HIGH SPEED STEEL WORK ROLLS – RECENT DEVELOPMENTS AND FUTURE TRENDS [1]

Michael Windhager [2]
Karl Heinz Ziehenberger [3]

Abstract

High Speed Steel (HSS) work rolls are gradually replacing High Chrome rolls in hot rolling practice. Differences in rolling conditions made it necessary to develop various HSS grades to fulfill all mill requirements. The introduction of two different HSS materials, designed for the shell of work rolls used in front finishing stands of HSM is discussed. One type has been developed for harsh rolling conditions in order to guarantee maximum crack resistance. The other type has been designed for maximum tonnage performance and surface smoothness. The influence of the HSS microstructures on the characteristics of these work rolls and the resulting consequences on roll performance are shown.

Key words: HSS; Work rolls; Development; Future trends.

[1] *42nd Rolling Seminar - Processes, Rolled and Coated Products; 25 – 28 October 2005 - Santos - SP - Brazil*
[2] *Dipl.-Ing. Dr. mont. Michael Windhager, Chief Metallurgist and Manager of Roll Technology and Application - ESW, Eisenwerk Sulzau-Werfen: http://www.esw.co.at*
[3] *Dipl.-Ing. Dr. techn. Karl Heinz Ziehenberger, Development Engineer - ESW*

EARLY STAGES OF DEVELOPMENT – DISCOVERY OF ADVANCED MICROSTRUCTURE

ESW started its HSS development in the early 1990s. The initial purpose was to create an extremely wear-resistant work roll in order to replace high chrome in hot rolling mills. The rolls performed well under normal rolling conditions but suffered from cracks when rolling accidents occurred. In the following years, several generations of HSS with a broad variation in shell microstructures were developed, produced and tested in hot strip mills worldwide, see Figure 1. In 1998 the first stage of HSS development was completed. The result was an HSS roll grade with isolated, finely dispersed special carbides. In 1999/2000 more than 50 work rolls were delivered to various hot strip mills throughout the world.

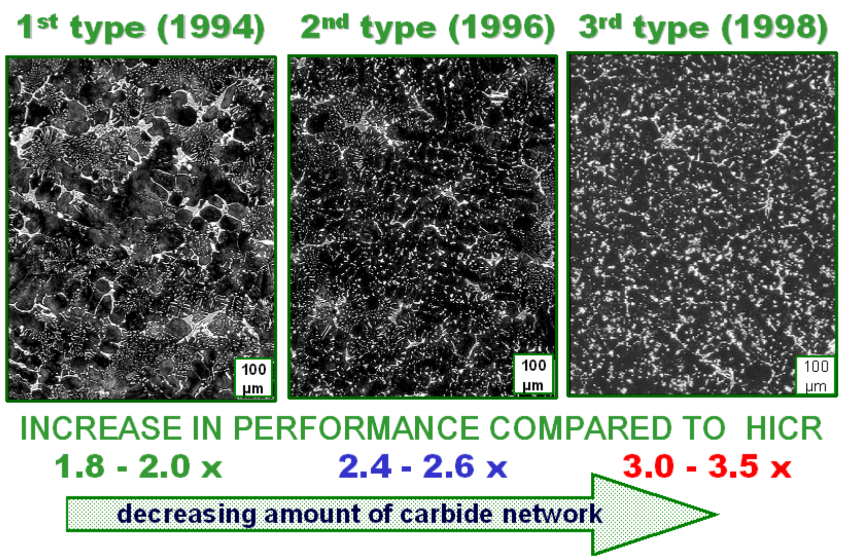

Figure 1. Development of an advanced HSS microstructure

The singular carbide type HSS rolls performed well. The main development goal, i.e. higher tonnage performance, was achieved. The HSS rolls of the latest stage of development showed very high wear resistance and reached a tonnage performance of up to 3.5 times the level of high chrome rolls.

In some mills 2 distinct types of problems occurred:

- In mills that had already been running at capacity rolling force when using high chrome iron, the rolling force limitations restricted the use of high speed steel. Obviously the friction coefficient of HSS was higher compared to high chrome.
- Under abnormal rolling conditions, i.e. when rolling accidents occurred, the rolls lost roll stock due to cracking. When the frequency of rolling accidents was too high, the cost/performance – relationship was unfavorable for HSS.

We therefore decided to develop a HSS grade with a lower coefficient of friction and better damage tolerance.

