**ESW - „The Specialist of Work Rolls for Hot Rolling of Flat Products”.**

Here:

**Work Rolls for Plate Mills and for Roughing Stands of Hot Strip Mills/Steckel Mills**

Dr.-Ing. Karl Heinrich Schröder  
ESW, Eisenwerk Sulzau-Werfen  
A-5451 Tenneck, Austria  
Phone: +43 6468 5285 100  
E-mail: ks@esw.co.at

**Key Words:** work rolls, plate mills, roughing stands of HSM, rolling conditions

1. **Introduction:**

   To understand why which roll grade in which application is needed, we have to study

   - rolling conditions and
   - the various roll grades and their properties

Plate, sheet, strip is hot rolled from (blooms and) slabs, usually 200 to 300 mm thick to a finished thickness of (<) 2 to (>) 6 mm. The total number of passes varies widely from (11) 13 in Hot Strip Mills (HSM), 8 - 13 stands, and Steckelmills (two stands) to 27 (or even more) in some (2-high) Plate Mills (PM), depending on the design and capability of those mills.

Some HSM's have a coilbox between roughing and finishing mill, Steckelmills roll always with only one finishing stand out of the Steckelfurnace into the other, PM do not use any devices to re-heat the plate after the slab has left the re-heating furnace, in contrary, temperature controlled rolling at (relative - < 800 °C) low temperatures are very common to reach high strength in the plate directly from hot rolling (X 60, 70, 80, ... pipe steel).

Because mills and products vary so widely, it is necessary to use special parameters to compare the rolling conditions pass by pass. In HSM's these parameters change stand by stand and different rollgrades must be used. Comparing the parameters of Plate Mills with these of HSM we can draw analog conclusions.
2. Normal rolling conditions

The rolling conditions of every pass of some rolling schedules of some HSM's were studied in detail [1].

The bite angle versus rolling speed, Fig. 1 [1], is limited by a curve experimentally found and used by SMS [2] and added to Fig. 1, which separates the safe - slippage and shatter free - from the unsafe area. The max. bite angle is strictly related to rolling speed - not (really) to the rollgrade. This curve for the max. bite angle versus speed is valid for PM and roughing mills as well; it is a jaw of nature and not to eliminate by ,,better" rollgrades. There might be a very slight influence of roll grades (lower carbon content of W.R. may help to reduce - but only very little)slippage problems, and this probably due to wider firecracks, which appear already after the first contact with the slab/plate). Slippage, shatter happens frequently when the numbers of passes in reversing mills are reduced, the reduction per pass is increased necessarily and nobody concerns rolling speed, so finally the curve max. bite angle - versus speed is crossed!

As far as we could check rolling schedules of PM's, shatter seems to be of no problem.

![Diagram](image)

**Fig. 1:** Bite angle vs. rolling speed relationship - important for the initial bite of slab or strip
The specific pressure \( (p) \) in the rolling gap is calculated [1] by dividing the separating force \( (P) \) by strip/plate width \( (b) \) and the contact length \( (L) \) between strip/plate and the work roll.

\[
p = \frac{P}{b \cdot L} ; \quad L = \frac{\alpha \cdot \pi \cdot D}{360}
\]

\( \alpha = \text{bite angle} \)
\( D = \text{work roll diameter} \)

In Roughing mills \( p \) is usually less than 150 N/mm\(^2\), fig. 2, in finishing mills \( p \) increases to 500 - 700 N/mm\(^2\) in F7.

Sticking, "slippage - pressure - welding" of strip material to roll surface is known widely for standard steel grades and on non-ICDP rollgrades (e.g. high chrome, Adamite,...) only for stand F7, 6, 5 (4) and has to be related to the specific pressure \( p \) (even rolling temperature and steel grades may have their input as it is known from stainless - "ferrit" - which tends to stick in the early stands of HSM to Non-ICDP - Rolls as well). To avoid sticking problems it is state of the art to use ICDP - Rolls: No explanation - but good help, so far.

