THE IMPACT OF THE ROLLING CONDITIONS ON THE ROLL SURFACE – WEAR, FIRE CRACKS, STICKING AND FRICTION – IN SECTION MILLS[1]

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Abstract

The conditions rolling heavy sections are very complicated and create different surface conditions (uneven wear, fire cracks, sticking) in various areas of the passes. Additionally the roll pass design influences wear. Rolling loads may cause breakages of the barrel or of collars. The varieties of surface defects and the required strength of rolls cause difficulties in selecting the most wear resistant material for the rolls. Conventional methods do not overcome these problems. It is recommended that to optimize the rolling conditions the bar surface temperature is equalized and that roll lubrication, good descaling and surface skin cooling is used. The goal is to achieve better roll and mill performance with more wear resistant materials.

Key words: Section mill rolls; Rolling conditions.

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1. **Introduction.** If wear were the only requirement of rolls then everything would be easy. There is a lot of knowledge and literature available regarding wear and there are roll materials from low through medium to high wear resistance. Diagram [(1)], shows wear resistance over an AE-value [(2)], an alloying equivalent for carbide forming elements,

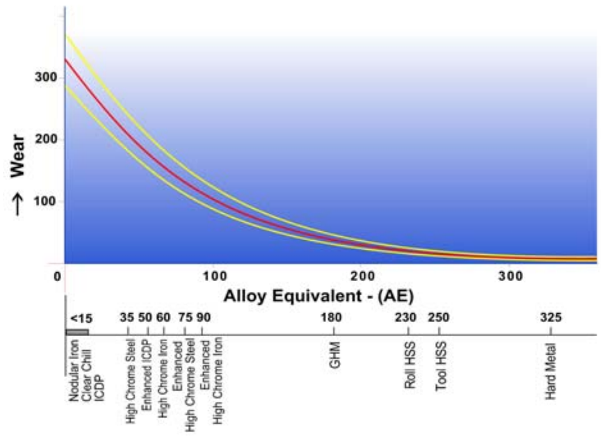

Figure 1. Wear as a function of the AE, the alloying equivalent.

(AE = 2x (%Cr) + 5x (%W) + 10x (%Mo) + 40x (%V) + *20x (%Nb) + 60x (%Ti), extended formula)*.

It is proven that the content and type of carbides determine the wear resistance of steel. Hardness of materials is often/always overestimated.

However, only in some rolling applications wear is the only property of significance. Particularly rolling long products with heavy sections, we are far away from this final stage of development and the rolling conditions are of high interest [(3)]. However, let us look at the singular situations, rolling flat products and wire/rod, where the rolling conditions are fully under control and how this was achieved.

2. In the past, **work rolls for hot rolling of flat products** were made of Low-C-Steels (until not too long ago even forged steel rolls were in service), cast steel (Adamite), alloyed indefinite chill (AIC) and variations of high-chrome-iron (Hi-Cr-I) and high-chrome-steel (Hi-Cr-St). Nowadays the trend is to high-speed-tool-steel (HSS) in almost all stands in hot strip mills. This is a *trend* and it will take some more time until it becomes reality everywhere. Changing rolling conditions and improving HSS-roll-grades will help. To achieve this result of one roll grade of maximum wear resistance in each stand it was necessary to develop better rolling conditions and to overcome many surface obstacles: fire cracks, sticking, banding/peeling, high friction etc[(1)]

   Many features were changed (literature is available) on the way to this level of *wonderful rolling conditions*:

   - Improved roll cooling
   - Antibanding/Antipeeling strip cooling (skin cooling)
   - Roll lubrication
   - Interstand cooling and descaling of the strip
   - Strip edge heating

New mill designs and layouts helped a lot to improve

- Coil box – equalizing the temperatures of both strip ends and turning upside down
- CSP mills – continuous strip production
- CVC – continuous variable crown – 6-High stands, inflatable b.u.rolls

3 The **rolling conditions in modern wire/rod mills** are even nicer than in hot strip mills. Three or four roll stands control everything perfectly rolling rounds or hexagons; the rolling speed is high and roll cooling is easy. As a result, in the finishing blocks, continuously rolling hard metal / tungsten carbide is in service (and even trials with "Ceramics" are on the way). The use of hard metal (and Ceramics) is limited by the maximum size in which these kinds of rolls (rings) can be manufactured today. In pre-finishing stands, HSS does the job and conventional roll grades (mainly SG – nodular iron) work only in the earlier stands.

4 So, what are the differences between these applications and **rolling heavy sections**? Traditionally roll pass design calculates *average* figures for reduction, rolling speed and bar temperatures, however, these figures vary widely in each pass. The rolling conditions vary from pass to pass and even in a single pass, we may experience great variations. I did not find any hint of roll makers, roll users or mill builder regarding these special rolling conditions. We have to deal with:

4.1 Breakages – critical stands should have high strength rolls.
4.2 Fire cracks
4.3 Sticking, and of course
4.4 Wear
4.5 Friction, contrary to rolling flat products, is no problem; if friction is not high enough "ragging" or other techniques will solve it.