SECOND STAGE OF DEVELOPMENT – OPERATIONAL SAFETY

Looking at the surface of high chrome iron and HSS work rolls after rolling, we discovered that the heat cracks which developed during rolling had major differences in appearance; see Figure 2. In high chrome iron the heat crack pattern is determined by the eutectic carbide microstructure of the shell material. In HSS, with virtually no eutectic carbide, the heat crack pattern does not follow any micro-structural pattern but is determined by factors such as strength of shell material, roll surface temperature and cooling conditions. In HSS rolls the heat crack pattern is much coarser and the cracks open wider than in the case of high chrome rolls. Obviously this heat cracking behavior is one of the possible reasons for increased friction between work roll and strip. (1)

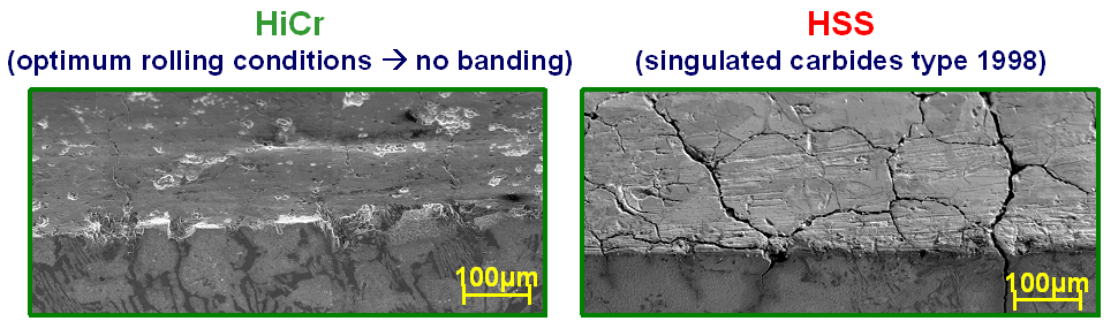

Figure 2. Samples cut from work roll surfaces after one rolling campaign; SEM images - angle of incidence of the electron beam is 45° to the roll surface

Our goal therefore was the development of an HSS grade with optimized heat cracking behaviour to guarantee a friction coefficient similar to high chrome rolls. Figure 3 shows the microstructure of this new type of HSS called *Konkordia* with its well balanced high quantities of C, Cr, V, Mo compared to previously developed competitive roll materials. The traces of eutectic carbide act as a crack-arresting microstructure, ensure the right heat cracking behaviour and also avoid shrinkage porosities during solidification of the shell. (2)

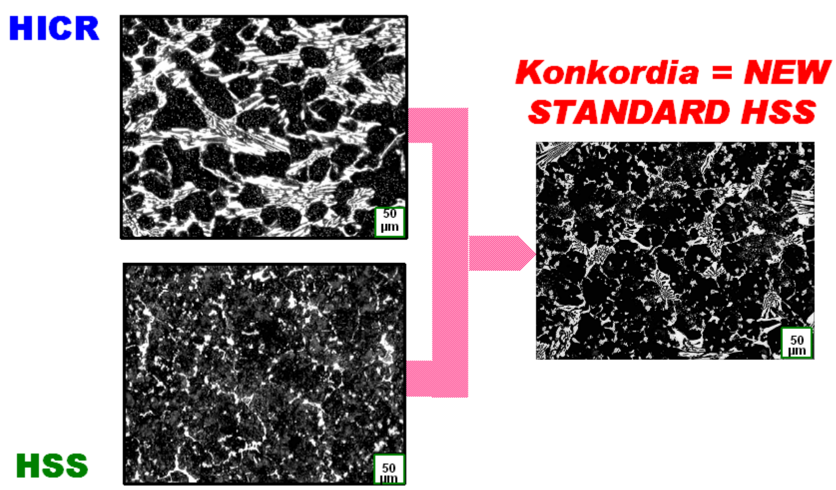

Figure 3. Microstructure of High Chrome, HSS and *Konkordia* shell material

Furthermore, the remaining eutectic carbide network helps to limit the internal stress in the work roll, which is essential for achieving a low rate of crack propagation in case roll damage occurs due to abnormal rolling conditions.[3] A good example for the operational safety of the *Konkordia* HSS roll type is illustrated in Figure 4, where a trial in stand F4 of a 7-stand HSM was carried out. During rolling a campaign of ferrite stainless steel, the strip was welded onto the roll surface and rolled through the gap in multiple layers. After grinding only 7 mm, the rolls were crack-free due to the crack-arresting microstructure, and could be put into operation again.

