grades can often help to improve surface quality and performance at an even better cost – performance – ratio than conventional grades.
In later year's carbide enhancement technology have been used also for Plate Mill work rolls. This gave as a result a higher surface hardness without actually changing the basic characteristics of the martensitic shell material. In addition the wear resistance has at the same time being increased without decreasing the thermal crack sensitivity.

ISSN 1983-4764

2.2 Conventional ICDP vs. Carbide Enhanced ICDP rolls

Roll wear is a rather complex phenomenon and composed of several mechanisms. Apart from all the theories the most common strategy in Plate Mill rolling is to “simply” improve the wear resistance of the work rolls by carbide enhancement. This can be done in many different ways and some are more successful than others.
Indefinite chill rolls are the most common roll grade being used for work rolls in Plate Mills and the shell material (working layer) consists basically of (Figure 4):

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

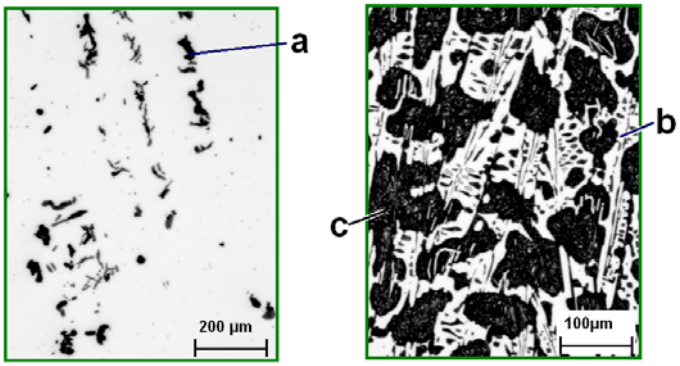

Figure 4. Main characteristics of Indefinite chill microstructure containing: a) graphite, b) cementite, c) Martensitic/Bainitic matrix.

One common characteristic of ICDP rolls is the hardness drop from the delivery ø to the end ø. This is normally due to the increase inthe 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) (Figure 5).

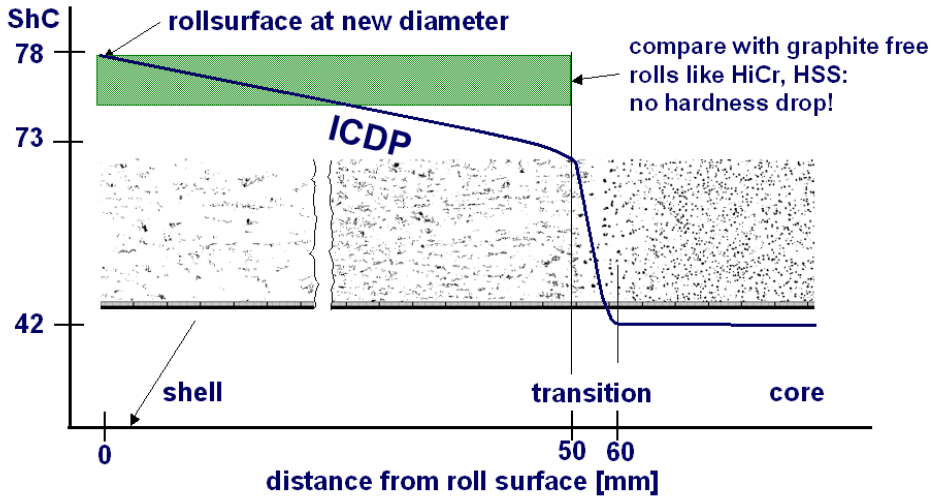

Figure 5. Characteristics of Indefinite chill work rolls considerable hardness drop between new and scrap diameter.

ESW has developed a special Enhanced ICDP (VIS) work roll grade that shows close to no hardness drop between delivery ø and scrap ø. In Figure 6 the left side

ISSN 1983-4764

the hardness measurement of conventional ICDP, on the right side the hardness measurement of “VIS” Carbide Enhanced ICDP is shown.

