ISSN 1983-4764

DYNAMIC EFFECTS AND TORQUE LIMITATION IN HEAVY PLATE MILL DRIVELINES[1]

Paulo Eduardo Chepuck Miazzo[2]
Kleber Almeida Ramos de Jesus[3]
David Bergström[4]
Daniel Myrgren[5]

Abstract

Driveline design for heavy plate mill is getting more complicated with the increased steel grades and wider mills, thus the request for increased rolling torque. Yet the dimensions stay the same as before to hold the rolling force on a manageable level. This put the driveline design to its extreme, due to reduced margin between design torque and operating torque. Torque levels in a driveline have for long been considered as even distributed over the distance of the driveline, with possibly a time difference. Natural frequencies other than the first have often been considered insignificant. We have discovered dynamic effects that vastly alter the torque levels in the driveline. The dynamics of a driveline is affected of its design, considering its stiffness, length, mass of inertia in combination with the gradient of the incoming torque peak. The motor control system is in addition working with or against the effect of the dynamic behaviour. We have simulated and case studied the dynamic behaviour of HPM drivelines to find an explanation to the behaviour, a potential design and solution to the problem of protecting a driveline from torque overloads, yet still is able to get maximum production out of the mill.

Key words: Dynamic drivelines; Rolling mills; Torque limitation; Driveline design.

[1] *Technical contribution to the 48th Rolling Seminar – Processes, Rolled and Coated Products, October, 24th-27th, 2011, Santos, SP, Brazil.*
[2] *Sales & Application Engineer - Voith Turbo Brazil.*
[3] *Sales Supervisor - Voith Turbo Brazil.*
[4] *Research & Development Manager - Voith Turbo Safeset Sweden.*
[5] *Sales & Marketing Manager - Voith Turbo Safeset Sweden.*

ISSN 1983-4764

1 INTRODUCTION

The global society is always striving for growth and increased productivity. The steel industry in general and heavy plate mill (HPM) industry in particular are no exception. The demands when designing a drivetrain for the heavy plate mill industry have increased over the years, making it more complicated. This stem from the modern trends seen in the industry:

- higher roll torque and roll force due to:
    - higher steel grade;
    - increased plate width;
    - increased reduction per roll passage;
    - increased output;
    - stronger motors.
- dimensional constrains, specially on the roll side;
- more sophisticated motor control systems.

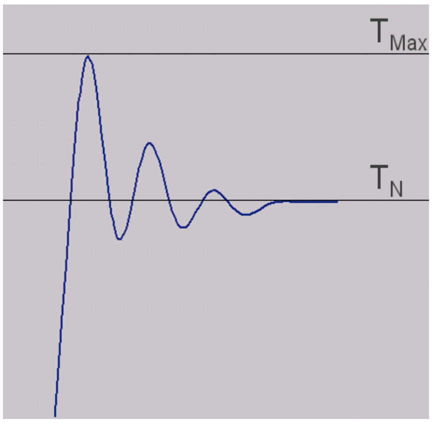
This put the drivetrain design to its extreme, due to reduced safety margin between design torque and operating torque. To keep torque in a manageable level a torque limiter is the best solution.(1)

Recent discoveries made by Voith, previously unknown to the industry, show that there are more things to think about when designing a drivetrain for a heavy plate mill.

2 BASIC KNOWLEDGE FOR DRIVETRAIN DYNAMICS

2.1 Torque Amplifying Factor

Everyone knows that torque can be amplified from drivetrain dynamics during plate entry, i. e. the Torque Amplifying Factor, TAF (Figure 1).



$$TAF = \frac{\text{Max Torque}}{\text{Nominal Torque}}$$

Figure 1. TAF illustration.

With the sophisticated motor control systems of today the TAF can be controlled, as shown on Figure 2. This is used to increase the scheduled roll torque.

ISSN 1983-4764

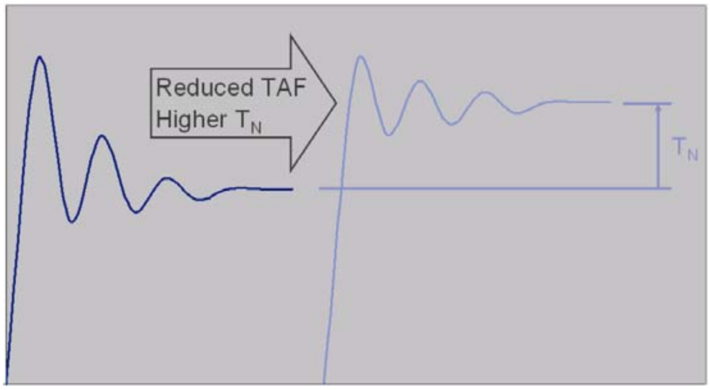


Figure 2. Higher roll torque illustration.

