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ROLL GRADE APPLICATION FOR HSM TO REDUCE TOTAL COST OF OWNERSHIP*

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Abstract
HSM can be divided into different groups such as Conventional HSM with Roughing stands and HSM without Roughing stands = Mills with just finishing stands. The roll requirements for different stands are quite different. In Roughing stands the temperature of the slab is very high. Therefore the resistance against thermal wear/fatigue is the most dominating factor. Today mostly Chrome Steel, Semi HSS and HSS rolls are applied. A comparison and evaluation of such rolls will be described. In the finishing mill the tendency/wish is to use HSS rolls in all the stands. The grade HSS is defined by at least a certain amount of carbide forming elements such as V, W, Mo, Nb etc. The matrix and other precipitations can be adjusted according to the need and situation in the mill. In the pre-finishing stands the HSS is already well introduced. In the last finishing stands the original HSS tended to stick and the cobble rate increased. New development decreased the problem and gave some very promising results. In the last finishing stands beside the high performance a higher resistance against incidents is needed. Solutions in this direction including e.g. residual stresses and special core material will be discussed. Proper testing and grinding procedures can avoid losses and reduce the TCO. Data sourcing and evaluation in regards of rolling and grinding is the key for the optimization of the TCO. Several examples and comparison between different applications will be given in detail and explained. Future possibilities will be discussed as well as results of latest trials in mills.
Keywords: HSM; TCO; Roll application; Roll material.

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1 INTRODUCTION

HSM can be divided into different groups such as Conventional HSM with Roughing stands and HSM without Roughing stands = Mills with just finishing stands. The roll requirements for different stands are quite different. In Roughing stands the temperature of the slab is very high. Therefore the resistance against thermal wear/fatigue is the most dominating factor. Today mostly Chrome Steel, Semi HSS and HSS rolls are applied. A comparison and evaluation of such rolls will be described. In the finishing mill the tendency/wish is to use HSS rolls in all the stands. The grade HSS is defined by at least a certain amount of carbide forming elements such as V, W, Mo, Nb etc. The matrix and other precipitations can be adjusted according to the need and situation in the mill. In the pre-finishing stands the HSS is already well introduced. In the last finishing stands the original HSS tended to stick and the cobble rate increased. New developments decreased the problem and gave some very promising results. In the last finishing stands beside the high performance a higher resistance against incidents is needed. Solutions in this direction including e.g. residual stresses and special core material will be discussed. Proper testing and grinding procedures can avoid losses and reduce the TCO. Data sourcing and evaluation in regards of rolling and grinding is the key for the optimization of the TCO. Several examples and comparison between different applications will be given in detail and explained. Future possibilities will be discussed as well as results of latest trials in mills.

2 TOTAL COST OF OWNERSHIP (TCO)

The steel industry has been facing hard times. The worldwide production is extremely high. Especially in China it has been growing quickly in the last years.. This led to a certain amount of overcapacity of steel in the world. In Europe the steel industry has been stagnant at the same level for years, but imports are causing a high competition on the market. Steel works have to run through cost saving programs to be competitive. Cases can be found where the raw bar is already more expensive than the final rolled product. This competition changed the behavior in the rolling industry. Just the strongest and most cost effective will survive. Another possibility is the diversification in products or the vertical range of manufacturing has to increase.
In any case every steel plant and rolling mill has to investigate how the production costs can be reduced. With this knowledge there are different ways to achieve the goal, to be competitive on the market. In a rolling mill there are several major cost types to be analyzed. It is necessary to look behind all edges and an open discussion has to start.
One item is in any case the most needed tool in a mill, the roll itself. Rolls are in operation and get thermal loads as well as mechanical loads. These cyclic loads are combined with friction, cooling water, lubricants, local thermal and mechanical overloads, thermal gradients and oxidation-corrosion. This all leads to different forms of wear and degradation of the roll surface and the roll has to be changed, tested and redressed for the next operational cycle. Servicing the rolls includes also the bearing inspection and other work in the roll shop. All together in a modern roll shop it is called roll shop management.
All these different steps in the procedure are input figures for the TCO approach.

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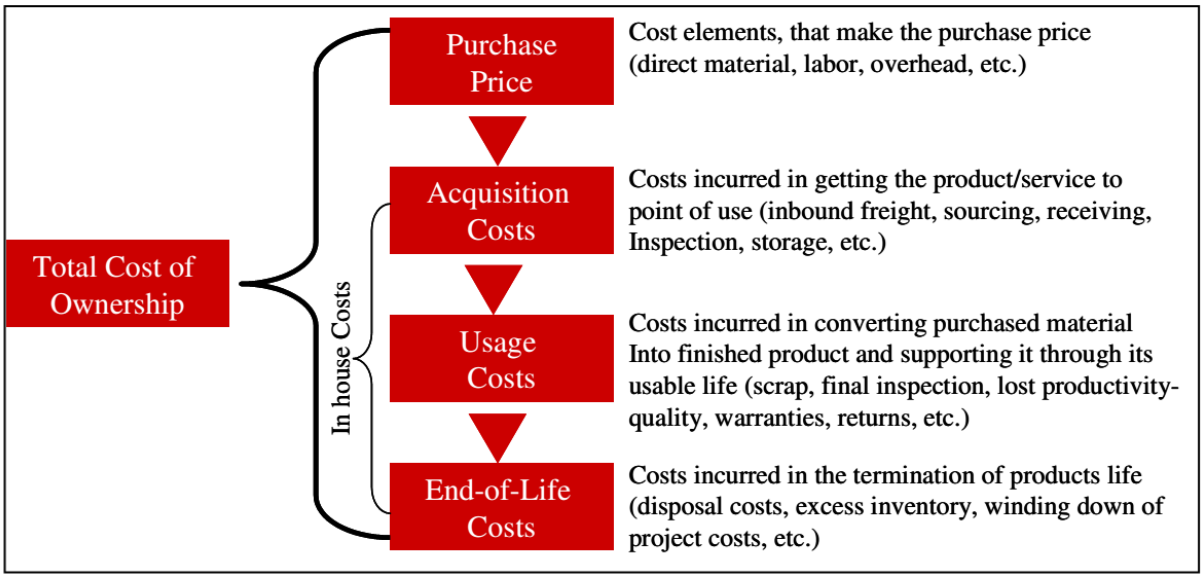

