# STATE OF THE ART WORK ROLLS
# FOR HOT ROLLING FLAT PRODUCTS

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## ABSTRACT

*State of the art work roll grades for roughing and finishing mill application are described, including characterisation of microstructure, hardness and residual stress levels. Most recent work roll developments are presented, including results of HSS rolls running successfully in roughing and finishing stands of conventional HSM as well as CSP-mills; HSS developments for Steckel mills are discussed in detail.*

## ROLL TYPES AND ALLOYING SYSTEMS

Over the last years, the use of work rolls for hot rolling of flat steel has changed. The following picture gives a short description of the recent history of roll grades development in a conventional hot strip mill (fig. 1).

In the **roughing stands**, conventional high chrome steel 70 – 75 ShC has been gradually replaced by new grades like carbide enhanced high chrome steel 75 – 80 ShC, ultra low carbon grades like Semi – HSS resp. matrix type HSS 80 – 90 ShC, Konkordia (= Cr-based HSS) and the variety of other HSS grades HSS 75 – 85 ShC. Due to roll size and production demands placed on the rougher rolls, these developments follow mainly the first finishing stands F1-F4.

The first 3 – 4 **finishing stands** have seen a development from high chrome cast iron 70 – 75 ShC to carbide enhanced high chrome cast iron 75 – 80 ShC, Konkordia 75 – 85 ShC (Chrome based HSS), and a variety of other HSS grades 75 – 85 ShC.

In the last finishing stands the situation is quite different. Conventional ICDP rolls 70 – 85 ShC which had been used over decades, are now being largely replaced by carbide enhanced ICDP rolls of different alloying concepts and performance – as well as safety levels. Graphite containing high chrome cast iron rolls and roll grades with no graphite in the shell are being used in some places, but more or less on a trial scale.

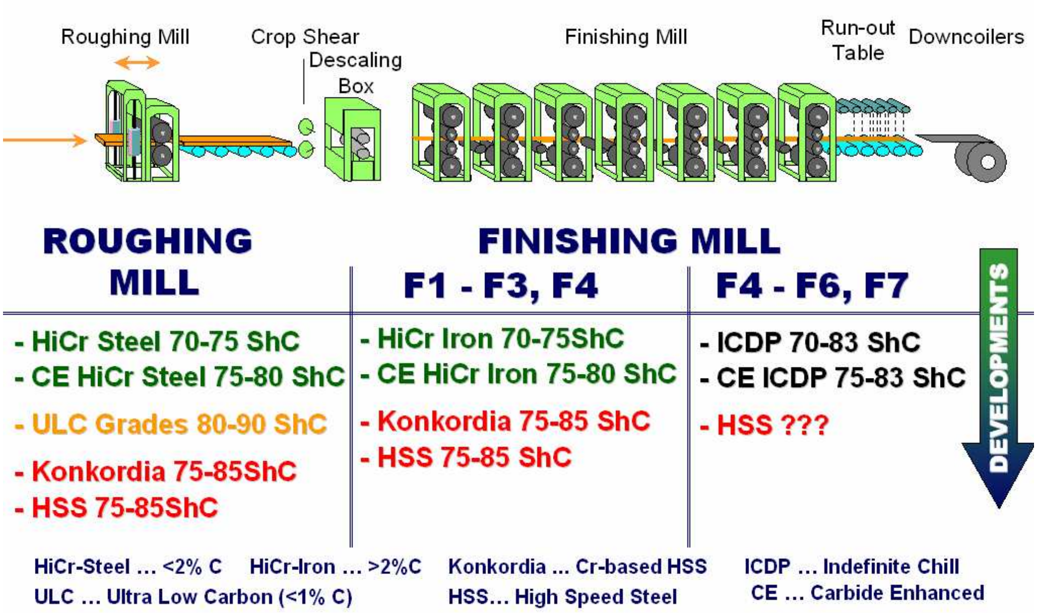


**Figure 1: work roll types for hot rolling of flat products**

The driving force for all these developments was the idea of improving the wear resistance and surface quality of the rolls in order to run much longer campaigns and to improve the efficiency of the entire mill (or at least maintain a certain campaign length, but rolling thinner gauges and harder steel grades).