2.2 Torque Travel

A torque peak travels down the drivetrain with the speed of sound.
Common perception is that it acts like a wave and therefore all points see the same torque level. This is not always the case! Dynamic behavior can create torque variations between different positions in the drive line.[2]

3 INVESTIGATION OF DRIVETRAIN DYNAMICS

The dynamic behavior of heavy plate mill drives has been studied with the help of:

- computer simulations of dynamics in drive trains;
- torque measurements on site in plate mills.

4 SIMULATIONS OF DYNAMICS IN DRIVE TRAINS

4.1 Simplified Model Drivetrain

The simplest model of a rolling mill drivetrain would be two inertias for the motor and roll connected by a tube for the shaft (Figure 3). By studying this simple model the most fundamental dynamics can be examined.

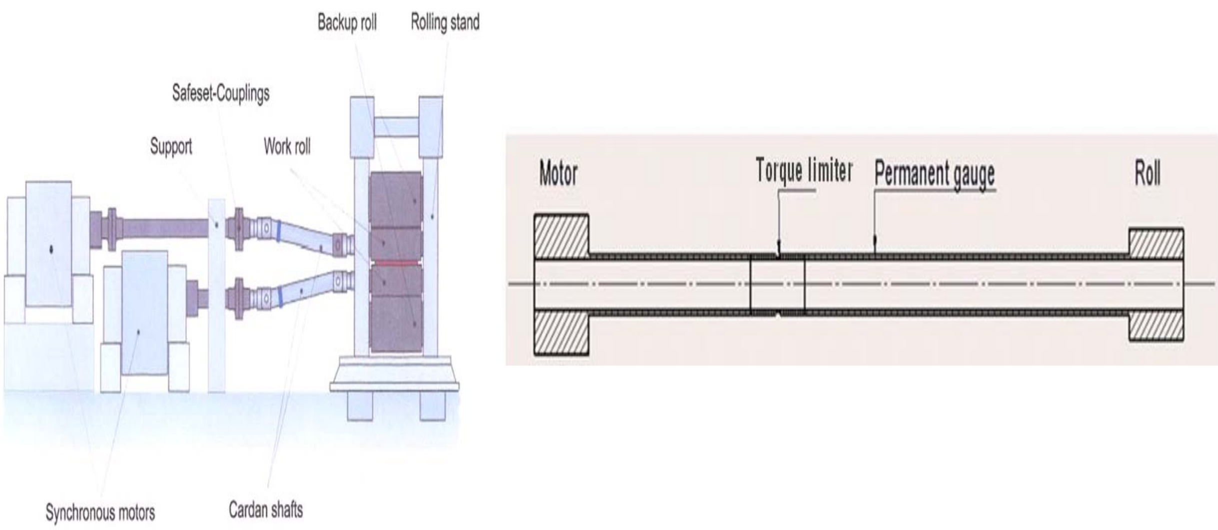


Figure 3. Rolling mill stand and the simplest model.

ISSN 1983-4764

The mechanical model is dicretized and put into a spring and inertia simulation program were the response can be calculated for any input from the motor and roll (Figure 4). The model also has a torque limiting device that can be given any ideal performance.

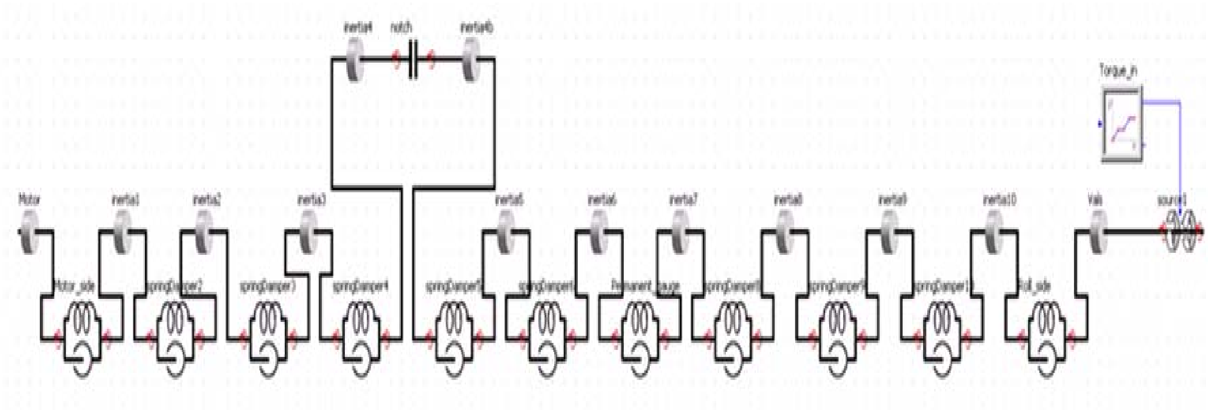


Figure 4. Discrete model of the simplified drivetrain.

4.2 Torque Dynamics During Release in Simplified Model

Torque response is calculated for a number of positions (Figure 5).