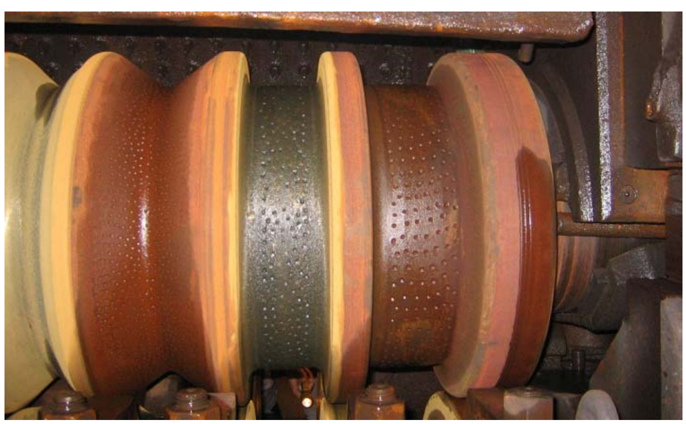

Figure 2. Ragging of a breakdown roll.

Because of these varying rolling conditions, roll grades vary widely for rolling heavy sections:

- Finishing rolls for rolling pilings are made of hypo- or (maximum) eutectoid steels(3), not a high wear resistant material.(*see picture 1*)

- Roughing and finishing rolls for rails are made of Adamite or graphitic cast steel, with up to two percent of carbon. Some mills use SG rolls for this application and are not interested in any change.
- In universal mills, we find SG, Adamite, Hi-Cr[5] and HSS (for vertical rolls in finishing stand[6]). The problem in the past was the horizontal finishing roll, because due to the side angle being vertical to the roll axle, these rolls after some wear never could be re-dressed for the same section. Hi-Cr brought some progress, however, the real solution could be the new development of rolls with adjustable width [7,8]
- [9] reports more about HSS for section mills.

5. Instead of using theories I want to discuss **typical experiences** of the results of unsatisfactory rolling conditions; some of these experiences are well known and/or described in literature.

   5.1 **breakage** problems due to normal rolling conditions

      5.1.1 Fatigue – happens only with rolls of deep grooves, long barrels and high loads: mainly limited to sheet *pilings* [3].

      5.1.2 High temperature gradients create thermal stresses, which may lead to brittle fracture of the barrel, *picture 3*

      5.1.3 Collar push off is typical of sections too big compared to the designed maximum size. There are some rules for collar dimensions, if they are neglected collar push off may happen.

Figure 3. Roll breakage due to too high temperature gradient/high residual stresses.

Figure 4. Severe fire cracks in a billet mill.

5.2 Fire cracks

5.2.1 *Picture 4* from a billet mills shows how strange it may go

5.2.2 That part of the bar cools down most, which has the greatest angle for radiation, this means “male parts (tips)” get cool, “female” parts remain hot. This is of course evident for all sections. Rolling angles normally only the bottom roll gets firecracks, what allows to choose a more wear resistant grade for the top roll. However, there is no progress because the rolls are changed due to the condition of the worst roll anyway.

5.2.3 Rolling rails only a limited zone between to head and foot shows fire cracks (the web).

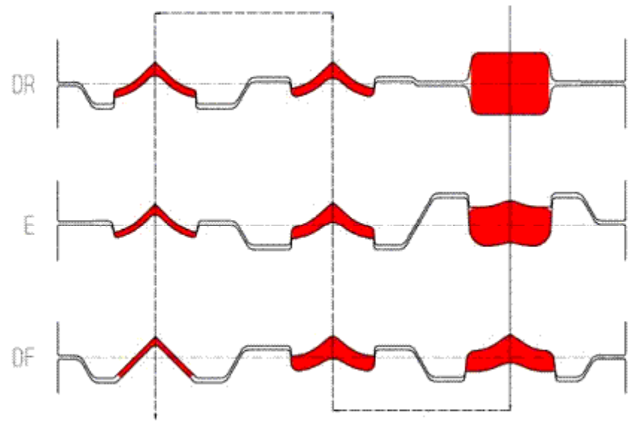

Figure 5. Typical pass design for angles[4]

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5.2.4 Rolling beams in a universal mill, we may find fire cracks only close to the web-flange transition.

5.2.5 Even rolling pilings may create fire cracks close to the lock.

Figure 6. Fire cracks rolling rails, [5]

5.3 **Sticking,** pick up of material from the rolled bar

5.3.1 In universal mills rolling bars the web may be hit, when this part is rolled too cold

5.3.2 Sticking in a billet mill, *picture 7*, is caused by extreme low rolling temperature.

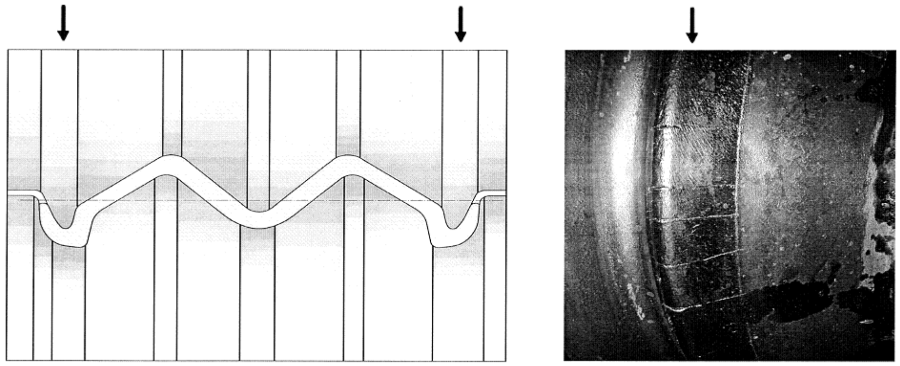

Figure 7. Fire cracks rolling sheet piling [3].