Not all ideas and concepts of improving the shell material could be realised, some of them failed in mill trials. The reason is quite simple (fig. 2):

- Double poured work rolls are big and very complex castings. The bigger the casting, the more likely the inner part of the casting will show smaller (or bigger) imperfections
- Shell and core material have different alloying contents, transformation temperatures and thermal expansion. This leads to high residual stress (compression stress in the shell, tensile stress in the core)
- High residual stress and imperfections in the inner part of the shell or in the transition zone shell – core may increase the risk of roll failure

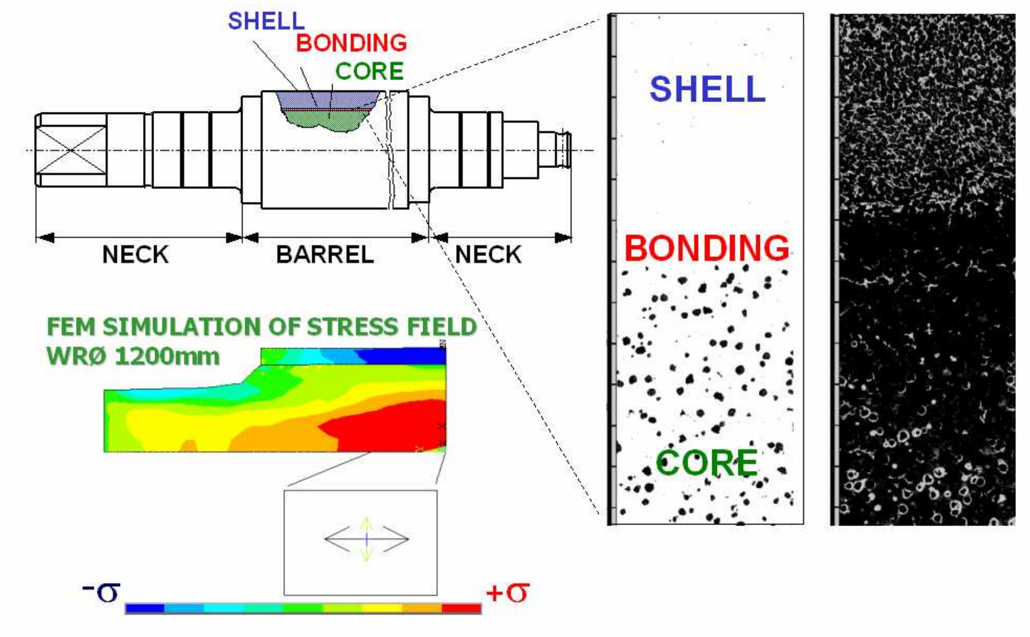


**Figure 2: principle of compound rolls [1]**

The development of shell materials and roll grades over the last years can be described as follows (fig. 3):

We can see a development starting from clear chill rolls to indefinite chill, then (after a long time) came high chrome iron and high chrome steel grades, which later were modified by carbide enhancement. After that we saw the development of HSS (beginning in the first finishing stands) and ultra low carbon grades (for the roughers).

This sequence of roll grades was characterized by a steady improvement of tonnage performance, although the hardness of the rolls did not change drastically.

Even more astonishing is the fact that the total carbide content of the roll shell materials decreased from around as much as 40% (clear chill and high hardness indefinite chill with low graphite content) to 5 – 15% only (in case of HSS). Ultra low carbon grades like Semi HSS may even show carbide contents below 5%.