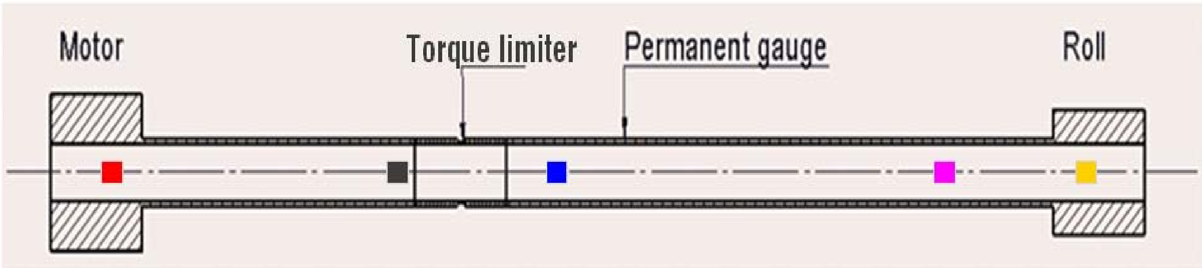


Figure 5. Torque simulation positions.

The model is stimulated with a torque peak from the roll side and response is calculated. The torque limiter is set to different values to control the release. As an example, please (Figures 6 and 7).

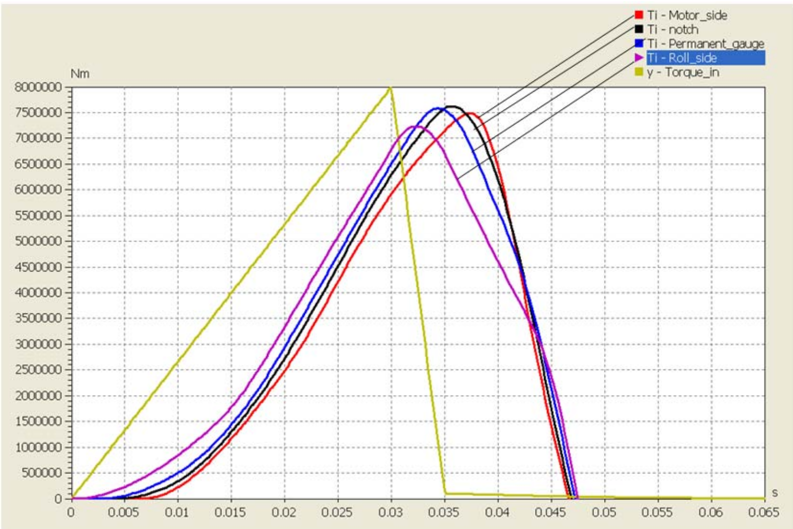


Figure 6. Load case without release.

ISSN 1983-4764

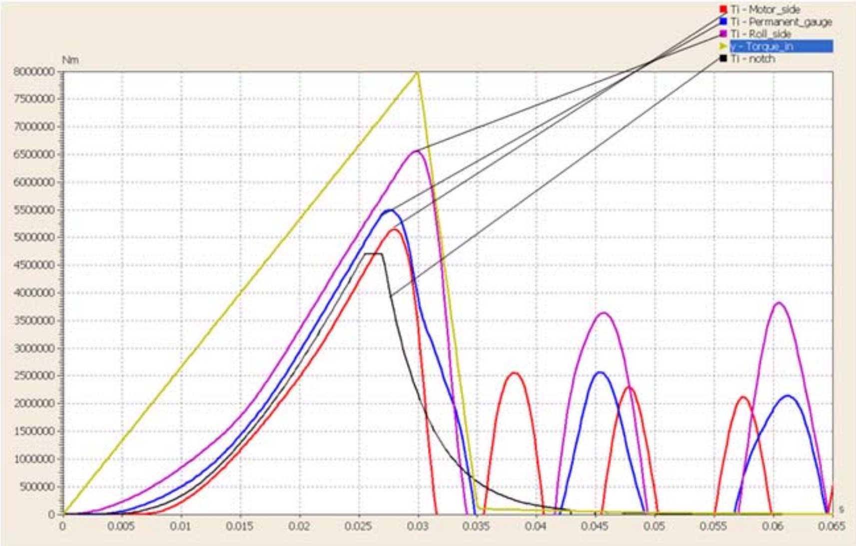


Figure 7. Loadcase with relase level 4.700 kNm, slip time 2 ms.

It is clear that the torque limiter lower the torque in all position of the drivetrain but not in the same extent everywhere.

4.3 Release Torque Amplitude Factor

For every position in the drivetrain a comparison between maximum torque and release setting in the torque limiter can be made.

$$RAF = \frac{\text{Max Torque}}{\text{Release Setting}}$$

4.4 Position of Torque Limiter

If the RAF values for a certain load case are calculated for the whole drivetrain a distribution curve can be made. It is interesting to compare what happens when the torque limiter is moved (Figures 8 and 9).