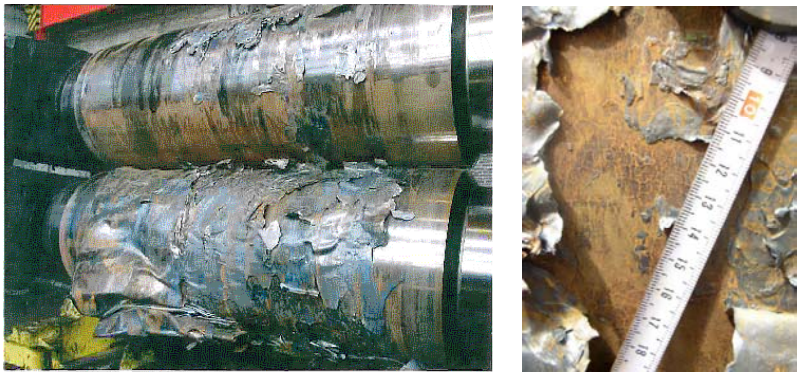

Figure 4. Mill wreck resulting in strip welded on *Konkordia* work rolls, stand F4 of a 7-stand HSM

Since then the *Konkordia* rolls have proven to be both wear resistant and damage resistant. Thus *Konkordia* became the first choice of HSS in mills with harsh rolling conditions and in mills familiar with the use of HiCr which wanted to start HSS trials. Until now over 200 *Konkordia* rolls have been delivered to hot strip mills worldwide; the general results are reported below:

- The tonnage performance of *Konkordia* was 2 – 2.5 times the performance of HiCr rolls
- The crack resistance of *Konkordia* was comparable to HiCr, hence superior to conventional HSS
- There have been no reports of increased thermal crown or rolling force compared to the use of HiCr

RECENT DEVELOPMENTS – SURFACE QUALITY, DOUBLE AND TRIPLE CAMPAIGN USE OF HSS ROLLS

The microstructure of *Konkordia* was designed with a network of Cr-based eutectic carbides to influence the heat cracks in a positive way. However, the Cr-based eutectic carbides in *Konkordia* caused too high surface roughness in some mills that aimed to run more than double campaigns without grinding, see Figure 5.

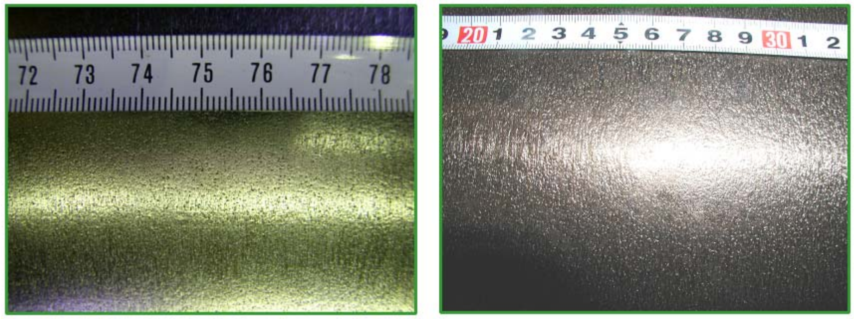

Figure 5. Barrel surface after rolling 2530t low alloy carbon steel in stand F4 of a 7-stand CSP mill (left) or after rolling a double campaign 4000t low alloy carbon steel in stand F3 of a 6-stand HSM (right)

The next stage in the development therefore had the following target:

To increase the surface quality
but maintain the integrity of the shell (no porosity)
and the high damage tolerance of the rolls.

In 2002 we started to investigate new HSS shell compositions that would allow different types of eutectic carbides to be introduced without any negative effect on surface roughness and internal stress.
By replacing a certain amount of chromium by molybdenum the eutectic carbide could be changed from M_7C_3 to M_2C-type. Figure 6 demonstrates the microstructure we finally developed to resolve the roughness problem. The difference in carbide formation and the distribution of carbide-forming elements can be seen on the basis of X-ray element mapping investigated in the SEM.