**So where did the performance improvements come from???**

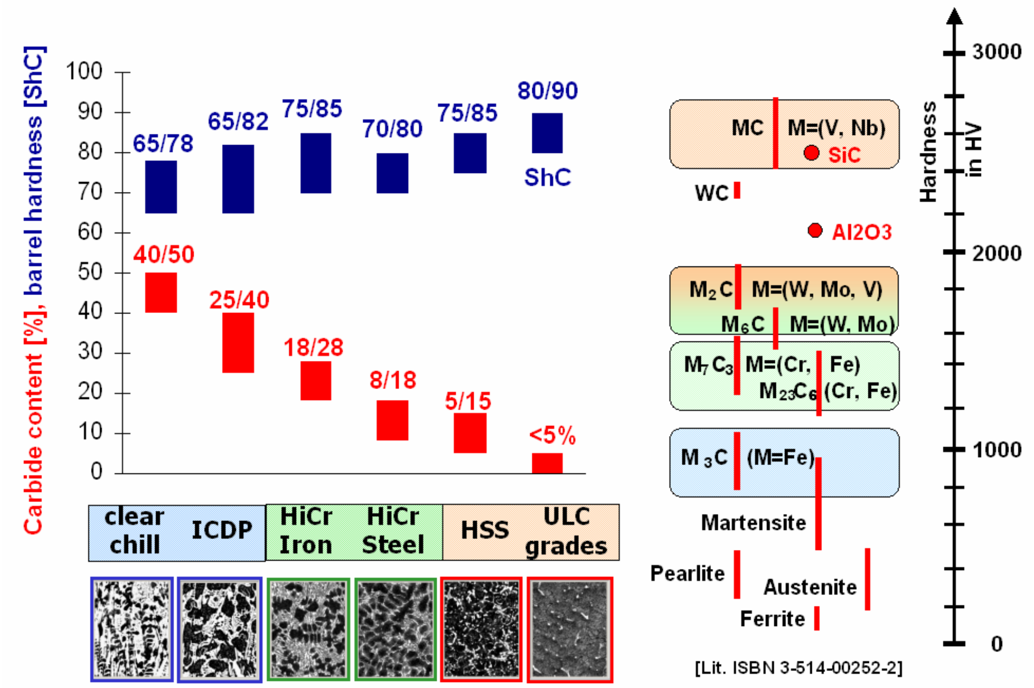


**Figure 3: roll grades for hot rolling of flat products [2, 3]**

It would be wrong to say that the big improvement of performance of modern roll types came from the new rolls only. The terrific improvements made in the hot rolling mills, efforts in automatization and planning of campaigns as well as introduction of newly developed lubricants and new testing and grinding practices in the roll shops have also played a major role. But it cannot be denied that also the roll makers have been successful in their efforts to improve their products.

In modern rolls, the carbide types and carbide hardness have changed totally.
We can distinguish between 4 different systems of shell microstructures:

- Clear chill and conventional ICDP and, with small variations concerning carbide types and graphite formation, also carbide enhanced ICDP
- High chrome iron and steel and, again with small variations in the carbides, the carbide enhanced types
- All variations of HSS
- Ultra low carbon grades

When we now have a look at the performance levels of different roll types used in roughing and finish rolling, we can state that:

- staying within the same system of shell microstructure, e.g. changing hardness of high chrome or using carbide enhanced high chrome instead of conventional high chrome, will certainly increase roll performance and surface quality – at least to some extent.
- Drastic increase of performance can only be reached by leaving the system and going for an advanced roll type.

Here are some examples of ESW's customers to describe the situation we can see in many hot rolling mills.

## Example 1: SINGLE REVERSING ROUGHER

WR Ø1250x2050 mm of a semi-continuous HSM rolling mainly carbon grades (fig. 4)

With conventional high chrome steel rolls 70 – 75 ShC, the campaign length was limited to an average of 24.000 tons.

Carbide enhancement and an increase in hardness to 75 – 80 ShC helped to increase the campaign length to 30.000 tons. In addition to that, an increase in surface quality could be observed – see fig. 5 illustrating the comparison in surface roughness.

A major increase in campaign length could be reached by moving towards HSS roll grades. A chromium based HSS 78 – 83 ShC reached an average of 42.000 tons, with less wear and better wear profile than the carbide enhanced chrome grade (fig. 6). At the early beginning there has been some concern using HSS rolls because of slippage and biting problems in this application, but up to now no problems were reported.