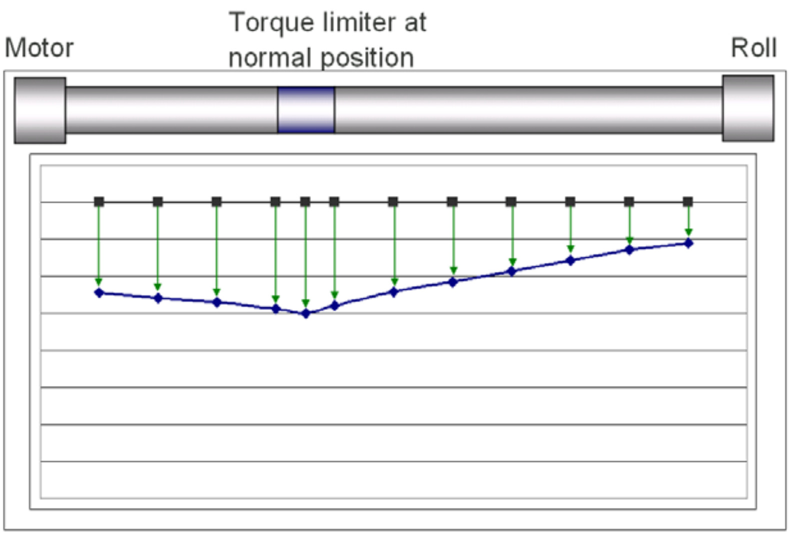


Figure 8. Torque limiter at normal position.

ISSN 1983-4764

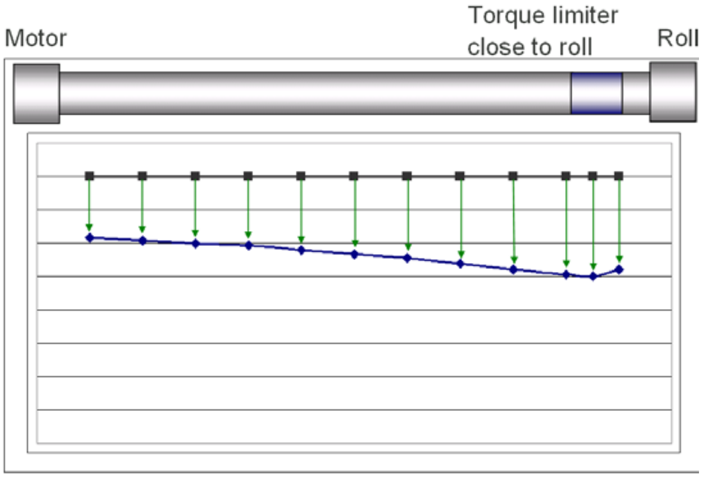


Figure 9. Torque limiter close to roll.

If the torque limiter is moved closer to the roll the RAF value in that end is lowered. It would be very beneficial to have the best protection at the roll end since that is where the torque peaks normally come from and also where the dimension are limited.

4.5 Detailed Model Drivetrain

A detailed discrete model is made for a pair of drivetrains in a real heavy plate mill (Figures 10 and 11).