In roughing stands and in early stands of finishing mills of HSM \( (p \leq 300 \text{ N/mm}^2) \) sticking is not experienced with standard C-steels, independent of the roll grade in use (ICDP, Adamite, High Chrome Iron, High Chrome Steel, Semi Tool Steel, HSS)

Analysing rolling conditions of PM's it becomes evident that the specific pressure \( p \) stays below 300 N/mm\(^2\) (most frequently below 200 N/mm\(^2\)). Therefore: no risk of sticking, no need to use ICDP in PM's for this reason!!

Fig. 2: Specific load in roughing mills and early finishing stands of HSM
3. Abnormal rolling conditions and roll failures caused by these

Mill stops with slab/plate in the gap happen frequently in many mills. Rolls do not like this situation! However roll damage does not happen due to the local heat-up of roll surface - but only due to quenching of this area. The best way to minimize roll damage due to mill stops is to react with the right strategy!

It is evident:

- the thicker the rolled material in the roll gap - the more heat goes into the roll
- the longer the local contact remains, the more heat goes into the roll
- when cold cooling water quenches heated up areas, it creates heat cracks.

To avoid heat cracks, severe fire cracking in case of a mill stop, it is necessary.

- to stop cooling water from running immediately
- to open the roll gap next
- to move the slab/plate out of the gap
- to wait long „enough“ (without cooling water!!) that locally heated area cools down totally to normal roll surface temperature
- to start cooling water before continuing rolling

Firecracks are of high risk for spallings, however there are some differences between the rollgrades. High Chrome Steel is very forgiving, High Chrome Iron is forgiving, ICDP does not stand any cracks of any kind at all (All cracks have to be eliminated, ground off totally from ICDP rolls after each run/campaign!!).

Barrel end spalling of back-up - and/or work rolls is more or less typically for some (roughning- / plate-) mills and is created by high pressure between work roll and back-up roll. Besides the mill design (sometimes different barrel lengths of backup and work roll) it is influenced by the crown of work roll and back up roll, the roll chamfer, wear of rolls (depending on the length of rolling campaign) and by roll bending.

The worst of all: Mill people try to compensate roll wear by roll bending - this, after a while, costs often a fortune. Rolls of high wear resistance, a good roll design (crown, back-up roll, chamfer, etc.) and frequent roll redressing reduce the risk of barrel end spalling.

Thermal breakage of work rolls of PM’s should not happen. However, all modern work rolls for hot flat rolling are double poured, consequently made with compressive residual stresses in the surface, which are compensated by tensile residual stresses in the roll centre. A thermal gradient from the hot surface to the cold roll center induces more stress of the same kind. In case that residual plus thermal stress exceeds the strength of the core material the roll breaks into parts - „thermal breakage“ - a spontaneous brittle fracture, and everything (residual-, thermal stress and strength) gets worse, the bigger the roll is! In old days (some 50 years ago) all plate mill work rolls were pre-heated whenever they were put into service. However, today no more plate mill work rolls are pre-heated - as long as they are not „to cold“, and it works. In old days the strength of grey iron core material was about 120 N/mm², today grey iron is better than 220 N/mm² and
many mills use ductile iron, because of work roll bending, high torque or other reasons and the strength is 400 N/mm². Further improvements will increase the strength to 500 - 700 N/mm², however, in case the W.R. is taken directly in service from subzero temperatures thermal gradient still might be to high and thermal breakage may occur.

4. Roll properties

Wear is very important for rolls, however wear is subject of many scientific papers and here we will only present some basic information:

- Fig. 3 shows the influence of carbon content and hardness on wear of steel;
- Fig. 4 presents the impact of carbide forming elements on wear,
- Fig. 5 gives some characteristics of various roll grades. Hardness is of no importance, wear resistance is improved by very high hardness carbides - this was the development of new roll grades since some years and it will continue for the next/near future time. (HSS, VIS, ....)

![Diagram of Krushov [3] - influence of carbon content and hardness on wear of steel](image.png)

Fig. 3: Diagram of Krushov [3] - influence of carbon content and hardness on wear of steel
Fig. 4: Wear vs. alloy equivalent (Range of alloys: 0.30 - 0.44%C; 0.02 - 0.38%Si; 0.31 - 0.83%Mn; 1.18 - 3.03%Cr; 0.08 - 3.04%Mo; 0.26 - 1.92%V; 1.42 - 5.85%W) - from [4]

Fig. 5: Range of barrel hardness and content of carbides different roll grades
Important for rolls is the sensibility of roll materials for crack initiation and crack propagation. These properties are basically influenced by residual stresses and the microstructure, carbides and matrix structure as well. In general the crack behaviour of various materials vary widely as already pointed out in chapter 3. The same as for firecracks (or even more important) is valid for cracks caused by local mechanical overload, cobbles, what is spoiling some plate mill work rolls when rolling temperature controlled pipe steel or other high strength material (spec. light gauge), where tail ends tend to whip, to double or causing local overloads in other ways. ICDP is crack sensitive - High Chrome Steel is not.

