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New graphitized HSS materials for rolls in finishing stands

Grafitisierter HSS-Stahl für Walzen in Fertiggerüsten

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Rolls in late finishing stands of hot strip mills often experience the shortest operation times of the whole production line because of excessive wear. At Karl Buch a new graphitized HSS roll material, Teranit F, was developed. Test rolls with this material were run at a German narrow strip mill show a significantly improved wear behaviour as well as superior product quality compared to conventional ICDP rolls (performance improvement by a factor of 2.3). Teranit F has the potential to allow a synchronization of the roll changes of the late finishing stands with earlier stands and to significantly reduce the total cost of ownership TCO of a mill.

Walzen in den Fertiggerüsten einer Warmbreitbandstraße haben aufgrund ihres ungünstigen Verschleißverhaltens oft die kürzesten Einliegezeiten. Bei Karl Buch wurde nun ein neues grafitisiertes HSS-Walzenmaterial, Teranit F, entwickelt. Tests mit diesen Walzen an einer deutschen Mittelbandstraße zeigen eine deutlich erhöhte Leistung (Faktor 2,3 im Vergleich zu ICDP), verbunden mit deutlich verbesserter Oberflächenbeschaffenheit des Produkts. Teranit F hat das Potenzial, eine bessere Synchronisation der Walzenwechsel von hinteren mit vorderen Gerüsten zu erzielen und erheblich Kosten einzusparen.

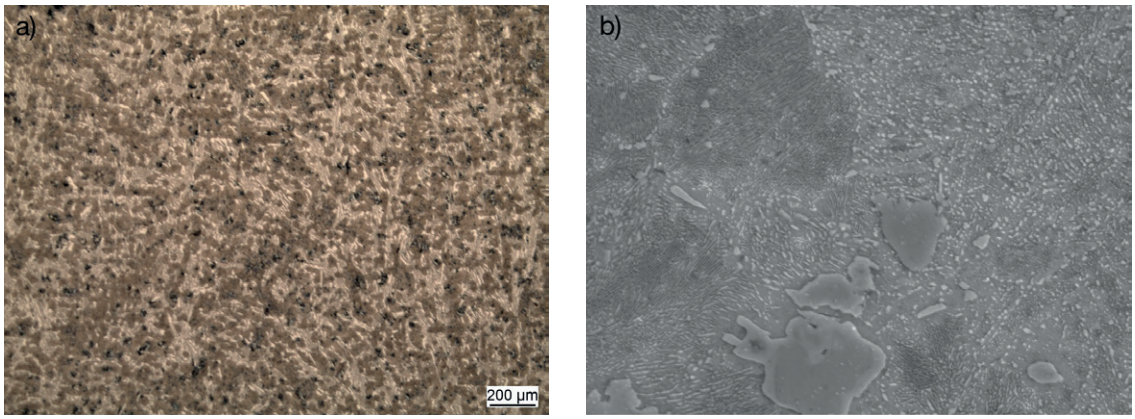
In finishing stands of hot strip mills Indefinite-Chill Double Pour rolls (ICDP) are commonly used. One strategy to improve the wear of ICDP would be to introduce carbides of the composition MC into the microstructure similar to HSS. Alternatively, simple graphitization of HSS can be done which means introduction of graphite into the martensitic matrix along with carbides MC. We at Karl Buch deliberately chose the latter strategy.

The first strategy discussed, i. e. improvement of ICDP rolls by microalloying was pursued intensely over the last decade; introduction of alloying elements such a vanadium, tungsten or niobium for formation of MC carbides was done and this led to qualitative wear improvement of the enhanced ICDP rolls, however, in the order of not more than 10 — 20 %. A typical performance of enhanced ICDP rolls in late finishing stands of a hot strip mill is about 4000 t/mm [1; 2].

Nowadays, requirements for longer campaigns force hot strip mills to search for more powerful roll materials. The goal is doubling the campaign length in finishing stands in order to synchronize the wear of rolls in late finishing stands with the ones in early finishing and roughing stands. Currently, too many roll changes in F5 — F7 are a hindrance to productivity improvement of the mill. This situation

Photo: Uwe Niggemeier, stahlseite.de

1 Roll process at finishing stand | *Walzprozess im Fertiggerüst*



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Microstructure of Teranit F: a) optical micrograph, overview: martensitic matrix with carbides and graphite; b) matrix structure with secondary carbides (SEM micrograph) (Source: Duisburg University)

Mikrostruktur von Teranit F: a) lichtmikroskopische Aufnahme, Überblick: martensitisches Grundgefüge, Karbide und Grafit; b) Grundgefüge mit Sekundärkarbiden (Rasterelektronenmikroskop, REM) (Quelle: Universität Duisburg)