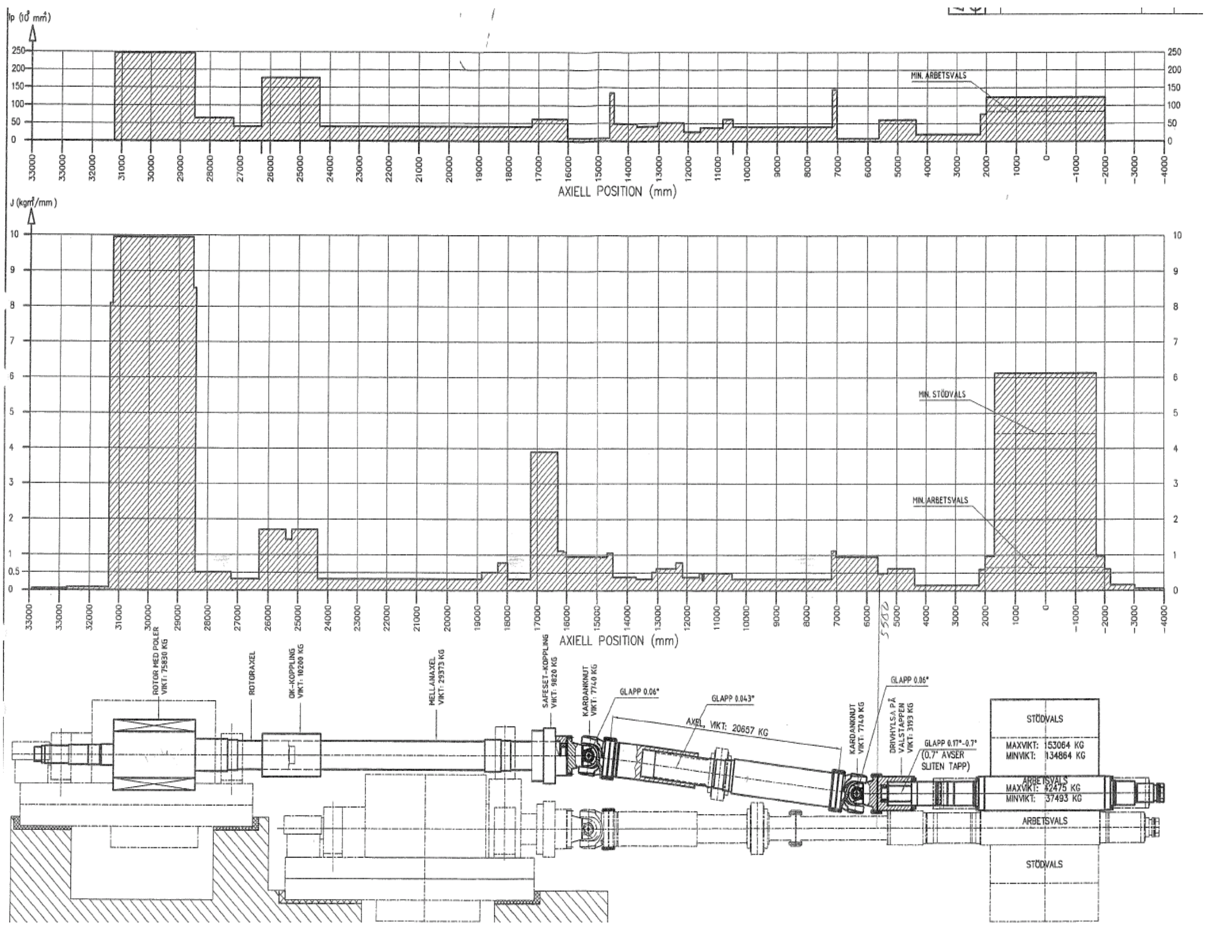


Figure 10. Distribution of inertia and stiffness in real top drivetrain for heavy plate mill.

ISSN 1983-4764

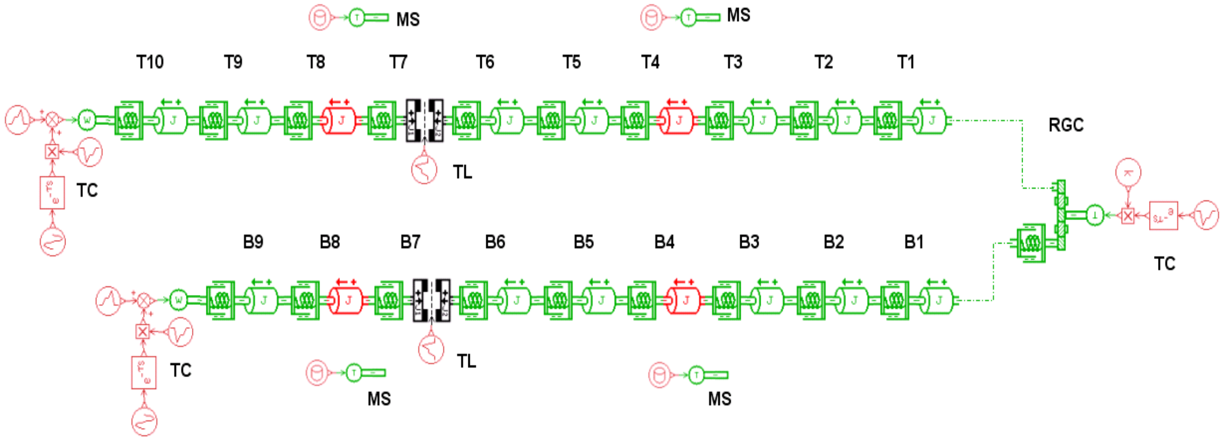


Figure 11. Discrete model of a real HPM drive.

The torque response in two positions in each drive is studied (Figure 12).

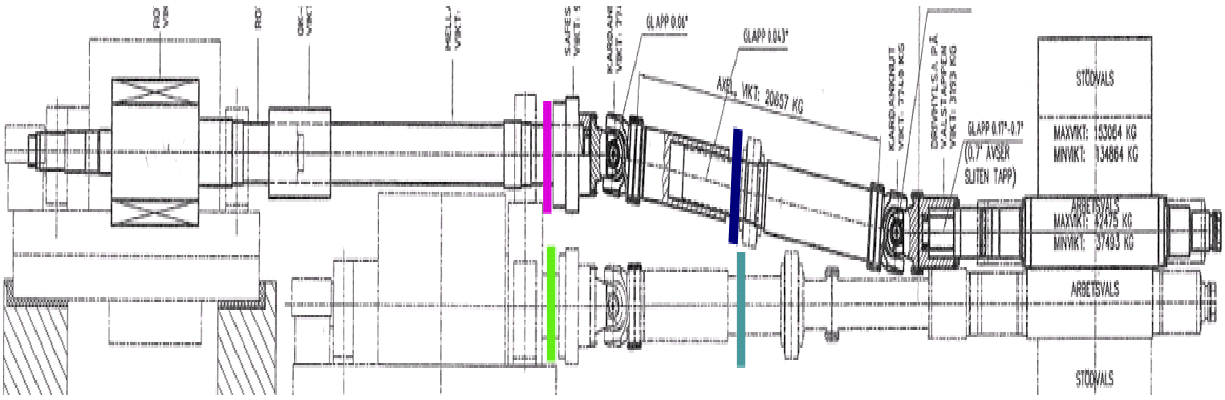


Figure 12. Torque simulation positions.