Figure 1: The TCO breakdown is merely a guideline; TCO categories vary depending on the nature of the product/service [1]

2.1. Input Factor Roll Performance / Roll cost

Most of the mills or roll shops are operating a roll shop management system. Still there are cases where the roll history card is manually written and the figures have to be typed into a spreadsheet and then an analysis can be done. This is already the first point where money and cost could be saved. Depending on the mill size (stands) and operation a manual system is not cost effective. Computerized roll management systems have the possibility to analyze and evaluate the full history of the roll during the entire roll lifetime. This gives the possibility more or less online at any time to get out the actual figures of all rolls in operation or circulation. The input parameters should be:

i. Date of operation
ii. Tonnage rolled
iii. Km rolled
iv. Pure wear
v. Normal redressing
vi. Extra redressing
vii. Classification of normal redressing and extra redressing
viii. Date of grinding
ix. Grinding time
x. Date of testing
xi. Test result of EC and/or UT
xii. Failure analysis after incident or accident

If these data is available any type of evaluation and processing of single rolls or roll groups is possible. This gives the opportunity to compare different roll types or suppliers and trial rolls to see the differences.
The pure wear of a roll is the most interesting input figure. It shows in relation to km or tonnage the ability of the roll to stay in the stand with a certain amount of wear. In most of the cases, the wear is not very high, but due to several reasons the roll has to be changed.

2.2. Roll related cost in operation

As already mentioned in the introduction, rolls have different behavior in the mill. Depending on the stand in the mill some of the factors are more or less influencing the campaign length:

i. Thermal degradation
ii. Mechanical impact
iii. Friction
iv. Oxidation / banding
v. Surface defects from microstructure
vi. Surface defects due to strip scale
vii. Incidents / accidents

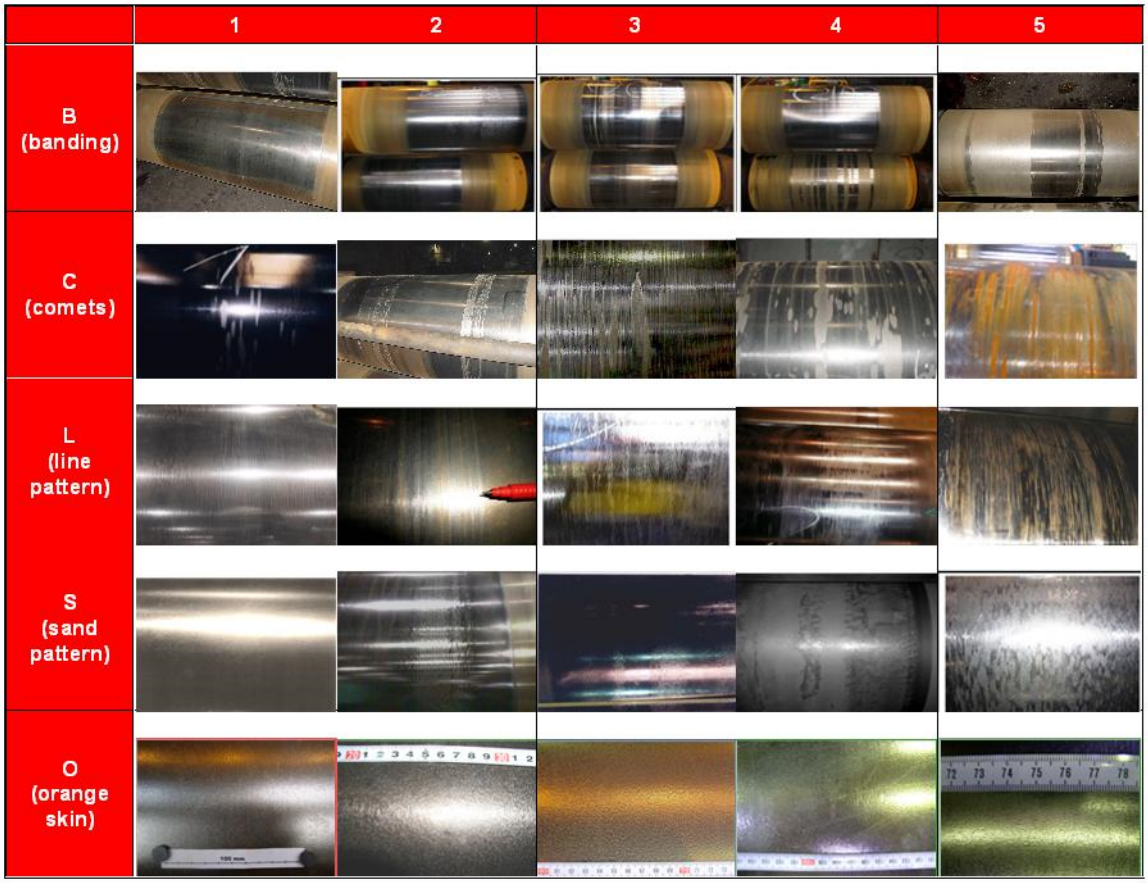

Figure 2: different examples of surface degradation and deterioration

The earlier stands such as Roughing stands and early finishing stands mostly suffer from thermal load and therefore material fatigue. Proper cooling and work roll crown can help. In many mills the rougher rolls have to make several passes with the hottest material. Depending on the reduction this can lead to vibration or slippage and other surface erosion effects. The consequence is a limited campaign length. Depending on the ability of the mill the right roll material can help to optimize the campaign length. Roll changes are always in coordination with planned roll changes in the finishing mill. Usually the roll change in a roughing stand is more time consuming compared to the finishing mill.