Property	Symbol	Magnitude	Unit
Tensile strength	R_m	900	MPa
Heat conductivity	λ	15.7	$W \cdot m^{-1} \cdot K^{-1}$
Thermal diffusivity	a	8	$m \cdot m^2 \cdot s^{-1}$
Heat capacity	C_p	470	$J \cdot kg^{-1} \cdot K^{-1}$
Thermal expansion	α	7.5	$10^{-6} \cdot m^{-1} \cdot K^{-1}$
Fracture toughness	K_{IC}	23	$MPa \cdot m^{-1/2}$
Friction coefficient (Teranit F / stainless steel)	μ	0.25 – 0.3	

3

Thermo-mechanical data of Teranit F | *Thermomechanische Daten von Teranit F*

4

Finishing stands of medium strip mill of Buderus Edelstahl

Fertiggerüste der Mittelbandstraße von Buderus Edelstahl

makes the last finishing stands a bottleneck for the whole mill performance, since the rolling process has to be interrupted only for changing rolls in the last stands, figure 1.

Graphitized HSS

Graphitization is an important factor for superior surface properties of the rolled product. A further important function of graphite is its ability to prevent sticking between roll surface and rolled product. The free graphite normally acts as a lubricant in the roll gap reducing the friction coefficient.

One of the strategies Karl Buch has followed for many years is graphitization of shell materials. Graphitized cast steel is known for superior performance [3]. Graphitized high chromium iron (Hi-CrI) has been applied in finishing stands of hot strip mills already for a couple of years [4].

Tests were run in a Steckel mill with respectable performance [4]. The rolled tonnage per mm was better than with ICDP, however, the costs of additional alloys were too high at that time to allow a significant financial benefit for the mills.

A further development led to today's graphitized HSS called Teranit F as material of choice. Teranit F was developed with the help of thermodynamic calculations (Thermo-Calc-Software) which allowed to assess composition and ratio of eutectic carbides within the matrix. Distribution and size of carbides was optimized by differential thermal analysis DTA of samples. Data from DTA was used to verify the necessary heat treatment of the graphitized HSS material. The new material was given the name Teranit F.

Properties of Teranit F

In 2012, first test rolls with Teranit F as shell and nodular cast iron as core were cast. Teranit F is subjected

to a special heat treatment to yield a microstructure typical for a HSS with preferentially a martensitic matrix, finely divided into primary and secondary carbides and free graphite. The samples do not display a ledeburitic structure similar to Indefinite Chill rolls. Graphite particles have non-regular shape and a size of about 10 — 20 µm. The overall graphite content is in the order of ca. 2 — 3 %, figure 2.

The tensile strength of Teranit F amounts to about 900 MPa and its hardness can be adjusted as high as 820 LD. Heat and thermal diffusivity were measured as well as fracture toughness and heat capacity. This data allows a precise prediction of the thermomechanical behaviour of the roll material in the rolling process. Particularly in the last finishing stands of a mill, crucial roll properties such as thermal crown can be calculated from the given data, figure 3.

Field test with Teranit F rolls

Teranit F rolls were tested in the last finishing stands of the narrow strip mill of Buderus Edelstahl GmbH in Wetzlar, figure 4, as well as in other mills [5]. The rolls for Buderus Edelstahl GmbH were manufactured with a negative mechanical crown of 0.015 mm and a surface roughness of R_a = 3.2 µm. A wide variety of products reaching from normal carbon steels up to stainless steel with a final thickness from 7.5 to 2.3 mm were rolled.

Comparison of Teranit F with enhanced Indefinite Chill under similar campaign conditions and programs showed a significant better surface state of the Teranit F rolls, figure 5. No surface damages or fire cracks occurred on the Teranit F rolls, even under tough rolling conditions. The rolls proved their robustness. Furthermore, no incident of sticking was reported.

Between campaigns, grinding was done typically in the range of about 0.2 mm (in diameter), figure 6. For ICDP rolls, much more grinding of the order of >0.3 mm per campaign was necessary.

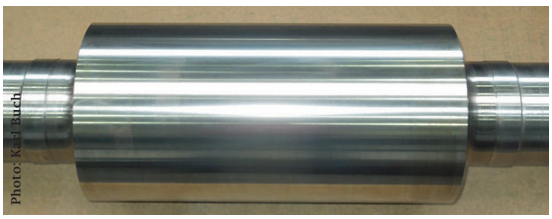
The wear profiles of both top and bottom work roll were even and smooth. The wear tests during very mixed programs resulted in a wear resistance which showed an improvement by a factor of 2.3 with Teranit F compared to ICDP, figure 7 [5 … 7].

With the low grinding rates, Teranit F rolls allow a significant extension of the campaign lengths, figure 8.

Concomitantly, grinding time is reduced which allows a further cost reduction in the sense of total cost of ownership TCO. This applies in particular to the most surface-critical stands in a rolling mill, namely the very last finishing stands.