For load cases is examined; with (Figures 13 and 15) and without (Figure 14 and 16) release and at both high and low gradient torque peaks. In the release case only one of the torque limiters is set to release.

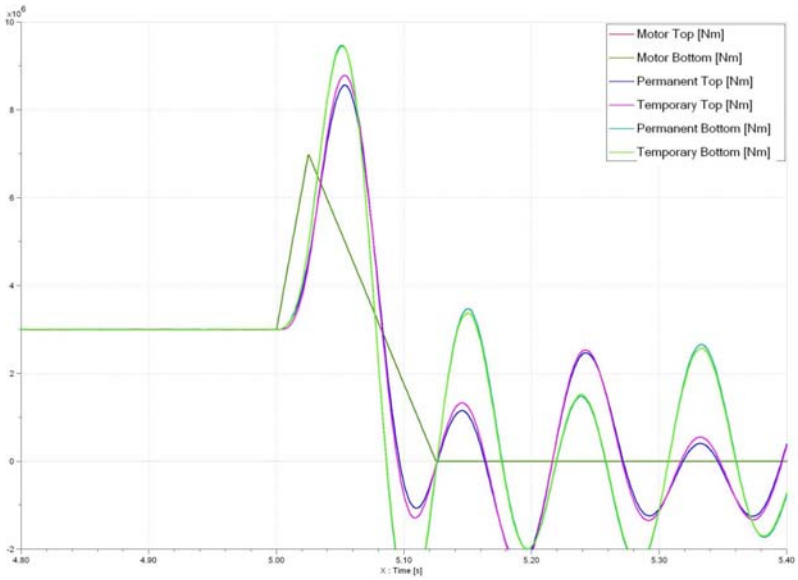


Figure 13. High gradient torque, no release.

ISSN 1983-4764

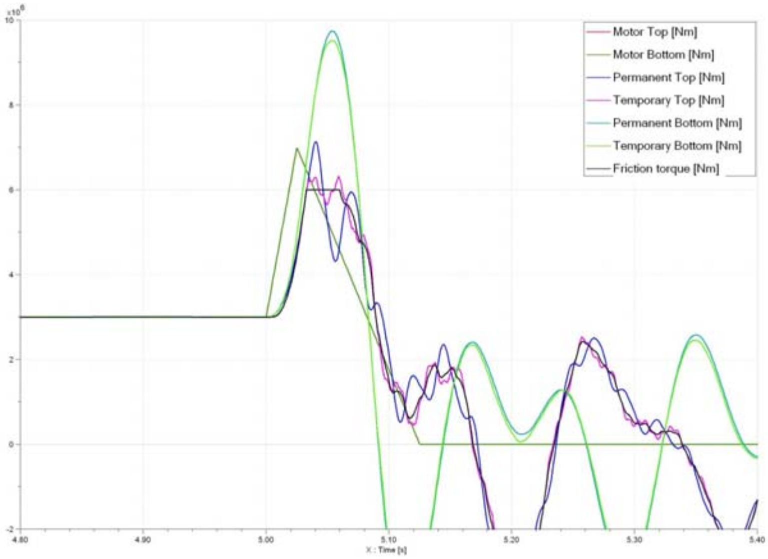


Figure 14. High gradient torque, release.

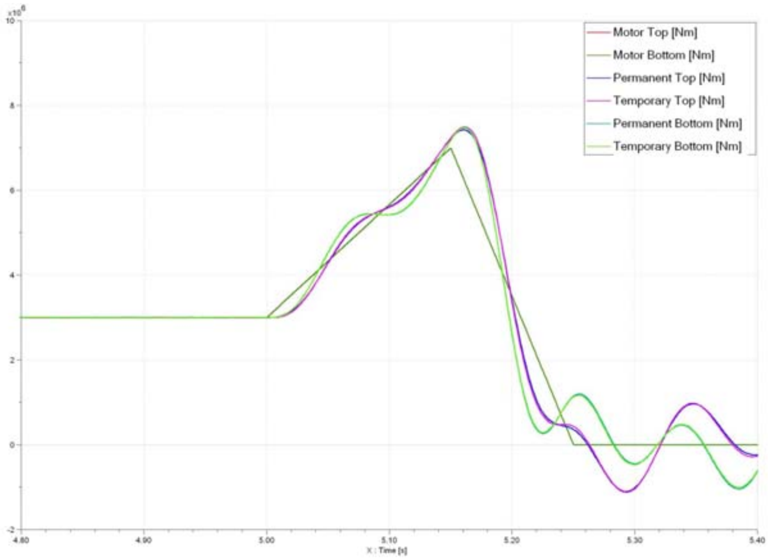


Figure 15. Low gradient torque, no release.