In the pre-finishing stands the limit depends on the work roll type the normal wear and in some cases the oxidation or banding behavior. Another factor is the mill design. Mills without roughing stand have similar problems in the pre-finishing stands as the roughing stands. Higher temperature and extreme reduction are the consequence and a higher frequency of roll changes has to follow.
The last finishing stands have a wide range of possibilities why a roll change has to be done. Generally the campaign length in a finishing mill is limited by the last finishing stands. The roll wear and as a consequence the profile, shape and surface quality of the strip is heavily influenced. Due to higher demand on profile and surface quality the campaign length can be reduced. Especially in these stands the extra, intermediate or earlier roll changes are influencing the efficiency of the mill.
The roll related cost factor in operation can be summarized as roll change cost and efficiency loss.

2.3. Cost due to strip failure

A very special case is the surface quality of the strip. Most of the mills are going down with the strip thickness. This thin and ultrathin gauge strip is a possibility to earn more money. The consequence is a new phenomenon of wear and roll change needs. The strip surface has to be very good. A higher amount of hot rolled coil is sold directly without cold rolling. The consequence is the installation of inline surface inspection systems (SIS). Once the SIS is alarming, the mill has to stop and the rolls have to be inspected. In worst case a certain amount of strip has to be scrapped or at least downgraded. This is causing extra cost and time, finally productivity is going down. In such cases it is essential to find out the root cause of the problem. Is it something related to the roll, the cooling, scale, lubrication or something else. Other strip failures can result from small incidents such as tail pinching, local mechanical overload and so on. On the other hand the microstructure of the roll also can give negative prints to the strip surface. In such cases the root cause has to be investigated and the roll quality has to be adjusted.

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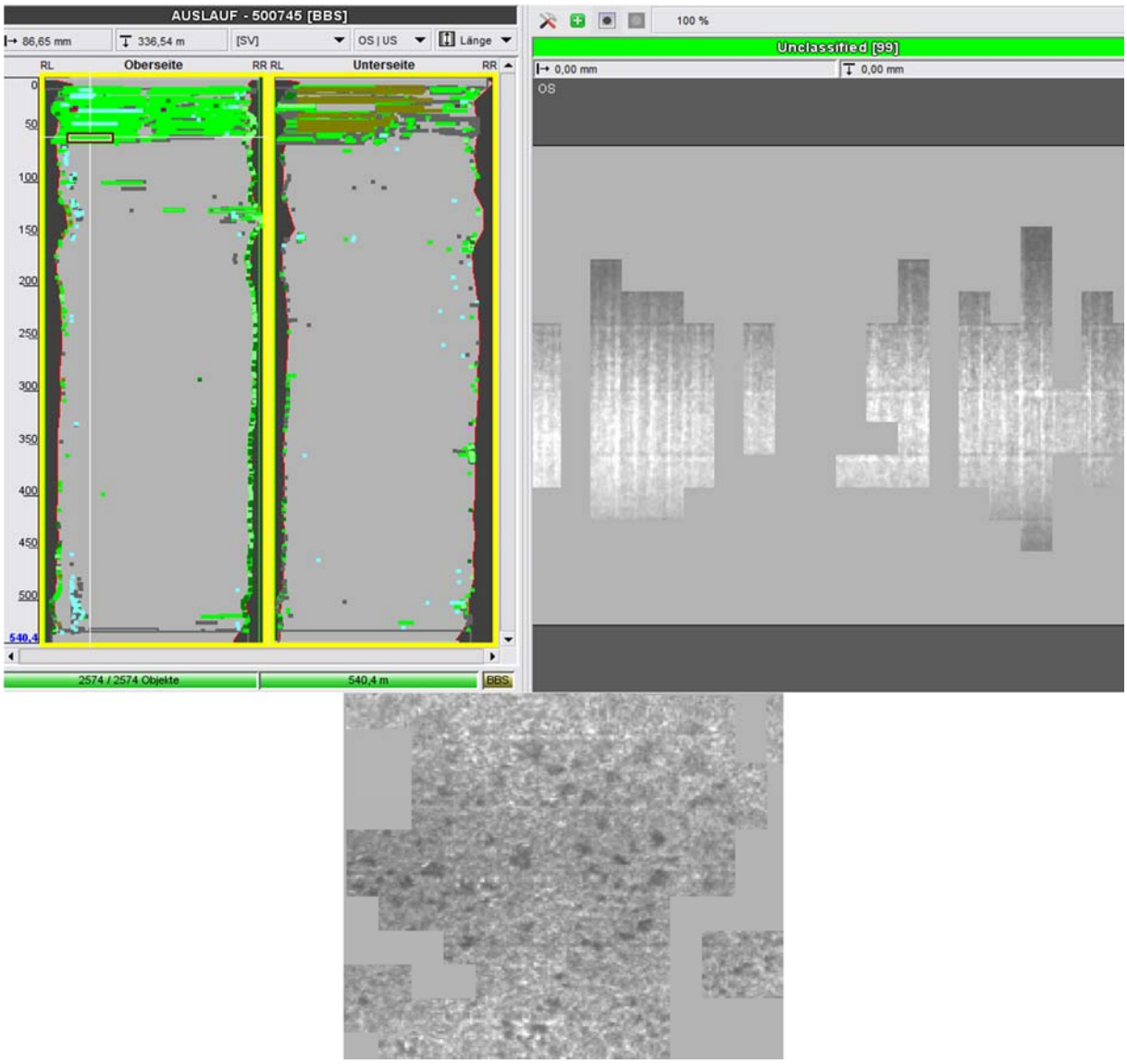