In plate mills without high tech devices for shape control - what is still state of the art almost everywhere - the thermal crown of W.R.'s is of high impact on strip shape. Normally rolling short plates W.R. are always cooled enough during rolling and between the passes and between plates so that thermal crown is small and constant. However rolling long plates of light gauge the crown changes from head to tail of the plate creating undesirable waves. In this case ICDP is favourable compared to High Chrome material because thermal crown of ICDP rolls is only half of that of High Chrome.

Today most (almost all) W.R. for plate mills or roughers are spun cast, most with nodular iron core material. Today ESW spins rolls up to Ø1250mm, in future maybe more, however the maximum finished weight will remain less than 30 tons.

5. The experience up to today with different work roll grades for hot rolling of flat products:

5.1. W.R. in roughing stands (incl. Steckelmills)

- "Nodular Iron" - still today in two high mills and "lowprice" in four high when too many rolls fail due to rolling accidents.
- "Adamite" - almost out of fashion, low price – low performance
- "High Chrome Iron" - good in some two high stands
- "High Chrome Steel" - state of the art
- "Semi - Tool Steel" - successful in some applications – but not good for stainless
- "HSS" - ???

5.2. W.R. in early finishing stands of HSM (F1 - 3(4))

- High Chrome Iron - state of the art
- High Chrome Steel - better than High Chrome Iron in some F1 stands (better forgiving)
- ICDP - only for stainless steels (ferritic) steels
- VIS - better than ICDP, hopefully comparable to High Chrome Iron
- HSS - successful in Japan, on trial elsewhere
5.3. W.R. in the last finishing stands of HSM (F7 (6,5)) in Steckelmills

- ICDP: the only grade in F7 outside Japan
- VIS: better performing than ICDP

5.4 W.R. in Platemills

6. Summary

- ICDP: the old fashion grade, with some advantages - might be replaced by VIS in the near future
- High Chrome Iron: state of the art (spec. for high strength pipe steel)
- High Chrome Steel: state of the art, very forgiving

- W.R. for plate mill and/or HSM are designed to give good performance under normal rolling conditions and to forgive many abuses due to mill accidents.
- W.R. are spun cast, double poured under exceptional process control, reliable and reproducible every time.
- ESW helps to select the optimum grade to get best performance
- ESW will continue to develop better grades for the future: high hard carbide enhanced materials and special HSM grades as well.

E – xcellent
S – ervise
W – orldwide

7. References

[2]: Information from SMS
[4]: Werkstoffkunde Stahl Hrsg. Verein Deutscher Eisenhüttenleute Berlin; Heidelberg; New York; Tokyo; Springer; Düsseldorf: Verlag Stahleisen
BITE ANGLE vs. ROLLING SPEED RELATIONSHIP

SEPARATING FORCE and SPECIFIC LOAD in ROUGHING MILLS and EARLY FINISHING STANDS of HSM
INFLUENCE of CARBON CONTENT and HARDNESS on WEAR of STEEL


WEAR vs. ALLOY EQUIVALENT

Range of alloys:
0,30 - 0,44%C
0,02 - 0,38%Si
0,31 - 0,83%Mn
1,18 - 3,03%Cr
0,08 - 3,04%Mo
0,26 - 1,92%V
1,42 - 5,85%W

Workstoffkunde Stahl Hrsg. Verein Deutscher Eisenhüttenleute Berlin; Heidelberg; New York; Tokyo; Springer; Düsseldorf: Verlag Stahleisen

ESW
RANGE of BARREL HARDNESS and CONTENT of CARBIDES DIFFERENT ROLLGRADES

ESW

EISENWERK SULZAU-WERFEN
R. & E. Weinberger Aktiengesellschaft