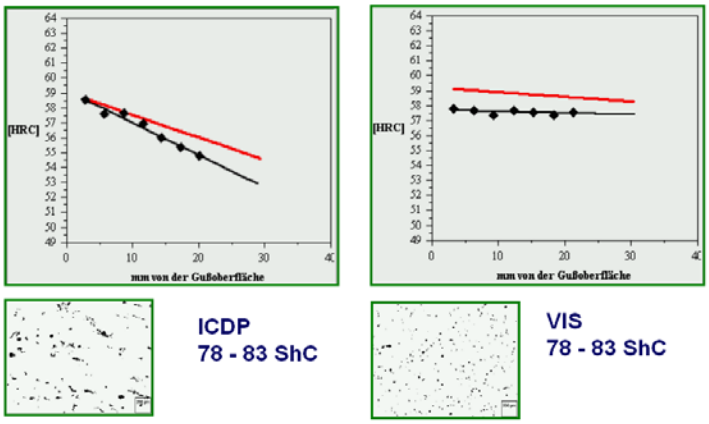

Figure 6. Improvement strategies for ICDP rolls - hardness drop of conventional ICDP (left) vs. Carbide Enhanced VIS (right).

In Figure 7 the difference in microstructure between conventional ICDP and the new Carbide Enhanced VIS grade is shown and the most important 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 specialhigh hardness carbides in the martensitic/bainitic structure (b), which do not exist in conventional ICDP.

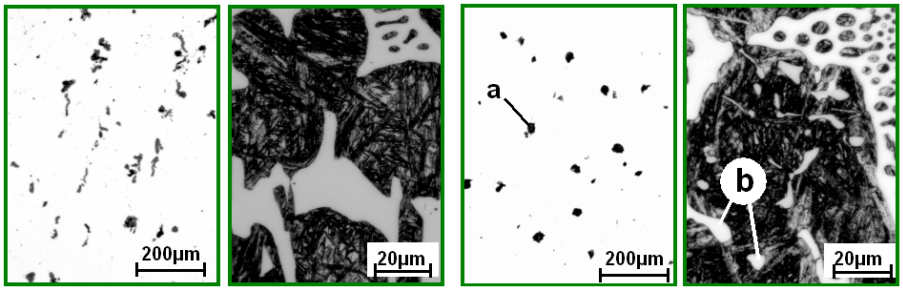

Figure 7. Improvement strategies for ICDP rolls - wear resistance: a) globular graphite particles; b) round-shaped High hardness special carbides.

The high roughness and lower tonnage performance of conventional ICDP close to scrap diameter is normally caused by a higher amount and coarser free graphite. VIS rolls has a more similar amount and particle size of graphite at new and scrap diameter (Figure 8). The High amount of graphite of ICDP close to scrap size causes a lack of carbide, and low wear resistance. VIS rolls normally show high carbide content even at scrap diameter.

ISSN 1983-4764

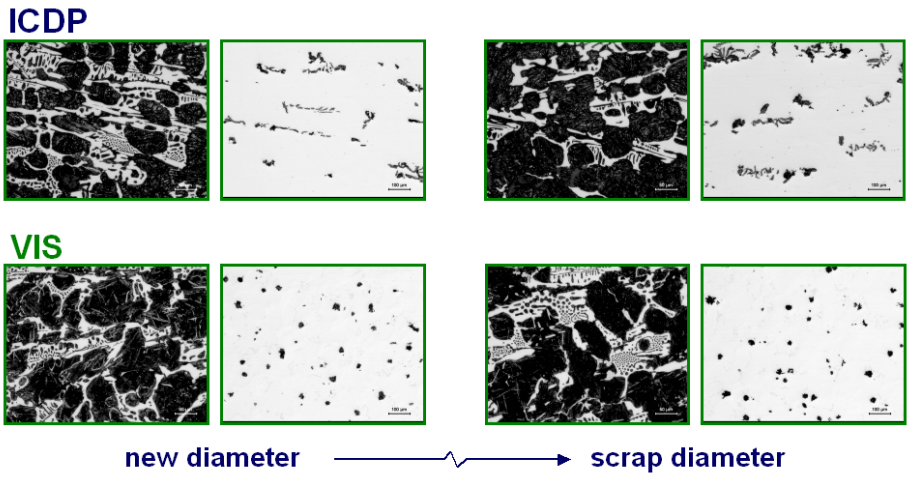

Figure 8. Improvement strategies for ICDP rolls – distribution of carbides and graphite of ICDP vs. VIS work rolls at new and at scrap diameter