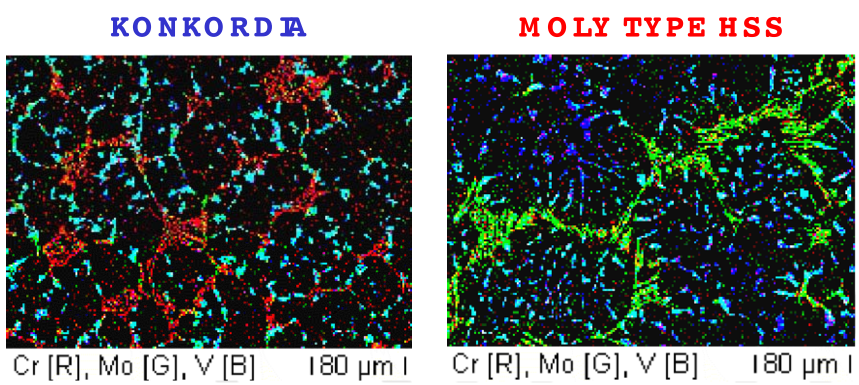

Figure 6. Microstructure of *Konkordia* type HSS and Moly type HSS shell material; X-ray element mapping: red – Chromium; green – Molybdenum; blue – Vanadium; black – iron matrix

In comparison to the eutectic chromium carbide the molybdenum carbide shows significantly higher hardness and a more favorable plate shape. This new microstructure shows the same positive behavior concerning integrity of the shell (no shrinkage porosity), wear resistance (high carbide hardness, see Figure 7) and overall roll hardness (75 – 80 ShC, even extendable to 82 – 88 ShC). The internal stress level could be maintained at a low level, thus providing the same safety as in the case of *Konkordia*.

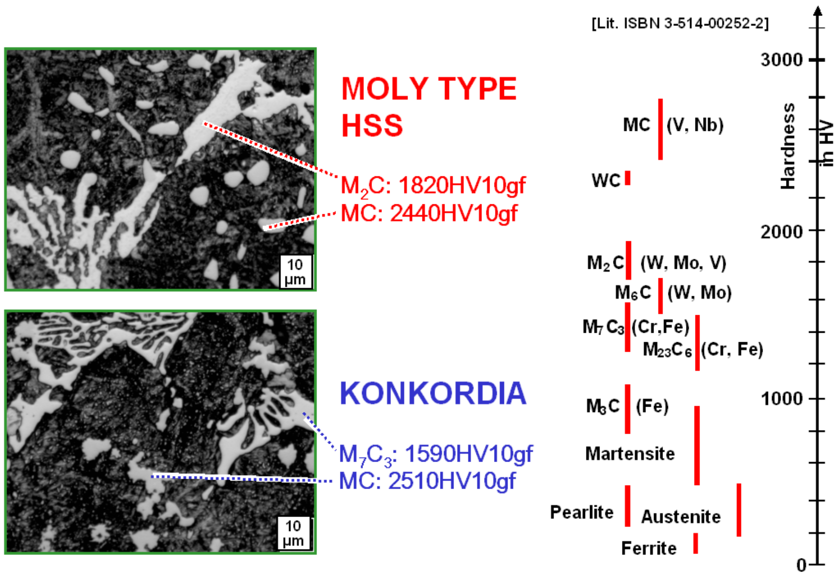

Figure 7. Vickers hardness of various carbides[4]

Compared to *Konkordia*, the Moly type HSS shows better surface finish in service. Figure 8 shows the roll surface after exposure in stand 2 of a 7-stand HSM (product: 3000 tons stainless steel). The surface was checked by the customer; it was possible to re-use the Moly type HSS roll without grinding. The smoother roll surface of the new rolls also led to a reduction in grinding per campaign, thus increasing the tonnage performance even further.

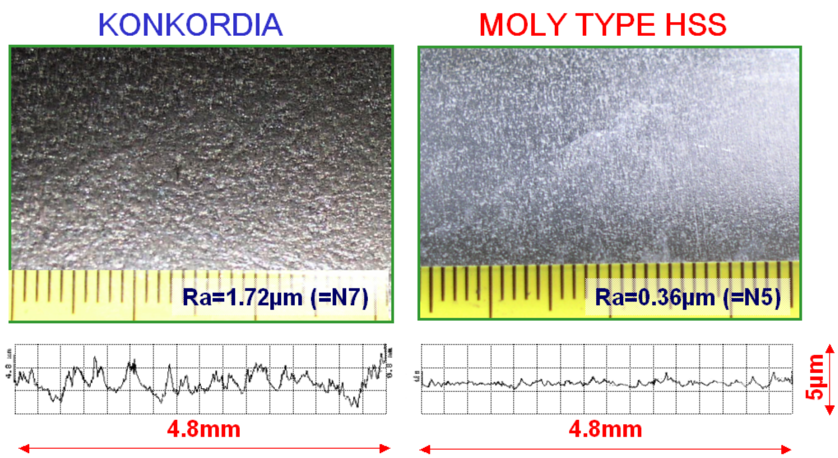

Figure 8. Barrel surface after rolling 3000 tons stainless steel in stand F2 of a 7-stand HSM

In the production of steel sheet for automotive application (car body) the Moly type HSS also showed a significant improvement in surface finish and it was possible to put it into operation 2 to 3 times without grinding. Figure 9 gives an example of roll surface after 2200 tons campaign length in stand 2 of a 7-stand hot strip mill.