Finally, a molybdenum based HSS grade 80 – 85 ShC now is successfully running campaigns of 65.000 tons, allowing the mill to roll a 1 week campaign without roll change. Thus, the Moly base HSS almost tripled the campaign length of the conventional high chrome steel grade.

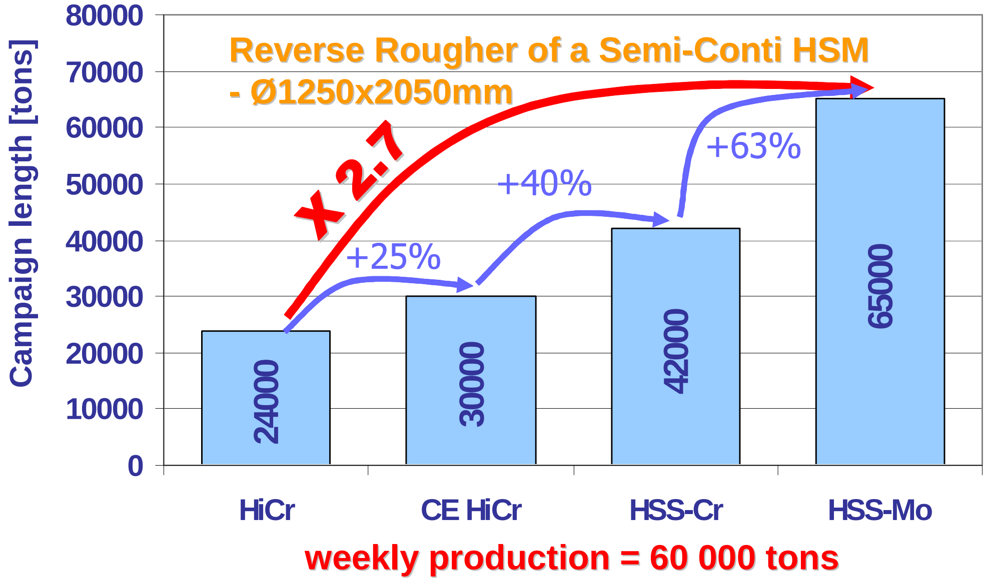


**Figure 4: increase in campaign length by changing the roll system in a single reversing roughing stand of a semi-continuous hot strip mill**

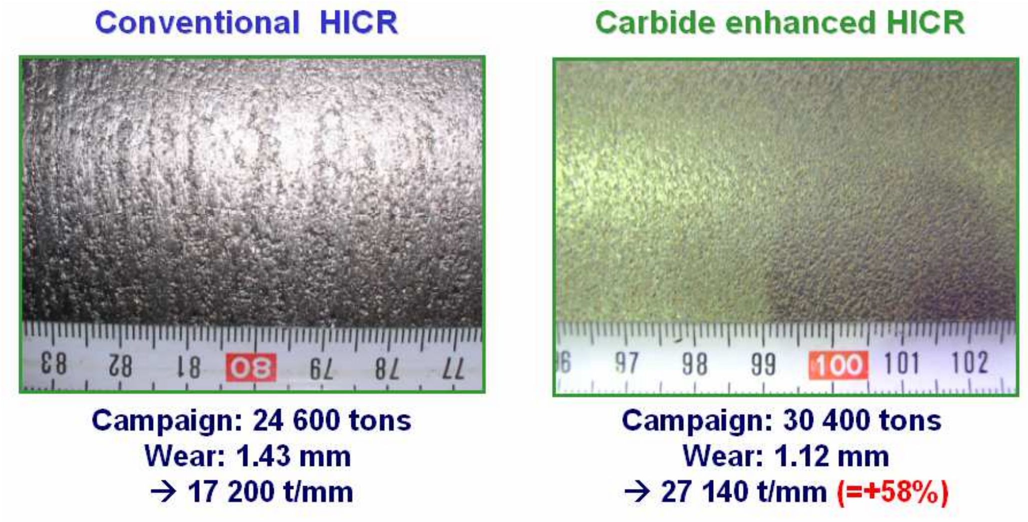


**Figure 5: barrel surface of work rolls (Ø1250x2050)**
**in a single reversing roughing stand of a semi-continuous hot strip mill**

