HOW TO INCREASE PERFORMANCE AND OPERATIONAL SAFETY OF WORK ROLLS [1]

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Abstract
The performance of hot strip mill work rolls usually is measured in tons per mm or wear kilometres per mm grind off. Main influences affecting performance are: roll related factors (wear resistance, operational safety including crack resistance, resistance against catastrophic failures like barrel breakage, spalling etc., and uniformity of shell microstructure and hardness); mill related factors (general working conditions including mill load, cooling, rolling program, roll shop practice – grinding and testing facilities and their proper use, etc.). From the roll manufacturer´s side, only the roll related factors can be influenced, and this is why sometimes excellent rolls may show unexpectedly poor results. In this paper, strategies to improve wear resistance and operational safety of HSM work rolls will be described.
Key words: Performance; Operational safety; Work roll; Hot strip mill.

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1 WEAR RESISTANCE

Roll wear is a complex phenomenon. Apart from all the theories, the last years of roll application in hot strip rolling have shown 2 strategies to improve the wear resistance of work rolls: improvement of existing roll grades by carbide enhancement, and changing to new grades like state-of the-art High Speed Steel.

1.1 Carbide Enhancement

In high chrome iron and steel shell materials, the chromium carbides have the highest impact on wear resistance. In the course of the years, a more or less uniform chemical composition of these rolls has been established worldwide.
To increase the wear resistance of these rolls, additional carbide forming elements can be introduced which increase the hardness of the eutectic carbide network. These elements and their hardness can be seen in Figure 1.
The higher hardness of these special carbides also allows to increase the overall hardness of the rolls without increasing the residual stress of the rolls. This has a major impact on the crack resistance of the rolls in operation.

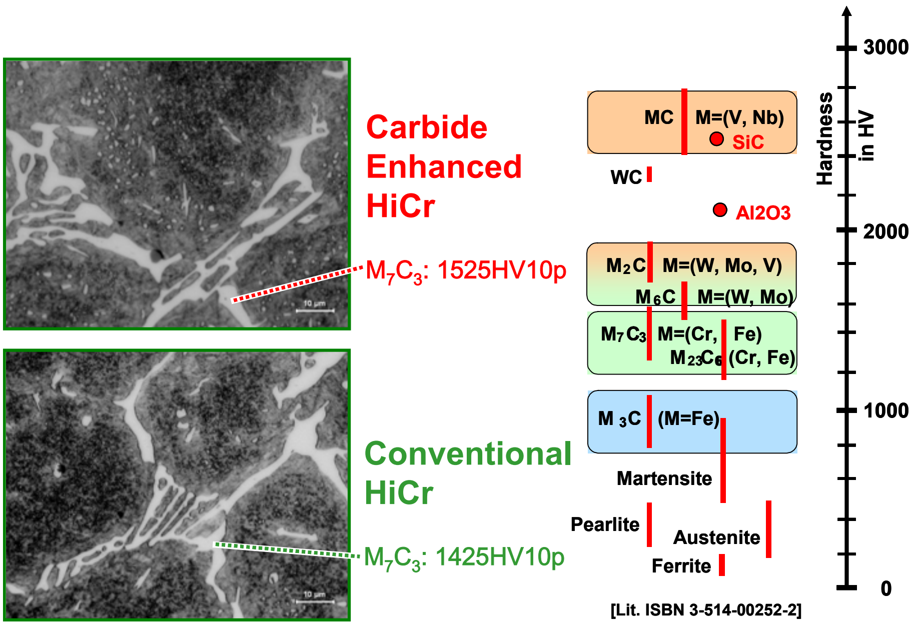


Figure 1: hardness of various carbide types

In indefinite chill rolls, the wear resistance depends on the amount and hardness of the eutectic carbide network (which, traditionally, consists of low-hardness Fe_3C) and the amount of free graphite. Therefore, carbide enhancement – the introduction of additional high hardness carbides into the shell material – is not enough.

1.2 Control of Graphite Content

High graphite content does not allow high performance because of poor wear resistance. Low graphite content does not allow high performance either, because the rolls will be prone to cracking. It is therefore important to measure the graphite content of the rolls and to find ways to influence it.