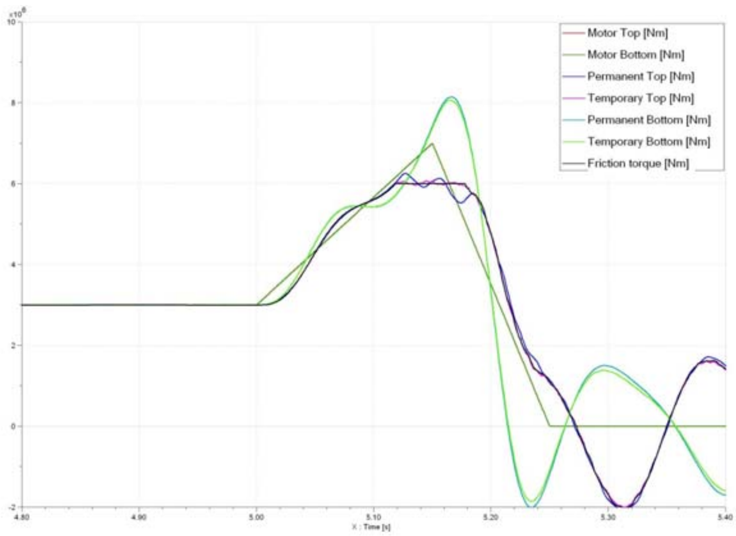


Figure 16. Low gradient torque, release.

ISSN 1983-4764

It can be seen that the torque is lowered by the torque limiter but it is not the same in all positions. The RAF > 1. It is also clear that the RAF values vary for different load cases. The low gradient torque gives RAF values very close to 1 meaning the torque is close to the set value for all the positions.

4.6 High Frequency Oscillations

A load case when one of the motors is stimulating the drive at a high frequency is studied in the detailed model. When the frequency matches one of the system's natural frequencies a resonance phenomenon takes place. The torque at the torque limiter position increase rapidly until the release limit is reached and the limiter releases (Figure 17). During the oscillations almost nothing can be seen in the normal measuring positions of the drive due to the specific resonance mode. This would be a valid explanation if a torque limiter releases without any recorded high peak from the torque measurement system.