Figure 3: surface inspection system print on the left, right and down surface

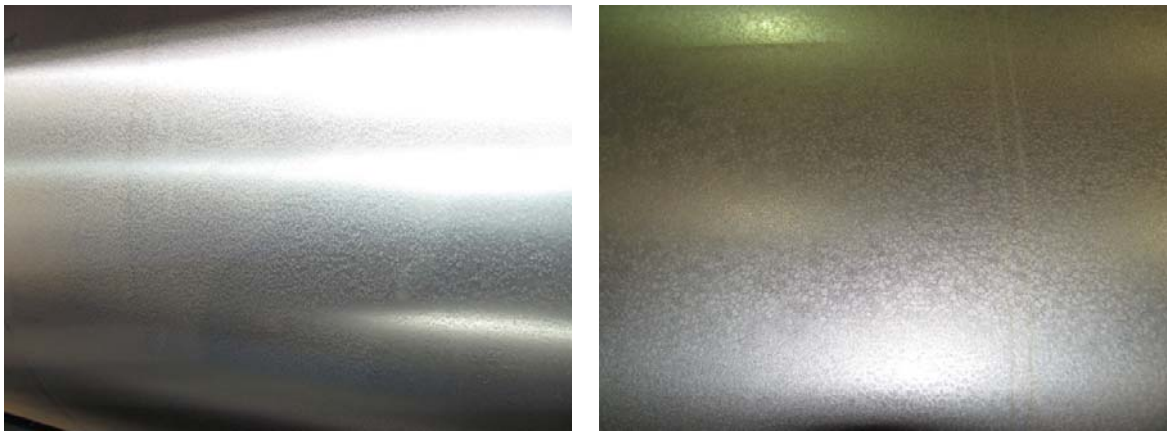

Figure 4: different examples of surface failures on a roll

2.4. Roll related cost due to test results

After a roll change rolls are cooled down and transported to the grinding shop. There the preparation for the grinding and testing of the rolls has to be done. There are roll shops where rolls have to be de-chocked for the grinding process, others don't need to do that. The grinding machine has to be equipped accordingly. Depending on the ability and possibility, the grinding in chocks can save a lot of money. This needs different bearing and chock maintenance and management.
The grinding process is normally started to remove the pure wear of the roll. Depending on the original profile of the roll and especially the application of the roll this can be close to 0mm but even up to 3mm. HSS rolls sometimes are working for 2-3 times without grinding so called multiple campaigns, but testing of the roll can be done to ensure that nothing has been overlooked. After the removal of the wear the common practice is to remove another fixed amount of roll-life. This shall ensure the roll is free from damages or deteriorated areas from the last campaign. In this area a lot of investigation can help to optimize the extra consumption of a roll. Depending on the procedure installed the next step is the inspection of the roll. In most of the roll shops Eddy Current testing is already a standard. In many roll shops a combination with Ultrasonic Testing is available. The UT can be done with different probes in normal direction, surface wave or even transducer/receiver configuration. This is very much recommended in any roll shop. The frequency of testing can be optimized, but the reality has shown a roll should be tested after every campaign otherwise a save operation is difficult to ensure. In most cases when other rhythms for testing are applied, such as every 2nd, 3rd campaign or after 5mm of usage, it happens that a roll failed directly after such a non-testing period. It is clear that the roll testing takes time but compared to possible losses in the mill due to minor or lager spallings followed by mill stoppage and production loss, the overall testing time is relatively low in cost.
Roll shops with actually too low grinding capacity have to find solutions for such a situation, but it is inacceptable to run a mill over longer periods without testing just to achieve better productivity or cost savings.
The interpretation and the adjustment of testing equipment is very important. Wrongly maintained testing equipment can lead to extraordinary grinding losses due to bad test results. To run full automatic inspection systems the user has to ensure (have to include) supervision of the test equipment and adjustments according to the rolls tested. In other words, it is not possible to use the same testing parameters for all roll types circling in a mill. There are too big differences between the applied materials such as Chrome Steel, Chrome iron, HSS, ICDP and graphitic HSS rolls.
The recommendation is to take a "footprint" of each and every new roll before the first service campaign. The results of this first test should show whether the common testing parameters are applicable or if they have to be adjusted for the future testings.
In Figure 5 you can see an example of a critical alarm setting. The ground noise of the roll is at a certain level. The alarm threshold for the grinder is close to the ground noise level. Every small deviation, which is not critical, will force the grinder to further grind the roll. This leads to unnecessary grind offs. In such a case the threshold should be adjusted according to the original footprint of the roll.
The other possibility is to install newest generation of testing equipment which is no longer operating with fixed thresholds. The relation between ground noise level and

single peak indication will be evaluated. This is the best method to reduce unneeded grindings and ensures the best possible detection of serious indications.