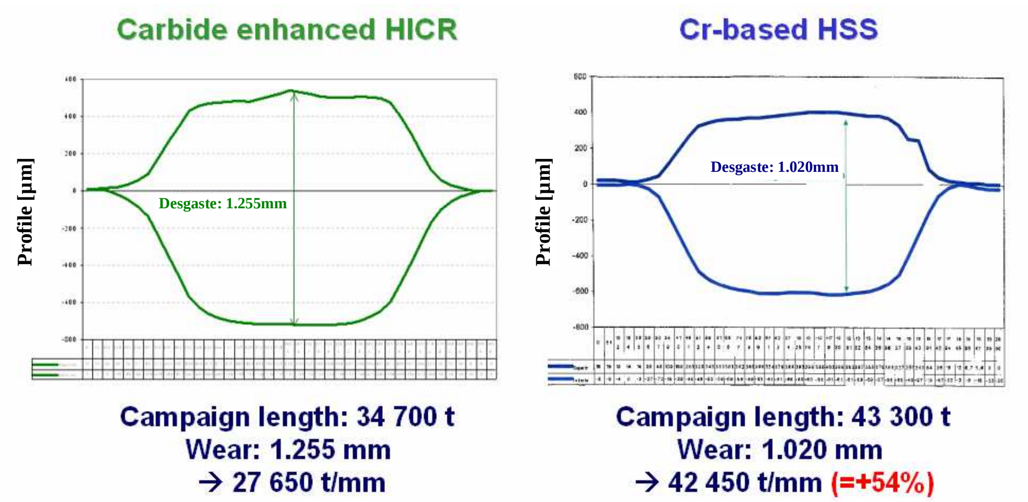


**Figure 6: wear profiles of work rolls (Ø1250x2050)**
**in a single reversing roughing stand of a semicontinuous hot strip mill**

## Example 2: FINISHING STANDS NO. 1 - 3

of a 7 stand HSM WR Ø740x1800 mm rolling mainly HSLA and automotive sheets (fig. 7)

Conventional high chrome iron rolls 70 – 75 ShC reached a performance level of 7400 tons/mm. ESW's method of carbide enhancement [4] and a 5 ShC increase in hardness pushed the performance to 8500 tons/mm. The average campaign length was 2.500 tons in both cases.

The introduction of our chromium based HSS type ("Konkordia") 75 – 80 ShC already doubled the campaign length, the performance level reaching more than 12.000 tons/mm. With the introduction of our molybdenum based HSS, 4 subsequent rolling programs could be run without roll change and grinding, thus increasing the campaign length to 10.000 tons and the performance to more than 22.000 tons / mm, 3 times the performance of high chrome rolls.

Running 4 programs now is possible due to the perfect surface condition of the moly base HSS, which shows much lower roughness values than the formerly used Cr based HSS type (fig. 8).