Figure 2 shows the big variation of graphite contents you can expect in case of conventional indefinite chill production compared with the small range of graphite contents that can be achieved in carbide enhanced rolls “VIS” by strict control of melting and melt treatment conditions.

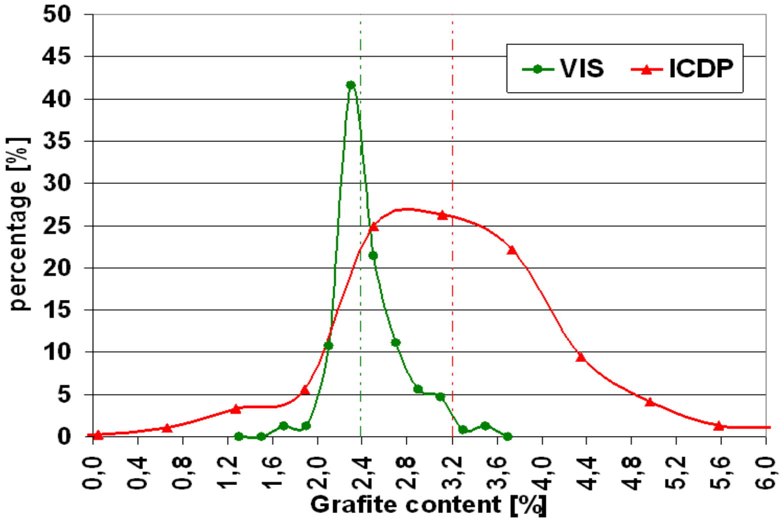


Figure 2: distribution of graphite content of ICDP and VIS work rolls

It is also important to avoid the increase of graphite content in the inner parts of the shell, to avoid poor wear resistance in the second half of roll life. In Figure 3, the graphite formation throughout the 90 – mm shell thickness of a carbide enhanced plate mill work roll shows no difference from surface to scrap diameter. Such a uniform graphite distribution is completely unknown for conventional indefinite chill rolls and can only be obtained in certain types of spun cast carbide enhanced indefinite chill rolls.

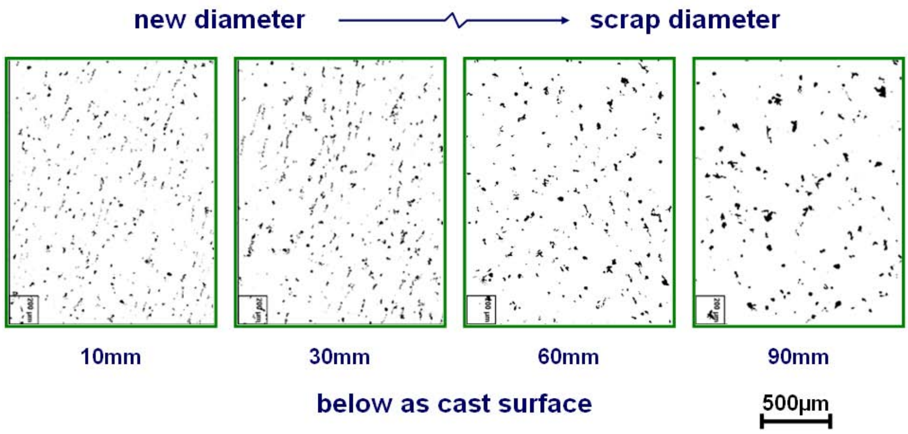


Figure 3: graphite formation in a VIS ® plate mill work roll from 10mm to 90mm below as cast surface (Ø1150x3500mm)

1.3 Changing to New Roll Systems

Experience has shown that improvements of existing roll grades can help to increase the roll performance, but only within certain limits.

To double or even triple the roll performance, a complete change of roll type is necessary.

This is the case when high chrome iron and steel rolls are being replaced by high speed steel work rolls of the last generation.
This tremendous improvement is based on several facts:

- The carbide hardness of high speed steel rolls is much superior to high chrome iron and steel;
- HSS rolls show a reduced amount of eutectic carbides, which increases the resistance against thermal fatigue and micro-cracking;
- Higher compression stress in the surface of HSS rolls delays the beginning of fire crack formation and wear;
- The uniform microstructure of HSS provides smoother roll surfaces, which allows to run double, triple or even more campaigns without grinding.