A 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 9 below demonstrates this. The narrow range for VIS rolls are achieved by a strict control of melting and melt treatment conditions.

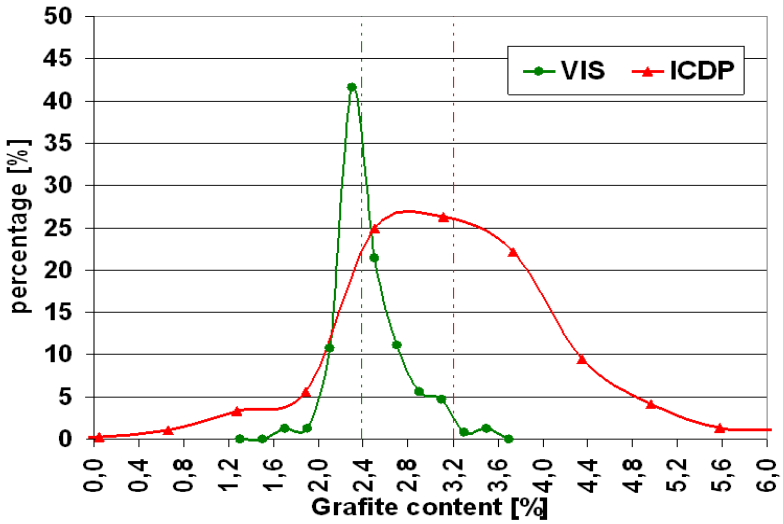

Figure 9. Distribution of graphite content of ICDP and VIS work rolls.

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

ISSN 1983-4764

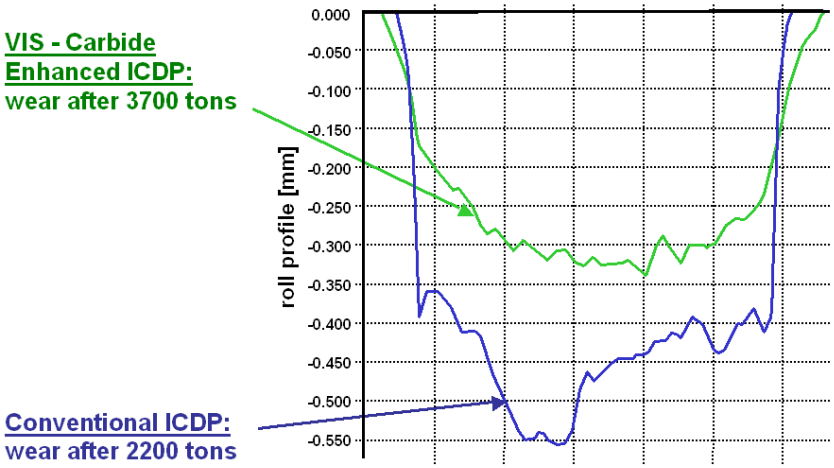

Figure 10. Wear profiles of conventional ICDP vs. Carbide Enhanced VIS- rolled product was stainless steel.

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. 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 thickness >8mm) VIS may reach up to 6000 t/mm (Figure 11).