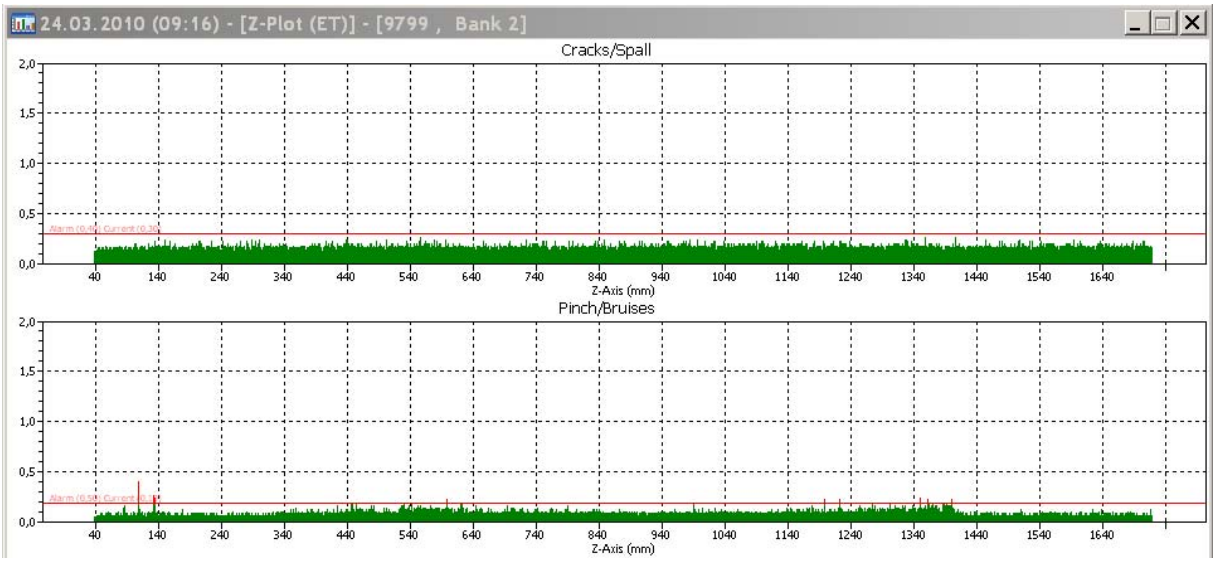

Figure 5: threshold of EC too close to ground level

2.5. Limited roll grinding capacity

The hardest item in a mill is surely the capacity of a roll shop. If over longer periods the grinding and testing is not available in the needed amount the result will be given in multiple problems. First the testing will not be done on time to get the rolls ready for the campaign. This includes a high risk of critical rolls in service. Spontaneous damages such as spallings or deep cracks will come in higher frequency. The other point is the surface quality of the roll. Sometimes rolls are going into service with very rough ground surface. This is not acceptable in the last finishing stands. The surface has to heal in the mill. This can go well, but also can lead to several surface related strip failures. Fast grinding makes the surface not only rough, but also firecracks can be imprinted. This can later on lead to crack growth during the mill operation and in worst case to total loss of the roll.

3. ESW's CONTRIBUTION TO TOTAL COST OF OWNERSHIP (TCO)

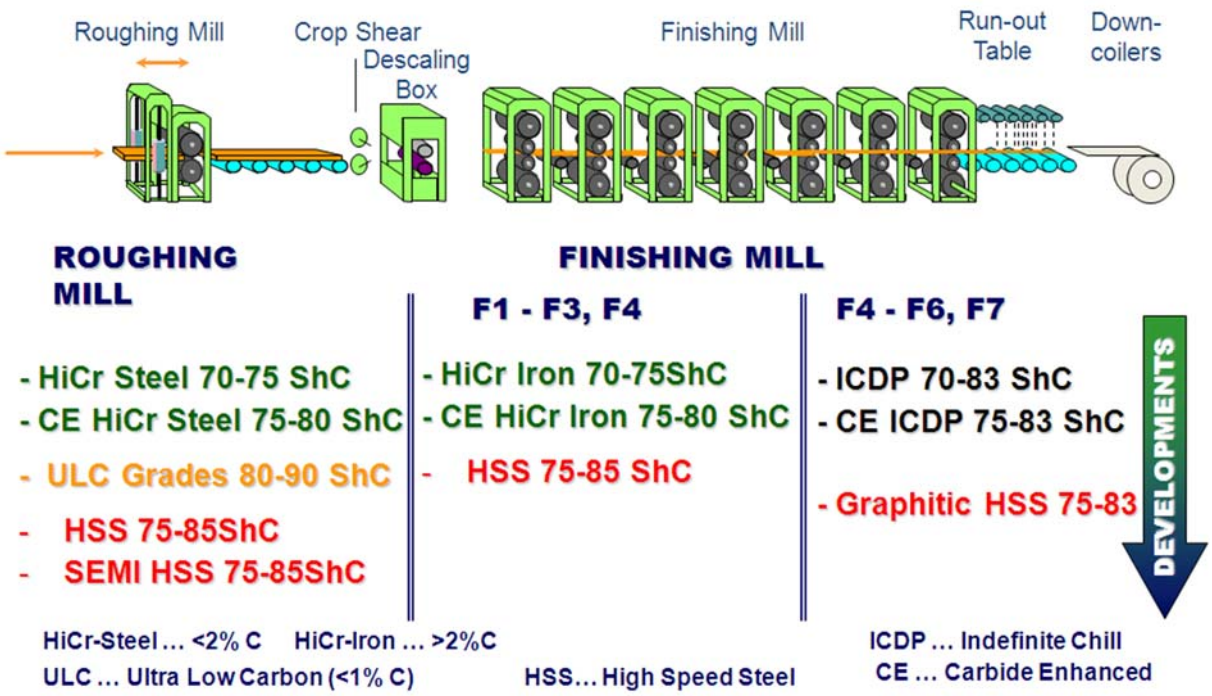

Figure 6: Principle of a HSM

In recent years ESW has developed new grades for all categories of mill stands. Some of them are nowadays already more or less standard grades, other new versions are in the trial process. Worldwide there are different types of Hot Mills in operation. But all grades can be used more or less in all configurations, sometimes adjustments have to be made.
A rough overview about a HSM is given in Figure 6

3.1. Roughing stand Chrome Steel – HSS – SEMI HSS (SEMIRA)

The standard grade for this application is the chrome steel roll. The solid state and easy handling combined with good firecrack resistance gives a valuable performance and safe handling.
One example is the comparison between a chrome steel roll and the latest development of a Molybdenum based HSS roll. The increase of performance was increasing the campaign length dramatically. The saving on cost was mainly driven by the reduction of roll changes and therefore higher productivity in the mill stand.