Figure 4 shows the comparison of typical high chrome shell materials and state of the art high speed steel materials used for roughing and finishing rolls.

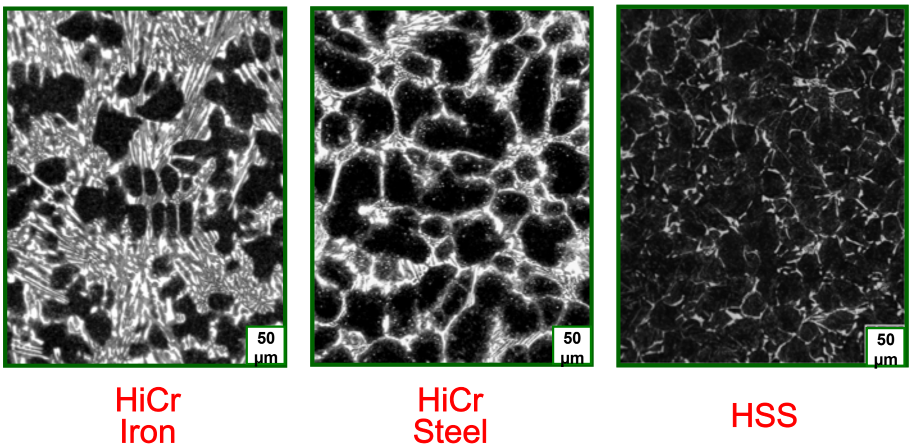


Figure 4: microstructure of chrome iron, chrome steel and HSS material

2 OPERATIONAL SAFETY

The demand for higher wear resistance of work rolls goes hand in hand with

- an increase in carbide content in the roll shell
- an increase in total alloying content of the shell
- an increase in roll hardness and – in many cases – residual stress
- a decrease in graphite content in case of indefinite chill rolls

This makes the rolls more sensitive against cracking. In many cases, this results in good performance of the rolls under normal rolling conditions, but lost roll stock as soon as wrecks in the mill occur.
What can the roll manufacturer do to improve this situation?
In general, there are some basic requirements for the operational safety of a double poured work roll:

- The bonding zone has to show high strength microstructure
- The residual stress in the work roll has to be moderate
- In case of HiCr and HSS: The heat treatment has to soften the martensite of the shell to provide good crack resistance
- In case of carbide enhanced Indefinite chill: a minimum graphite content in the shell has to be maintained to avoid high crack sensitivity

This leads to the following measures that have to be taken during roll production:

2.1 Bond Zone

Every roll has to undergo a 100% ultrasonic testing procedure of the bond zone between shell and core. Equipments are available on the market, although it needs a lot of experience to distinguish between signals triggered by small changes in the microstructure of the bond zone (which would do no harm) and signals that indicate porosities or inclusions that really might harm the integrity of the bond and the safety of the roll. In many cases, critical signals have to be confirmed by manual – testing.
Figure 5 shows the result of an automatic bond test of a double poured work roll. The dark spots indicate zones of strong signals which require manual testing.