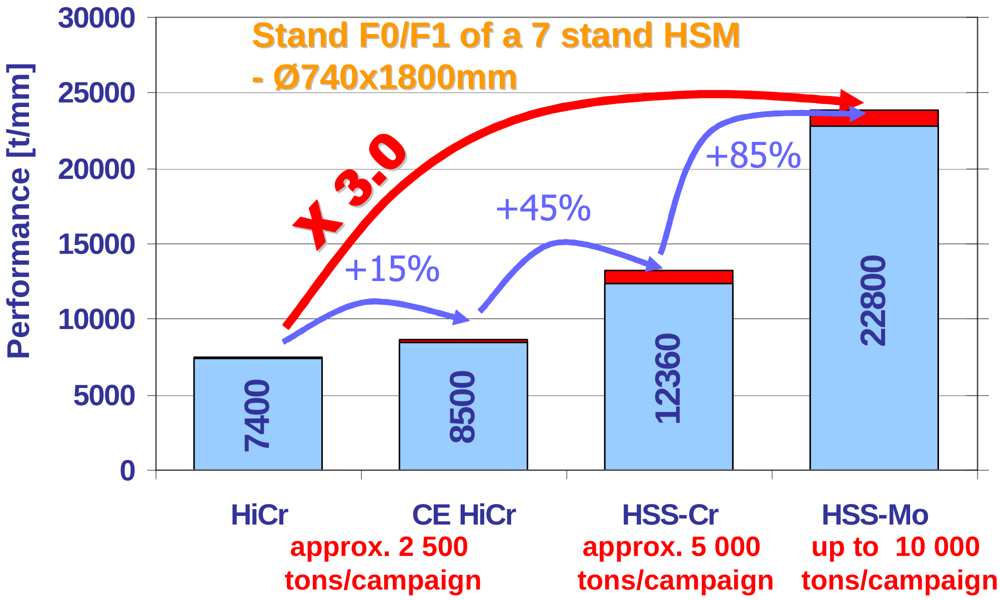


**Figure 7: increase in performance by changing the roll system in stand F2 of a 7 stands hot strip mill**

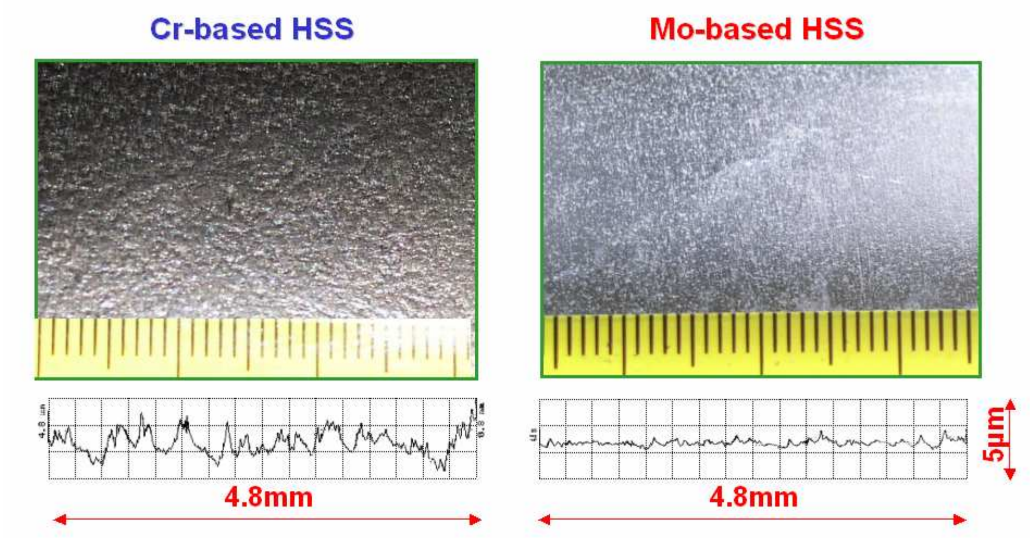


**Figure 8: barrel surface after rolling 3 000 tons
in stand F2 of a 7 stands hot strip mill (Ø820x2350) [5]**

Concerning the last finishing stands, the picture is somewhat different.

## Example 3: FINISHING STANDS NO. 5 – 7

WR Ø715x2250 mm of a 7 stand HSM rolling mainly carbon steel (fig. 9)

Carbide enhanced ICDP rolls have increased the average performance level from 4760 to 6170 tons / mm, i.e. 30%. This increase in performance is due to improved wear resistance triggered by the introduction of high hardness special carbides, compacted graphite (instead of coarse lamellar graphite) and the elimination of hardness drop during the lifetime of the roll (fig. 10).

However trials to further increase the performance by using higher amounts of special carbides in CE ICDP or using graphite free roll grades like HSS have failed in most cases.