ISSN 1983-4764

Figure 7: Reduction of Mill downtime related to Roughing Mill work roll changes [2] and performance

Table 1: Work index increase due to the WR development [2].

Production (t)	WR Campaign - Target (t)	Scheduled WR Changes (#)	Δ Roll Changes (#)	Time per Roll Change (h)	Δ Total Time (h)	Calendar (h)	Work Index Savings (%)
4.000.000	13.000	308	254	0,50	127	8.760	1,45%
	75.000	53					

The latest development at ESW is the SEMI HSS grade SEMIRA. This roll type gives very similar results in tonnage and performance to a full HSS.

Figure 8 and 9 show the actual roll profile as ground (green curve) and in comparison after the campaign.

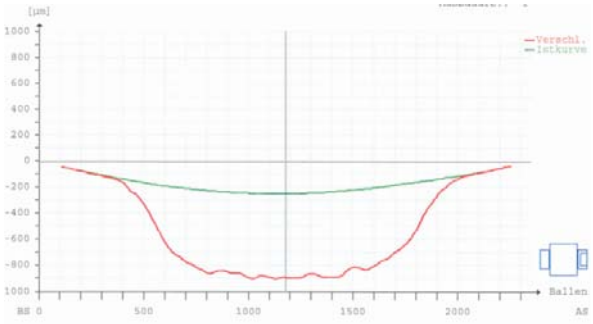

Figure 8: Cr Steel after 24.000t

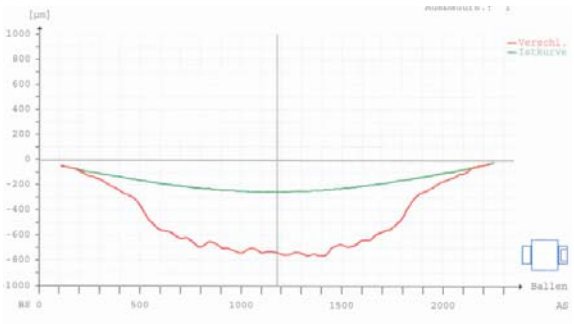

Figure 9: SEMIRA after 41.000t

The wear is similar (900 at Cr Steel and 800 at SEMIRA) but the tonnage rolled has increased from 24.000 to 41.000tons.

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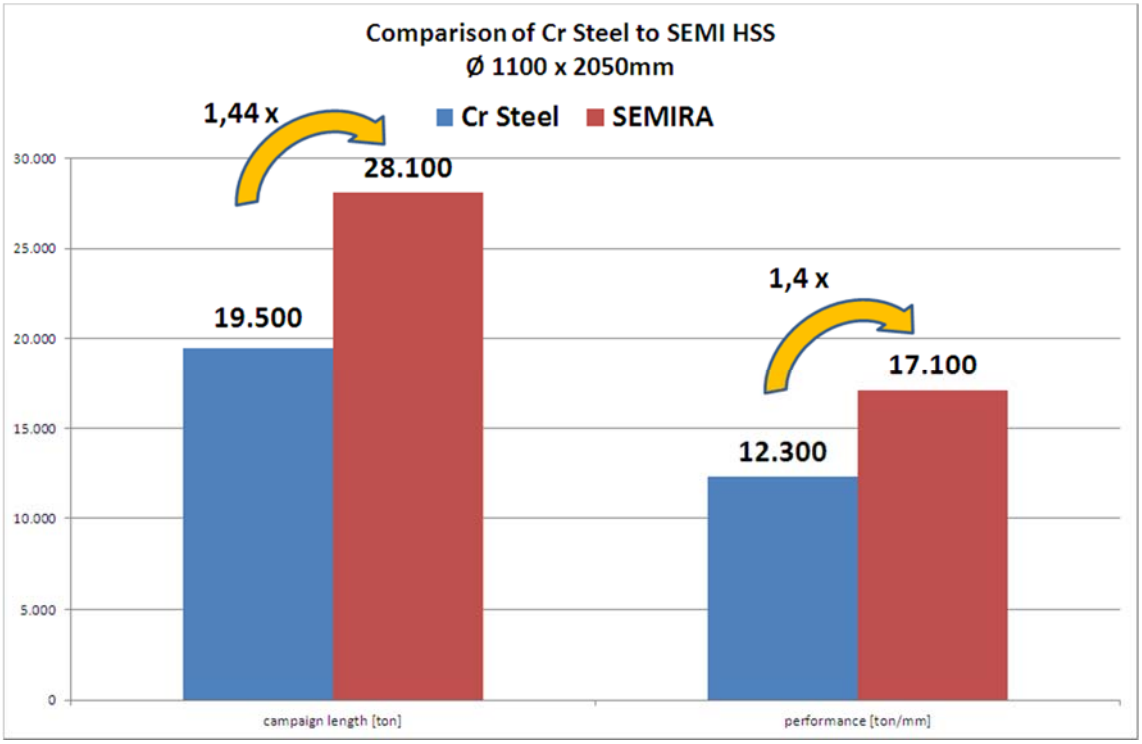


Figure 10: Performance comparison of Chrome steel to SEMI HSS SEMIRA

3.2. First finishing stand Hi Chrome – HSS - AMADEA

In the first finishing stands the High Chrome iron and the enhanced version is often replaced by the standard HSS Mo-based. In this case the performance figures are already at a very high stage. An increase needs further experiments in different alloying concepts. ESW decided to invest in special software to calculate possible alloys. Combined with experiments of ladle treatment it formed the basis for a new type of HSS rolls for this application. The new brand called AMADEA has a special microstructure with new added special carbides.