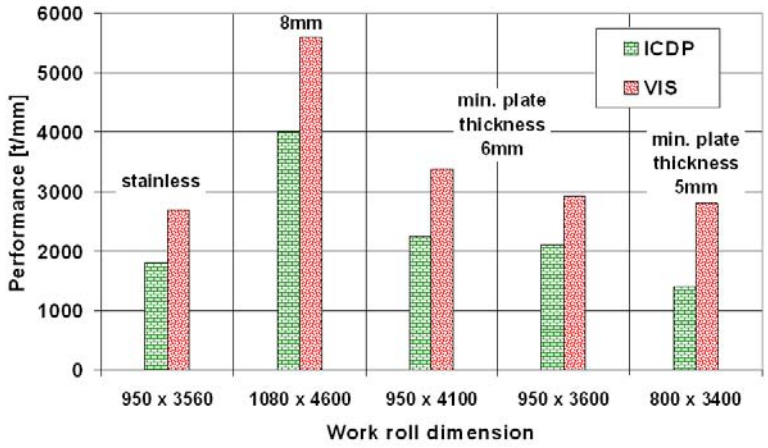

Figure 11. Performance conventional ICDP vs. Carbide Enhanced VIS plate mill work rolls.

2.3 High Chrome Steel and Carbide Enhancement

In the course of the years a more or less uniform chemical composition of these rolls has been established worldwide (generic roll material). High Chrome cast iron and High Chrome steel work rolls show a very uniform carbide distribution from the delivery ø to the end ø that gives these rolls almost no hardness drop at all (Figure 12).

ISSN 1983-4764

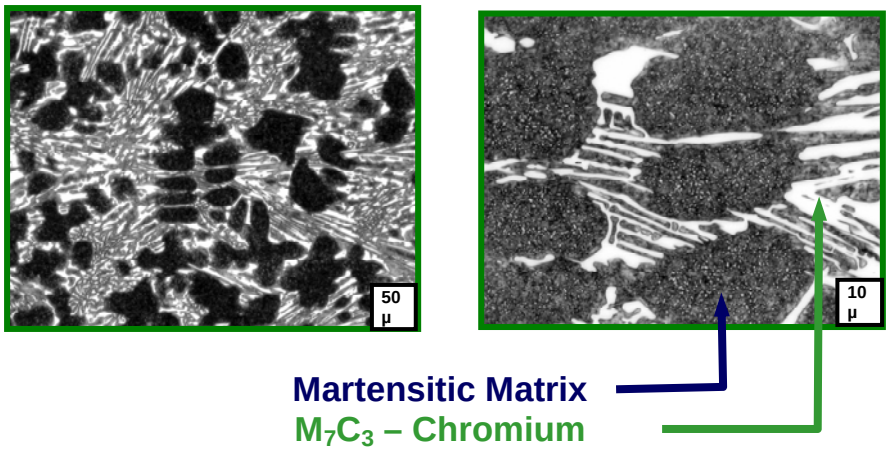

Figure 12. Microstructure of High Chrome iron.

In many cases a High Chrome iron is not the best solution for plate mill application. Compared to Indefinite Chill the wear resistance is much higher but the high amount of eutectic carbides gives a lower resistance against thermal fatigue. The High Chrome steel concept with a lower total carbide content and thus a higher resistance against thermal fatigue has often proved to be the better solution. The change in microstructure between High Chrome iron and High Chrome steel is shown in Figure 13.