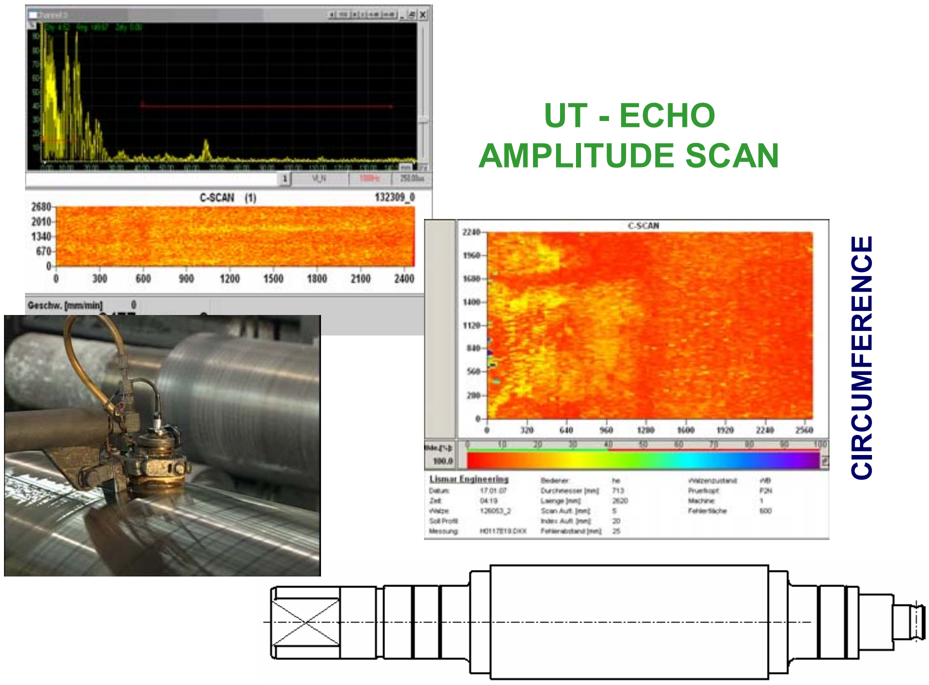


Figure 5: automatic UT bonding test

2.2 Residual Stress

It is necessary to measure residual stresses in the work rolls on a regular basis. There are different testing methods available. Figure 6 shows the equipment used for the ring core method. The result of the measurement can be seen in Figure 7, which shows the changes of residual stress from the surface of the roll down to a depth of 4,5 mm. From this measurement, you can calculate a medium stress level in the shell of the roll.
With this compression stress level in the shell, you can calculate the tensile stress level in the core of the roll. For the safety of the roll, it is very important not to exceed a certain limit of tensile stress in the core to avoid barrel breakages when the roll is in service.[1]

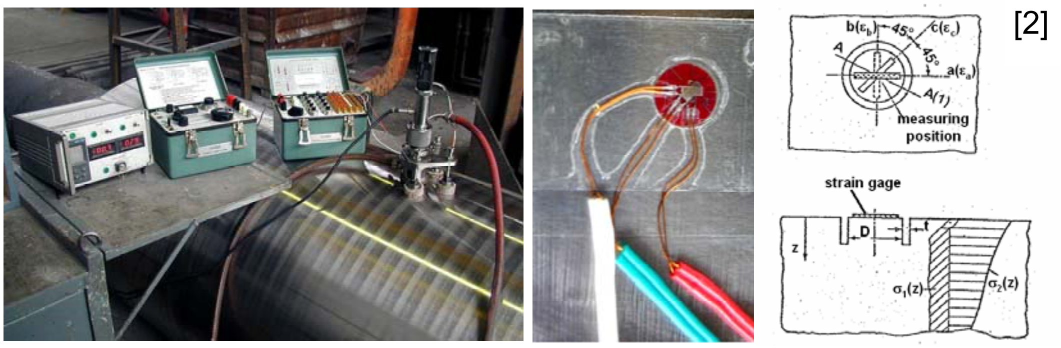
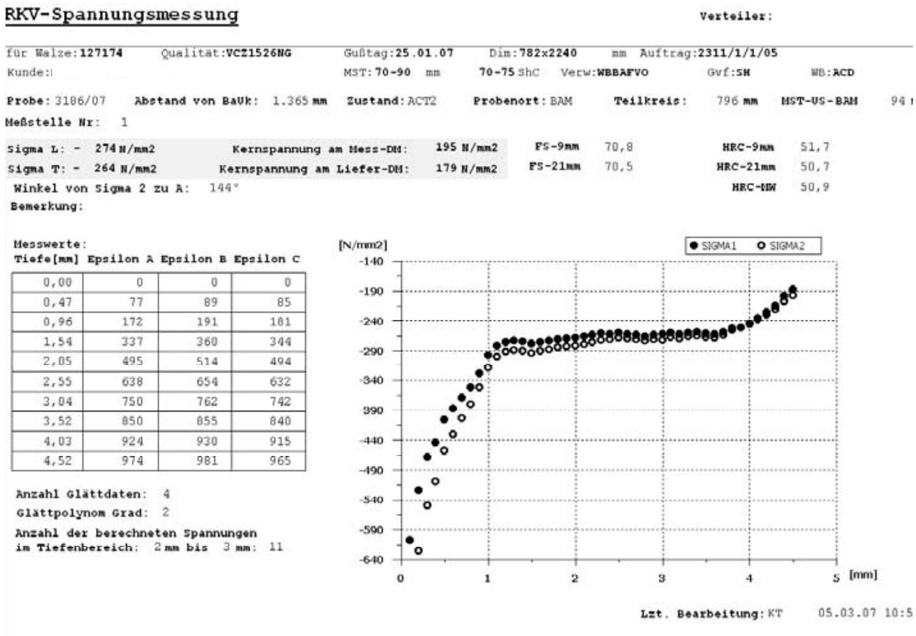