5.4 **Wear** is always the problem number one; however wear is very unevenly distributed.

5.4.1 *Picture 8* shows how wear varies at a rail roll [4]

Picture 8. Severe sticking in a billet mill

5.4.2 In universal rolling of beams (channels, rails) mainly the vertical to the axle parts of the rolls are involved

5.4.3 For piling see literature [3,13]

6. **Conventional ways to minimize these failures** (due to normal rolling conditions), and how to attack these problems.

6.1 Breakage

6.1.1 Hot rolling at high temperature reduces roll separating force and stresses in the roll. In case of sheet pilings the best solution is rolling in universal mills. Here strong mandrels and short barrels are used and high wear resistant sleeves (which hopefully do not split)

6.1.2 Good roll cooling reduces high thermal gradients in the rolls, and – if there is no cooling at all – long gap times between bars help to reduce thermal gradients. And of course, if this case is typical for a stand, the rolls should bare low residual stresses.

6.1.3 Collar push off is a problem of the roll design, it is often impossible to solve this problem with any "special" roll grade. Only a better pass design is a reliable solution.

6.2 Fire cracks

6.2.1 Better roll cooling helps to reduce fire crack problems and sometimes it eliminates them. To gamble with roll grades is an everyday occurrence; however, changing sensibility to fire cracks will have high impact on other properties – wear.

6.3 Sticking

6.3.1 Rolling at higher temperatures will reduce this problem

6.3.2 Better roll grades are available, however, always with different properties: strength, wear.

6.4 Wear

6.4.1 Roll pass design has a high impact on wear (3, 10). There are many factors, which influence wear; especially the angles in the grooves are very important.

6.4.2 For better materials of higher wear resistance, see chapter 1.

6.4.3 Literature [3,11] reports of the use of emulsion instead of cooling water in rolling pilings.

6.4.4 Rolling sections, descaling is mentioned in literature only occasionally, and when [4,12] only in front of the rougher.

It is evident that none of the available roll grades can solve all problems under the normal rolling conditions at the same time. The conventional methods to improve roll performance are helpful, however, limited.

7. What else can **I suggest**, **to improve rolling conditions?**
So far only "gambling with roll grades" and "improving roll cooling" are the conventional tools, however, back to chapter 2, I reckon there is much more to do, to change, to improve the rolling conditions and we can learn from rolling flat products, hot rolling of strip.

7.1 **Fatigue strength** of a roll is not only a question of the material strength but is also highly influenced by residual stresses in the roll. Cast steel rolls may be safer against breakage than forged ones – or vice versa; this is just the question of roll making technology.

7.2 **Breakage due to thermal stresses** is always a result of rolling conditions and residual stresses in a roll, both factors have to be under control; roll user and roll maker have to address this problem wherever it exists.

7.3 Even roll cooling may be crucial for **fire cracks**, there is more. Firecracks appear only in concentrated local areas. Where the bar is hottest and heat transition to the roll is good it will create fire cracks, see examples in chapter 5.
Simulation calculation of rolling heavy sections shows clearly how much (some hundreds of degree C! which impacts on fire cracks and wear) surface temperatures of bars may vary. [5,13]

There is the task to minimize the variation of surface temperatures of bars.

7.3.1 Either the sections are rolled relatively cold and the coldest parts are intermediately heated up (with induction heating as strip edges – or with intermediate reheating furnaces) – or at least the bars should be isolated between the passes.

7.3.2 Alternatively, the sections are rolled as usual and the hot spots are directly, locally cooled with water spray nozzles.

7.4 Rolling speed has high impact on **fire cracks;** higher speed reduces the heat transfer from bar to roll and consequently this reduces heat penetration into the roll and fire cracks [(1)]. The influence of the rolling speed is more critical than the selection of roll material.

7.5 The best way to reduce **wea**r wherever and everywhere – in any machine and in rolling mills - is to apply lubricants, spraying oil at the critical areas – not everywhere, but just where it is needed (there are many disadvantages for using emulsions)

7.6 Scale surely increases **wear** on rolls, no matter whether this is high hard high temperature scale or lower temperature scale; all scale increases wear. High pressure skin cooling (analogous to "anti-peeling-cooling" in hot strip mills) which acts as descaling of secondary scale at the same time will help to reduce wear.

If we can overcome successfully the main problems of rolling heavy sections, namely breakage, fire cracks and wear, then we have the chance to increase roll performance and to choose materials that are more wear resistant.
It should be worthwhile to introduce the methods developed in rolling flat products into the rolling mills for heavy sections.

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