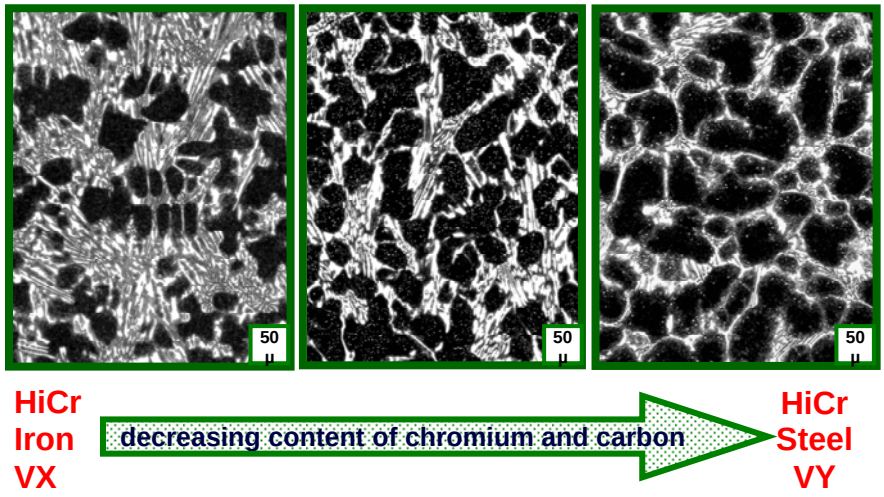

Figure 13. Microstructure High Chrome iron and High Chrome Steel

To further increase the wear resistance of High Chrome Steel carbide forming elements can be introduced that increase the hardness of the eutectic carbide network. Various elements and their hardness can be seen in Figure 14.

ISSN 1983-4764

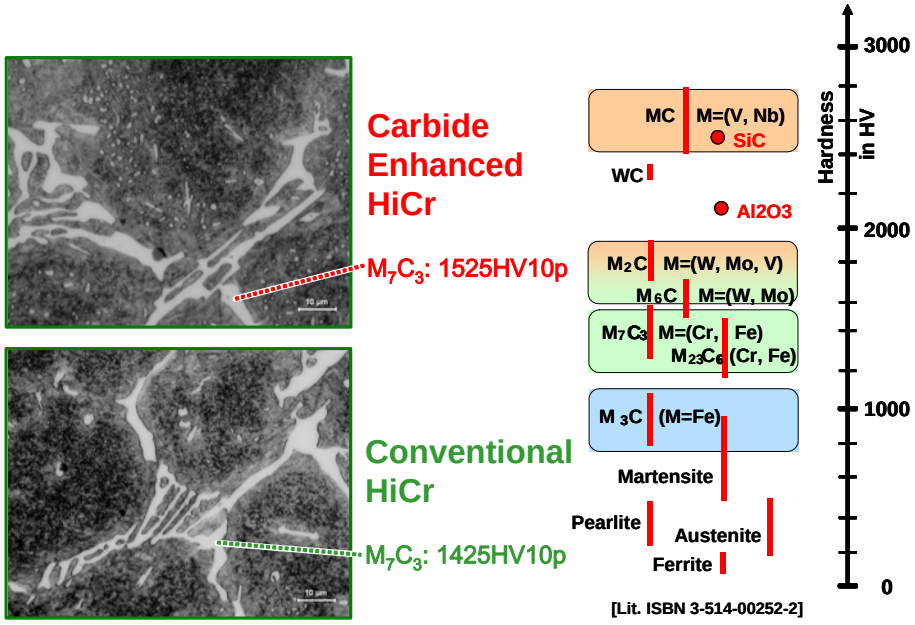

Figure 14. Hardness of various types of carbides

The Carbide Enhanced High Chrome steel rolls have been tested in many plate mills with using a big variety of work roll dimensions and the increase of roll performance is between 20 and 100% (Figure 15).