Figure 6: ring core methode for residual stress measurement



RKV-Spannungsmessung　　　Verteiler:

für Walze: 127174　Qualität: VCZ1526NG　Gußtag: 25.01.07　Dim: 782x2240 mm　Auftrag: 2311/1/1/05
Kunde:　MST: 70-90 mm　70-75 ShC　Verw: WBBAFVO　Gvf: SH　WB: ACD

Probe: 3186/07　Abstand von BaUk: 1.365 mm　Zustand: ACT2　Probenort: BAM　Teilkreis: 796 mm　MST-US-BAM　94
Meßstelle Nr: 1

Sigma L: - 274 N/mm2　Kernspannung am Mess-DM: 195 N/mm2　FS-9mm 70,8　HRC-9mm 51,7
Sigma T: - 264 N/mm2　Kernspannung am Liefer-DM: 179 N/mm2　FS-21mm 70,5　HRC-21mm 50,7
Winkel von Sigma 2 zu A: 144°　HRC-MW 50,9
Bemerkung:

Messwerte:

Tiefe[mm]	Epsilon A	Epsilon B	Epsilon C
0,00	0	0	0
0,47	77	89	85
0,96	172	191	181
1,54	337	360	344
2,05	495	514	494
2,55	638	654	632
3,04	750	762	742
3,52	850	855	840
4,03	924	930	915
4,52	974	981	965

Anzahl Glättdaten: 4
Glättpolynom Grad: 2
Anzahl der berechneten Spannungen im Tiefenbereich: 2 mm bis 3 mm: 11

Lzt. Bearbeitung: KT　05.03.07 10:5

Figure 7: result of residual stress measurement by ring core method

2.3 Heat Treatment

High chrome and HSS work rolls need a complicated heat treatment to obtain the right hardness and residual stress for their proper use. It is not enough only to measure the hardness at the end of roll machining. The hardness and the degree of shell transformation from austenite to martensite has to be checked and monitored during the whole process of heat treatment. This requires a lot of samples which are taken from the barrel edge of the rolls during several stages of heat treatment. Figure 8 shows a spall sample and a complete file of our heat treatment record for a high chrome roll.