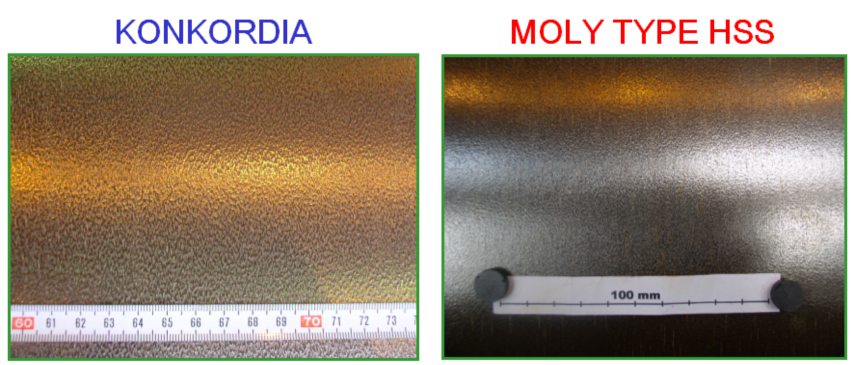

Figure 9. Barrel surface after rolling 2200 tons car body sheet in stand F2 of a 7-stand HSM

ROLL SUPPLIES

Since starting the development of HSS work rolls in the early 1990s ESW has delivered more than 450 HSS, and the number of rolls per year is increasing rapidly. In 2005/06 ESW will deliver approx. 250 HSS rolls to 33 customers worldwide – see Figure 10.

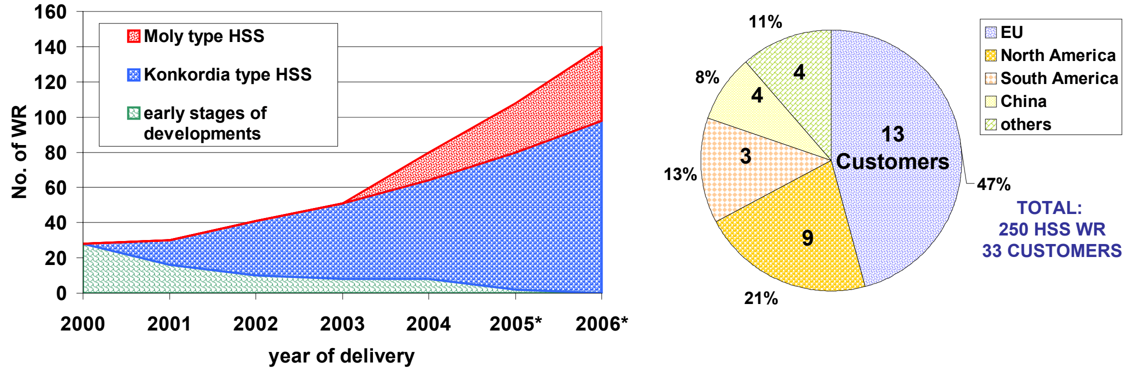

Figure 10. ESW HSS work roll deliveries or share of deliveries and the number of customers supplied in 2005 (* prediction based on current order volume)

CONCLUSION

ESW started its own HSS development in the early 1990s.
The demands of the European market for damage resistance and cost/performance ratio were the driving forces that led to the development of *Konkordia*. This HSS roll grade is now well established in many mills.
In the latest stage of HSS development we made a major change in the shell microstructure. This resulted in the successful combination of the advantages of *Konkordia* (high safety and damage resistance) and the ultimate surface quality of full HSS grades.

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. Rolling Seminar - Process and Rolled and Coated Product, ABM, September 2000, Curitiba, Brasil

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

4 S. Wilmes, H. J. Becker, R. Krumpholz, W. Verderber: **"Werkzeugstähle"**, Chapter D11 out of **„Werkstoffkunde Stahl - Band 2: Anwendungen"**, ISBN 3-514-00252-2, Verlag Stahl-Eisen 1985, S.382