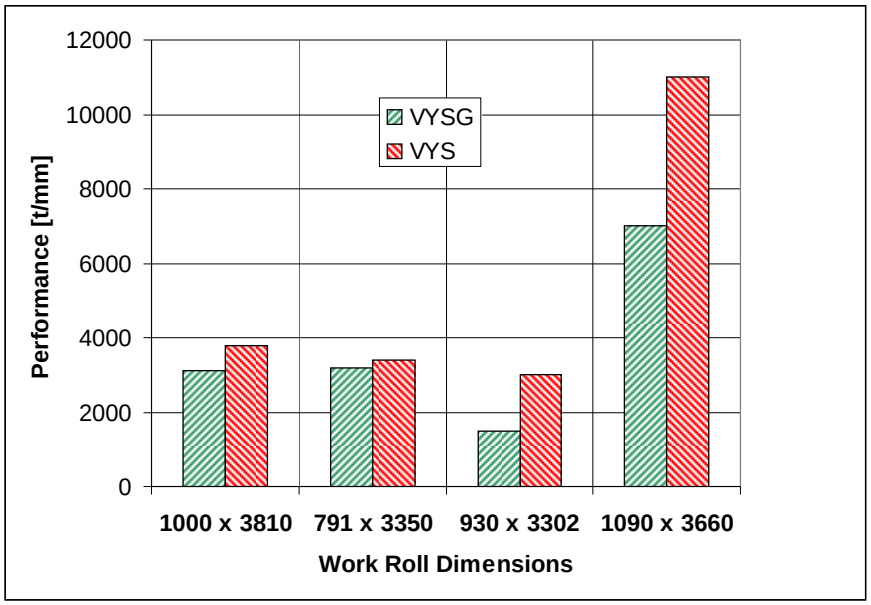

Figure 15. Performance [t/mm] High Chrome steel vs. enhanced High Chrome steel.

There have been very few reports on any negative effects of this carbide enhancement on roll behaviour, surface roughness etc. It could therefore be expected that Carbide Enhanced High Chrome steel rolls will over time have a good chance to replace standard High Chrome rolls for plate mill application.

ISSN 1983-4764

3 FUTURE DEVELOPMENTS AND OPPORTUNITIES – PLATE MILL WORK ROLLS

Following the recent development trends in the Roughing stands of the HSM it is not too courageous to anticipate that the next quantum leap in the Plate Mill would be the introduction of a HSS work roll. This development would probably be concentrated on the roughing stand in the Plate Mills with a 2-stand configuration. Unlikely the development in the Roughing Mill of the HSM the “pressure” from the customer segment for such a roll is today not high at all. The driving force is more coming from technical side of roll making – “it should be possible to use HSS”. Such an introduction (if feasible) would drastically decrease the total consumption of Plate Mill work rolls.
More likely development in the near future is further perfection of the grades that already exist today, that is to say ICDP and High Chrome iron and Steel, with respect to carbide enhancement and structure refinements.
There have been projects concerning building extremely wide Plate Mills (8-9 m) in recent years that basically is hold up by the fact that these rolls cannot be produced by the conventional methods used today – not to forget the production of the Back Up rolls needed. Rolls with these dimensions have thus to be produced using today eccentric methods such as:

- Producing double poured rolls in 2 parts and “weld” together
- Producing the work roll layer by welding process
- Forged work rolls
- Powder Metallurgy
- Etc.

Without going into further details it has to be concluded that to overcome these “difficulties” huge investments and R&D efforts are needed for such a project to ensure success.

4 CONCLUSION

Indefinite Chill and High Chrome (Iron and Steel) rolls are currently used for Plate Mill work rolls.
Carbide enhancement is an effective tool to further increase the performance level of all these roll grades without causing obvious negative effects on either surface quality or operational safety.
It is therefore assumed that Carbide Enhanced roll types for this segment will in the near future completely replace the conventional roll types.

REFERENCES

1 K. H. Schröder, B. Feistritzer, M. Windhager, K. H. Ziehenberger: "Progress of Carbide Enhanced ICDP (and Remarks on Coefficient of Friction of HSS Work Rolls in Hot Strip Mills"; 37. In : Rolling Seminar - Process and Rolled and Coated Product, September 2000, Curitiba, Brasil, ABM, 2000. p. 317-323.
2 K. H. Ziehenberger, M. Windhager: "Konkordia - ESW Work Roll for Flat Products"; ESW customers information brochure, September 2002.
3 K. H. Ziehenberger, M. Windhager: “Recent Developments in HSM Rougher Rolls – Risks and Chances”; MS&T 2005 Conference, ISS, September 2005 – Pittsburgh, PA, USA. MS&T, 2005. p. 38-41.

ISSN 1983-4764

4 S. Wilmes, H. J. Becker, R. Krumpholz, W. Verderber: "Werkzeugstähle Werkstoffkunde Stahl - Band 2: Anwendungen“, ISBN 3-514-00252-2, Verlag Stahl-Eisen 1985, chapter 11, p. 382-395.
5 M. Brandner, M. Windhager, K.H. Ziehenberger: “Improvements in Plate Mill work rolls“. In: SARUC 2008, South Africa. Saruc, 2008. p. 55-59.