Many mills have made the same experience. As soon as the carbide level of the rolls exceeds a certain limit (and the graphite content of the rolls diminishes), cracking problems occur even after minor rolling incidents. In some cases,  surface roughness due to strip welding occurred.

From the theoretical point of view, some enhancement strategies could create carbide enhanced ICDP rolls with extremely high wear resistance, providing performance levels of 10.000 t/mm, but these rolls would require perfect rolling conditions which in reality cannot be found in most mills running either close to the limits of their technical capabilities, or even exceeding them regularly to fulfil the demanding requirements of today´s steel markets.

Obviously, there seems to be a need for a change in the roll alloying system for the last finishing stands, but so far no solution is in sight.

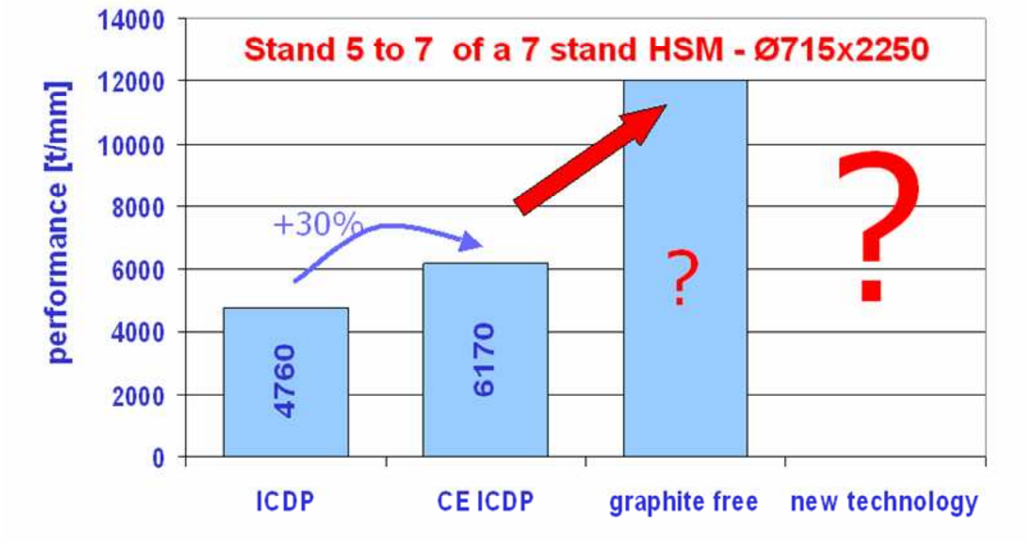


**Figure 9: increase in performance by changing the roll system in stand F5 - F7 of a 7 stands hot strip mill**

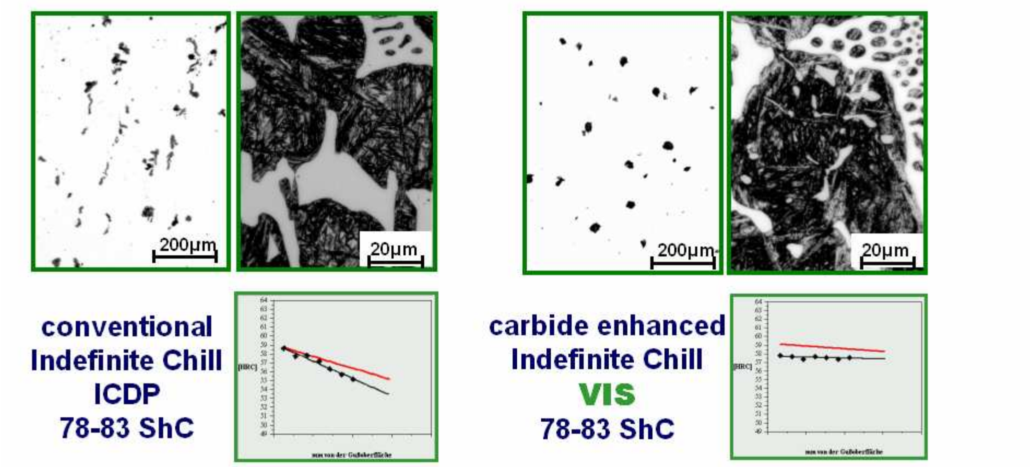


**Figure 10: comparison of shell microstructure and hardness drop of conventional ICDP and carbide enhanced Indefinite (VIS) [6]**