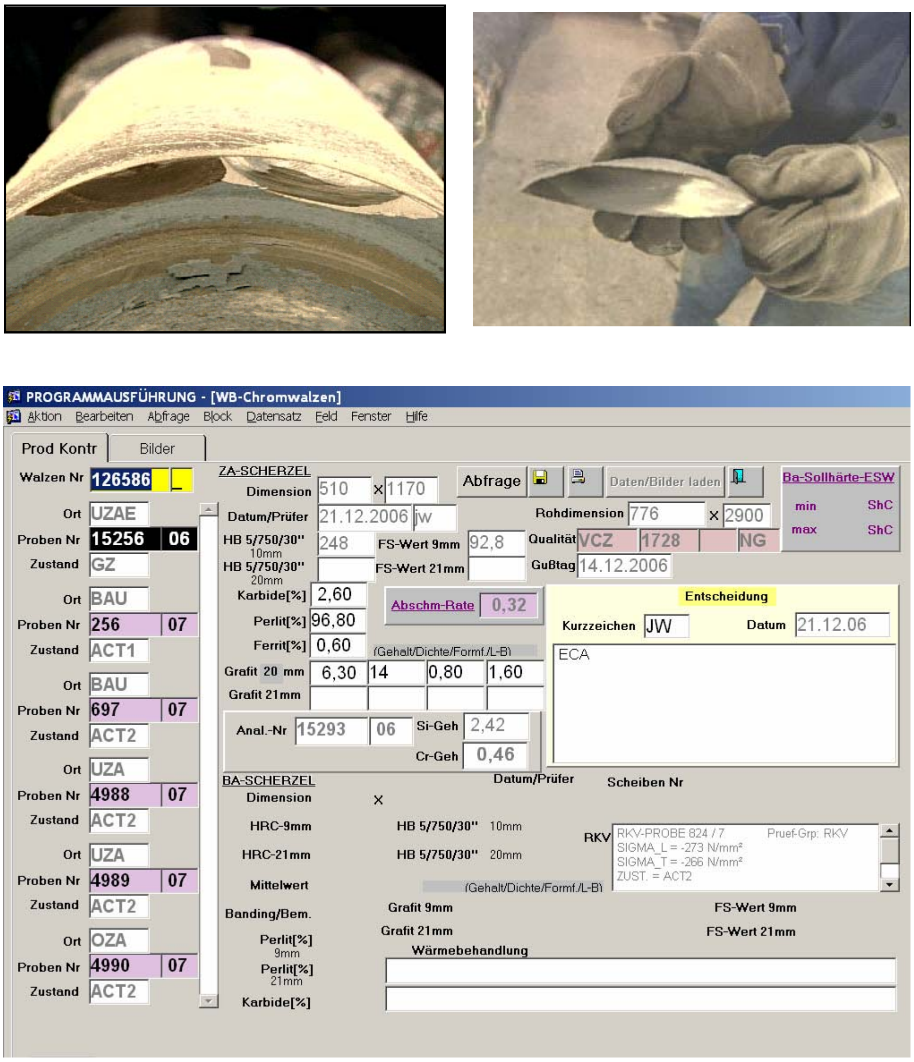


Figure 8: sampling of roll and heat treatment records for quality control

3 UNIFORMITY OF ROLL PRODUCTION

Modern techniques of roll testing and data base management allows monitoring of production data and roll properties and tie them together by statistical process control.
The smallest possible range of critical roll properties is essential for providing rolls with reliable safety and performance expectations.
That is why, from our experience, the combining of:

- extensive testing during production
- transferring of all test data into a data base
- constant use of state of the art statistical process control and
- use of SPC data for refining the production process

are key issues for state of the art roll making.
Figure 9 shows a compilation of production data available for SPC investigations. As an example, Figure 10 shows the development of graphite contents in all rolls of a certain indefinite chill type between 2005 and now. By closely following the development of certain key figures (like graphite content, hardness, stress level, casting temperatures, shell thickness …) any deviation in the production process will be found immediately and counter-measures can be taken within a very short period

of time. This allows to maintain a high and consistent quality standard of the total roll production.