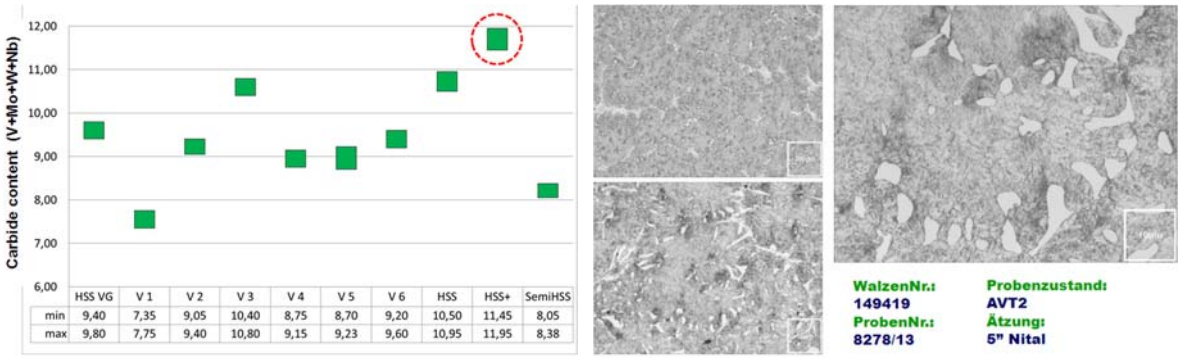


Figure 11: Alloying content of carbide precipitation forming elements and microstructure of such material

The first results in performance after half of lifetime have shown that AMADEA is reaching an improvement of about 10%.

3.3. Last finishing stand VIS – VANIC- VANIS – VANIMO (graphitic HSS)

In this group of application the widest development took place. The ICDP or in general the graphitic work roll group for the last finishing stands has always been the group with the highest frequency of roll changes. The wish to harmonize the roll changes with the first finishing stands was given for a long time. Since the modern mills can change the rolls within 5 minutes, the need was dropping down, but all other mills with higher time consumption still wanted to increase the campaign length. On the other hand the strip quality is heavily influenced by the last stands. The last stands in most mills are the ones with the highest incident rate. The compromise looked for was a very resistant and high performing roll. These are contradictory properties and not easy to achieve. A certain compromise was found and combined with excellent testing facilities the new approach is possible to reach.
The results in several mills have proven that the new VANIMO grade is performing extremely well. Beside the low consumption of roll the campaign length could be increased dramatically. These happened especially in very abrasive rolling programs. On the other hand the uniformity of such a grade is very essential. The long lasting campaigns are degrading the surface of the roll in an extreme way. Every segregation or unevenness of the microstructure is visible on the strip and the roll has to be changed immediately or, even worse, the roll may not be able to run in the last stand. The optimization of this roll grade was done by “pure trial and error” in lab tests beside calculations with high sophisticated solidification phase calculation programs. The final result is a roll grade which opens a wide range of applications. This includes not only last finishing stands of a conventional HSM, but also Steckel mills, plate mills and all kinds of thin strip mills without roughing stands.

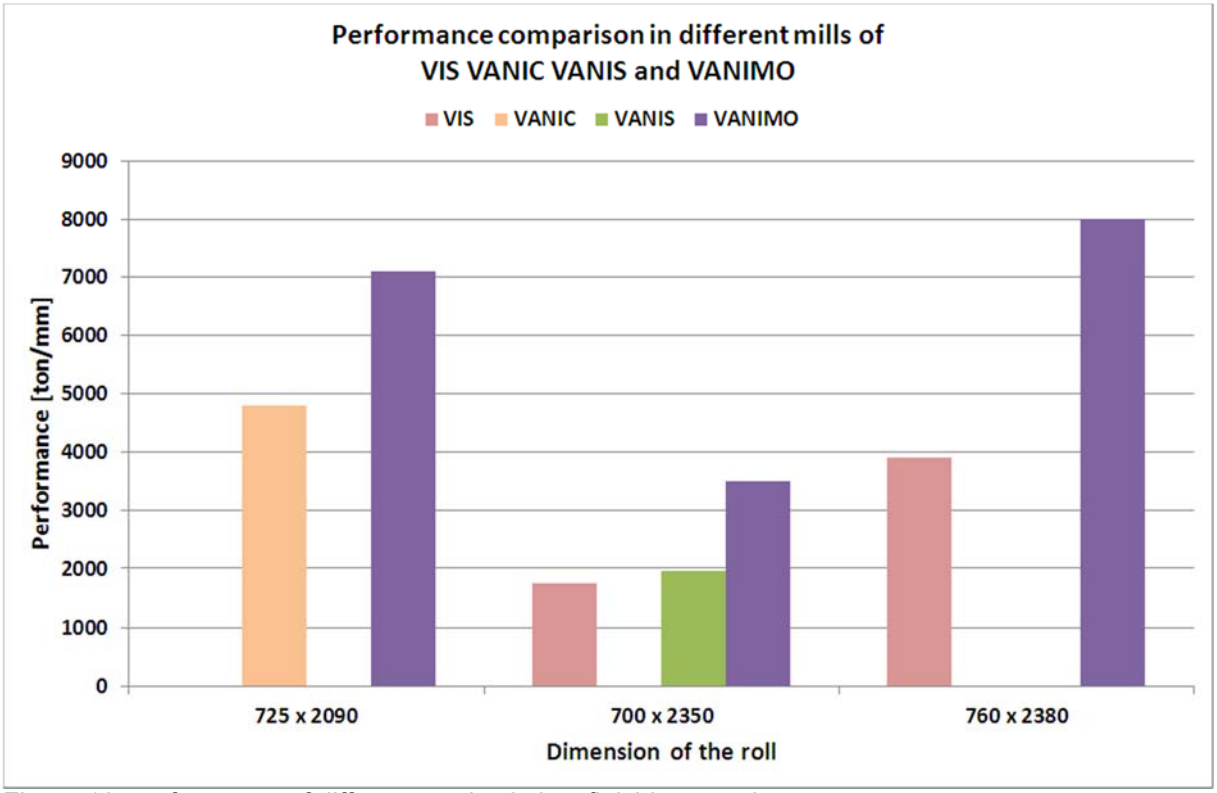
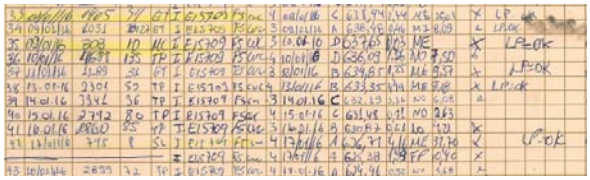