## Example 4: STECKEL MILL

WR Ø690x1870mm of 6-high stand rolling exclusively stainless steel (fig. 11)

Stands which are rolling the final pass of the strip commonly suffer from specific problems when graphitic free rolls are used (surface finishing, cracking, sticking, etc.). Trials with high chrome cast iron rolls usually failed in Steckel mills. Meanwhile the rolling conditions of some Steckel mills were improved for the use of advanced HSS rolls, some HSS-trials are in progress and excellent results are achievable.

With conventional ICDP and carbide enhanced ICDP a stainless steel manufacturer reached 140 – 180 t/mm in his 6 high Steckel mill (fig. 11). This mill has changed partially to HSS in the Steckel which now perform up to 1 000 t/mm. So by changing the roll system from ICDP to HSS a phenomenal increase in performance could be realized – no negative consequence to the surface quality was observed.

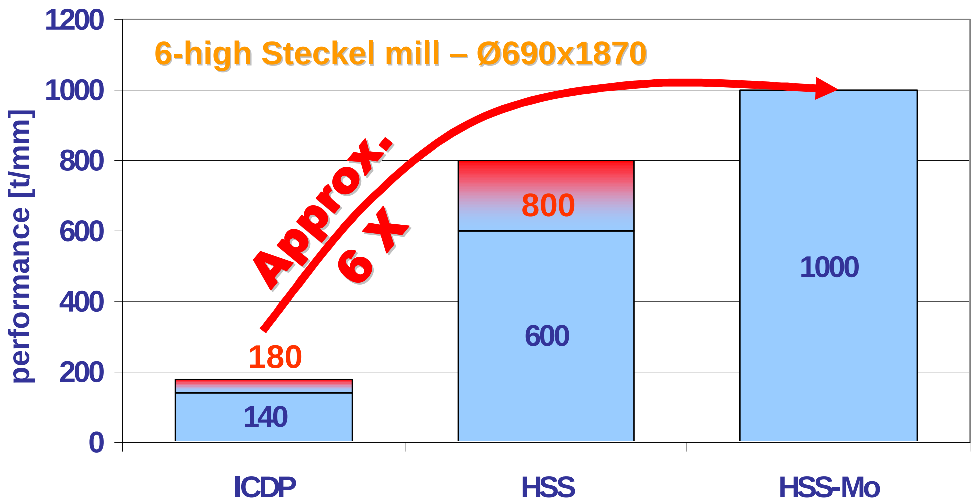


**Figure 11: increase in performance by changing the roll system in a 6-high Steckel mill**

## SUMMARY AND OUTLOOK

The roll industry has developed new roll grades belonging to different systems concerning alloying and microstructure of the shell material. Big steps of improvement in work roll performance can only be reached by leaving a system and going for the next (and better) one.

A change in the work roll system will certainly require investments and efforts from the roll user´s side to get the full benefit from the system change. This includes

- introduction of roll gap lubrication for HSS
- optimizing rolling conditions to avoid thermal and mechanical overload of the rolls
- upgrading the roll shop with modern crack detection systems (eddy current, surface wave UT)

A significant improvement of roll performance in the last finishing stands will not happen in the immediate future. The rolling conditions in most mills nowadays do not allow the use of very high alloyed CE ICDP rolls or HSS rolls (which would be a step into a new alloying system).

The development of HSS types exclusively for the last finishing stands, or of roll grades with even higher wear resistance than HSS, will only happen as soon as roll makers are encouraged by improving mill conditions (no more tail end slapping, no thin gauge rolling in mills that have not been design to roll thin gauge, etc.) that would allow the use of such sophisticated rolls on a large scale.

## ACKNOWLEDGEMENT

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