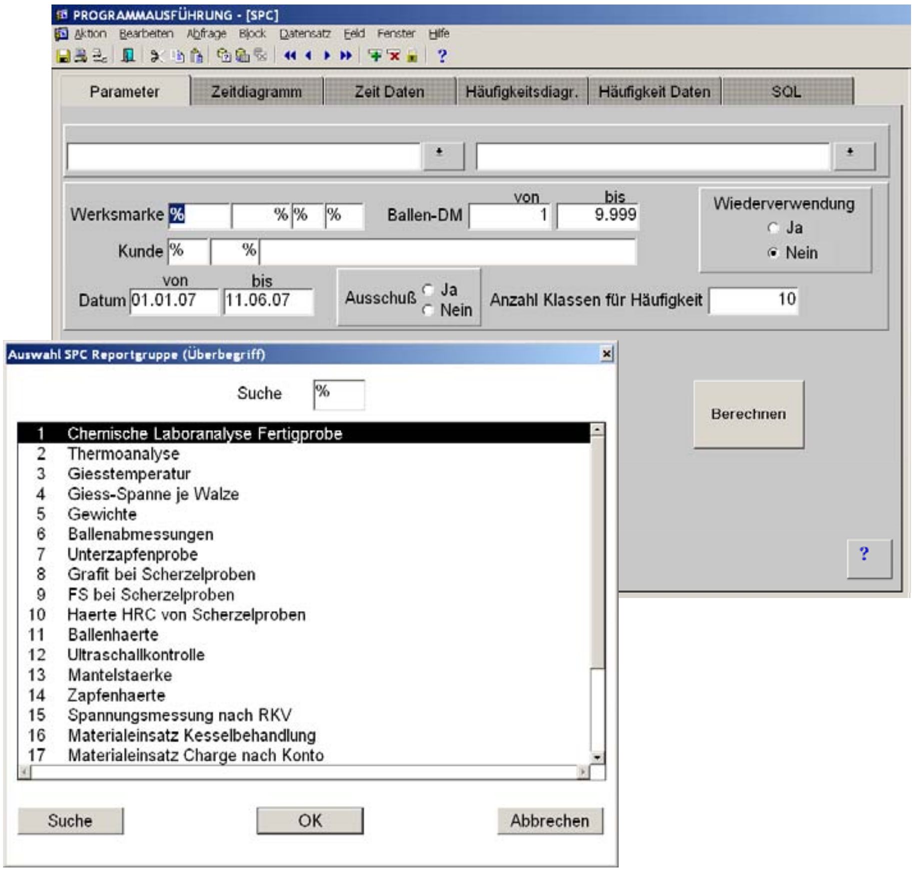


Figure 9: SPC data recording of essential roll production parameters

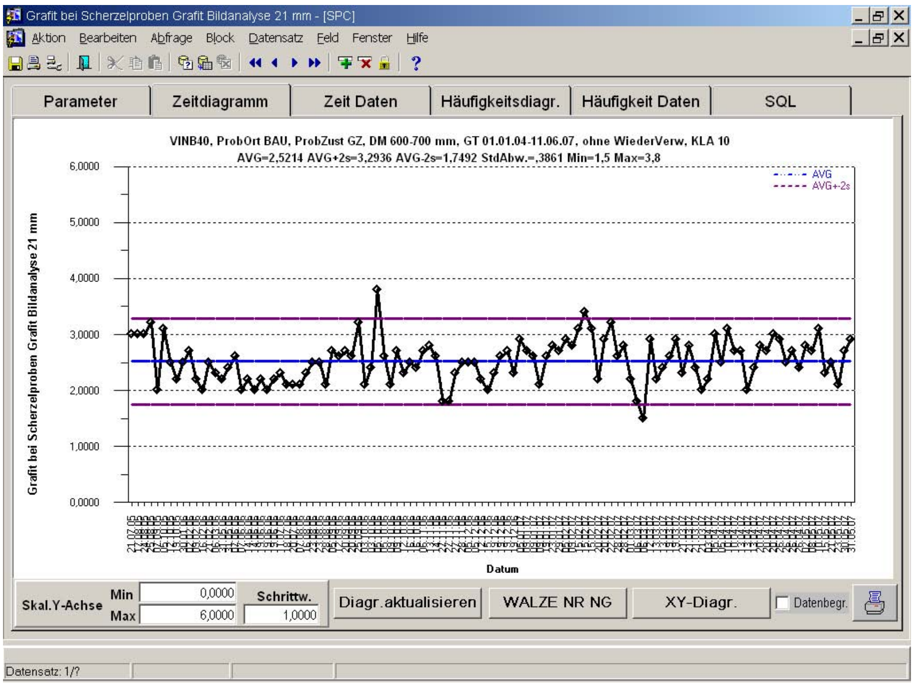


Figure 10: SPC of graphite content in a certain indefinite type between 2005 and now

4 CONCLUSION

The production of high performance work rolls not only implies the use of state of the art materials like HSS and carbide enhanced ICDP.
The uniformity of products and the high safety standard required by today's market can only be met by stringent use of modern testing technology, data recording and SPC techniques.

REFERENCES

1 K. H. Ziehenberger, M. Windhager: **"Recent Developments in HSM Rougher Rolls – Risks and Chances"**, Iron & Steel Technology, Sept. 2006, pp. 38-41, AIST - Association for Iron & Steel Technology; PA, USA
2 H. Wolf, H. Borgmann, E. Stücker: **„Weiterentwicklung des Ring-Kern-Verfahrens zur Messung von Eigenspannungen"**, Arch. ‚Eisenhüttenwesen 44 (1973) Nr. 5, S. 369-373