Conclusions

The application of graphitized HSS Teranit F for rolls in finishing stands leads to an improvement of surface quality of the rolled products as well as to better favoured roll properties. Average wear of these new



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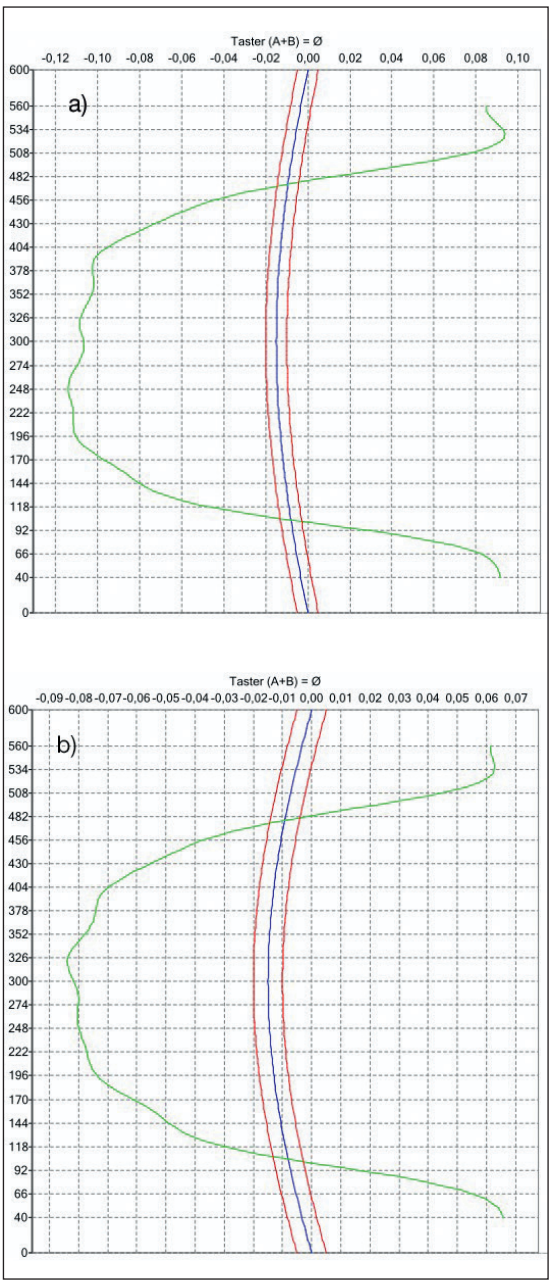
Roll surface Teranit F roll after a typical campaign of rolling ca 32 000 t of mixed material

Oberfläche einer Teranit-F-Walze nach einer typischen Kampagne von ca. 32 000 t gemischter Walzprodukte



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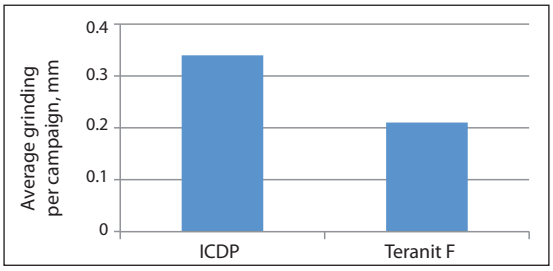
Wear profile Teranit F rolls: a) top roll, b) bottom roll

Verschleißprofil Teranit-F-Walzen: a) Oberwalze, b) Unterwalze



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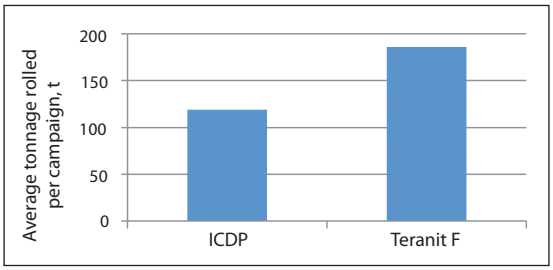
Average grinding of Teranit F compared to ICDP

Durchschnittlicher Abschliff von Teranit F, verglichen mit ICDP



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Average tonnage rolled per campaign with application of graphitized HSS rolls in the finishing stand of a hot strip mill

Durchschnittliche Walztonnage pro Kampagne von Teranit F, verglichen mit ICDP im Fertiggerüst

rolls is roughly only half the wear of conventional enhanced ICDP rolls. The new rolls also proved their robustness and shock resistance in field tests.

Graphitized HSS Teranit F can be considered a new material for finishing stands with most promising properties. It may replace ICDP-type rolls in the near future because of significantly better performance (factor 2.3).

Top requirements on the surface quality of the rolled product in earlier or even roughing stands may demand application of Teranit F. The new graphitized HSS material has a low wear combined with a high resistance against fire cracks, very good anti-sticking properties and excellent surface properties of the product. These characteristics could be proven in further field tests in industry.

Rolls with graphitized HSS Teranit F as shell material allow an improvement in product quality, a significant increase in productivity of the mill as well as a substantial reduction of costs (TCO).

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[3] Zybill, C.; Goryany, V.; Schubrikoff, E.; Almeida, R.; Fenners, K.: Kalibreur (2014) No. 75, pp. 71/78.
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