Figure 12: performance of different grades in last finishing stands

Figure 13: surface of VANIMO after 3000tons

3.4. After sales service and performance follow up

The after sales service includes technical discussions with the technicians in the mill. Technical items can be mailed and will be answered as soon as possible. Support in regard to testing and test result interpretation is an integrated part of our business. Internally at ESW we are keeping track records of all our customers. Depending on the Roll history availability we are evaluating the performance data. In our ORACLE database we keep short records about the evaluation record with an outlook for future deliveries. It doesn't matter how we get the data from our customer. We will handle them and make our standard evaluation to see which type of roll is better for each mill. Our know how and experience makes us fit for our second part of business, the recommendation of right roll grade for our customers.



2	F4	unten	15.03.2014 08:30	776,20	15.03.2014 14:00	775,80	N1	0,00
3	F4	unten	16.03.2014 08:00	775,80	16.03.2014 16:00	774,90	F0	0,00
4	F4	unten	17.03.2014 07:30	774,90	17.03.2014 11:30	774,10	A0	0,00
5	F4	unten	18.03.2014 01:00	774,10	18.03.2014 07:00	773,80	N1	0,00
6	F4	unten	18.03.2014 23:00	773,80	19.03.2014 03:00	773,60	C0	0,00
7	F4	unten	19.03.2014 15:00	773,60	20.03.2014 03:30	773,30	C0	0,00
8	F4	unten	20.03.2014 18:15	773,30	21.03.2014 01:00	772,80	N1	0,00
9	F4	unten	21.03.2014 14:30	772,80	21.03.2014 18:15	772,40	A0	0,00
10	F4	unten	22.03.2014 05:30	772,40	22.03.2014 13:00	771,90	N1	0,00

Figure 14: Examples of customer data received at ESW

From such data we are generating our evaluation and give feedback to the customer. Curves as shown in Figure 14 are a helpful tool for analysis.

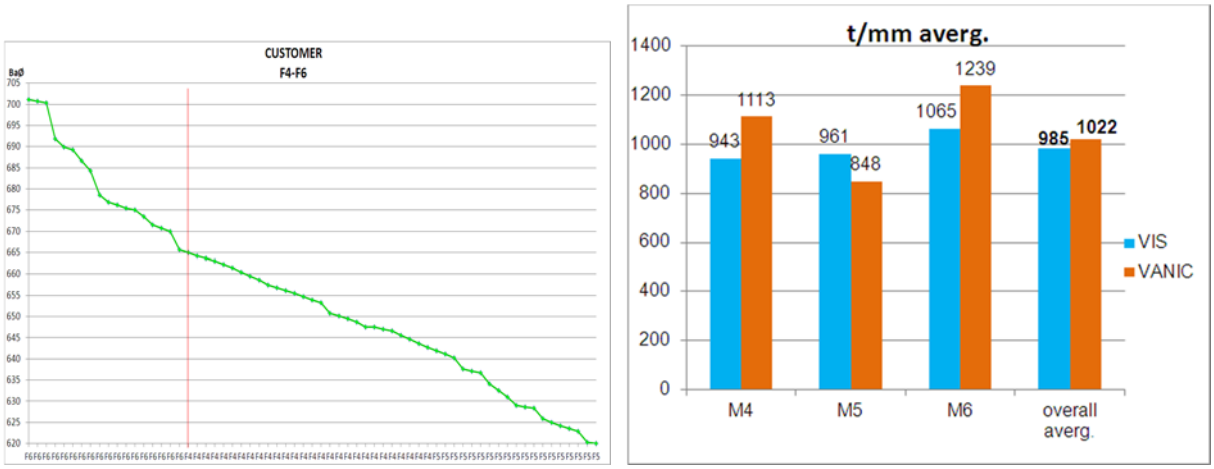


Figure 15: Diameter development curve, right: grade comparison within a mill and stands

4. CONCLUSIONS

Rolls are a key factor to reach higher productivity and directly influencing TCO at the rolls user's end. Over the years ESW rolls have proven that they allow higher productivity, higher efficiency and finally more profitability. Numerous different customers have done trials with several new grades and most of said trial-grades have been approved and been implemented as standard grades in the meantime. We are still working hard to improve the work roll performance, including the necessity to deliver rolls with acceptable resistance against rolling incidents or accidents. The higher the ability of a roll to perform in high level the more it is important to have proper testing facilities and well trained people to interpret the test results. Together with the roll specialists of ESW the proper planning of trials is possible. There is a clear win - win situation for both parties. The consistent production of high level work rolls makes ESW a partner for all kind of trials in HSM.

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