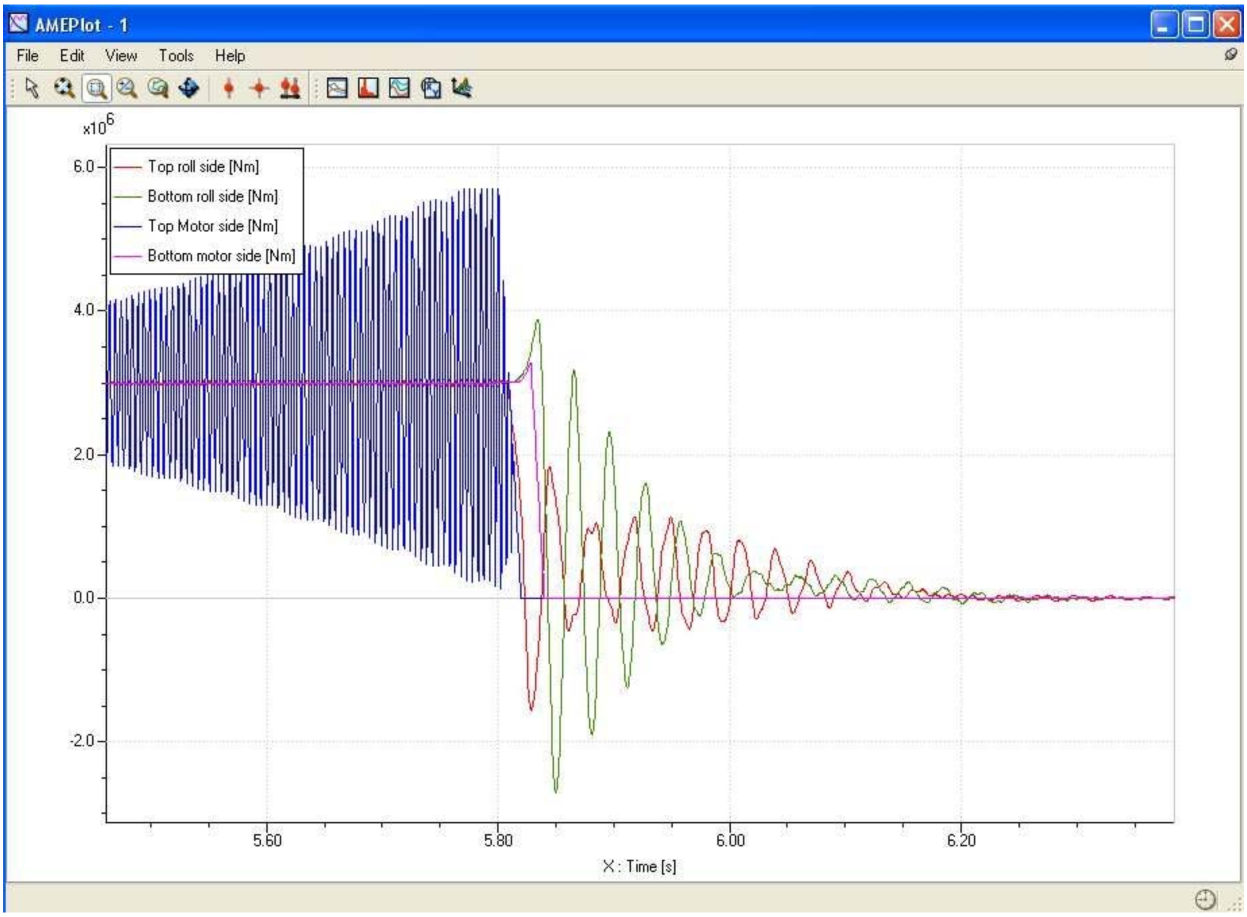


Figure 17. Simulation of high frequency oscillations in heavy plate mill drivetrains.

5 TORQUE MEASUREMENTS IN PLATE MILLS

A few heavy plate mill drives have been studied. For this two torque measuring systems (TMS) on each drive have been used, as shown on Figure 18.

ISSN 1983-4764

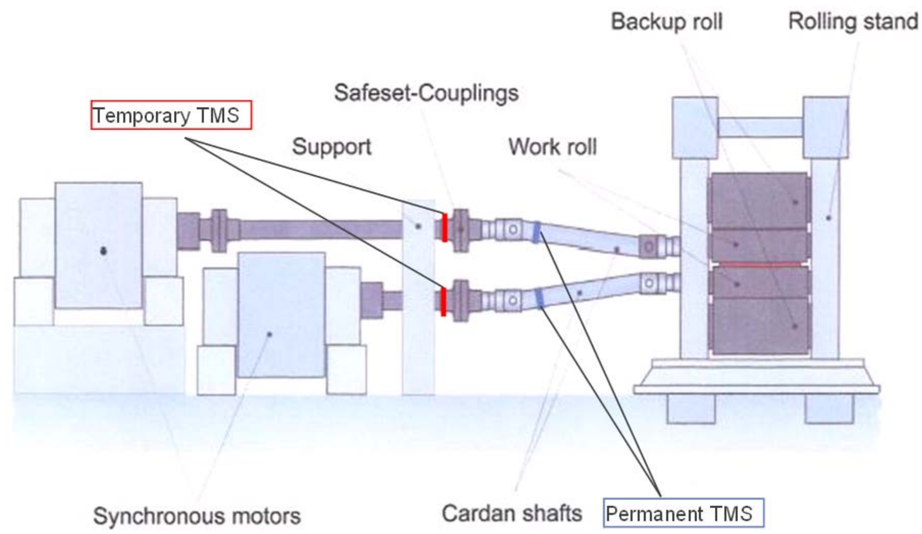


Figure 18. Heavy plate mill outline with two torque measurement systems on each drivetrain.

5.1 Motor Induced Dynamics

At one heavy plate mill some torque events with high relative torque differences were found, please (Figure 19).

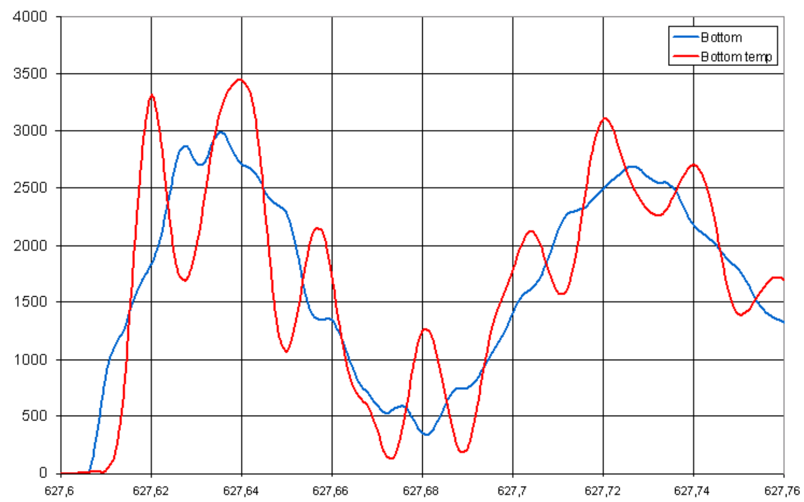


Figure 19. Torque differences for same driveline.

The reason for this was that when the torque changed rapidly, with a high torque gradient, the motor control system over-steered and started to stimulate the second natural frequency of the drivetrain. When this problem was detected the motor control was easily adjusted and the problem was eliminated for good.
It is however proof that rapid torque changes cause dynamic behavior.

5.2 High Gradient Torque Dynamics

Torque was recorded during an event when the top motor of a heavy plate mill drive cut the power for some reason. Then the bottom drive takes all the load and therefore sees a high gradient torque peak (Figure 20).

Figure 20. Torque measurement from a top motor cut event.

At the very top of the peak the difference between the two measurement positions in the bottom drive is found to be 7%, as shown on Figure 21.

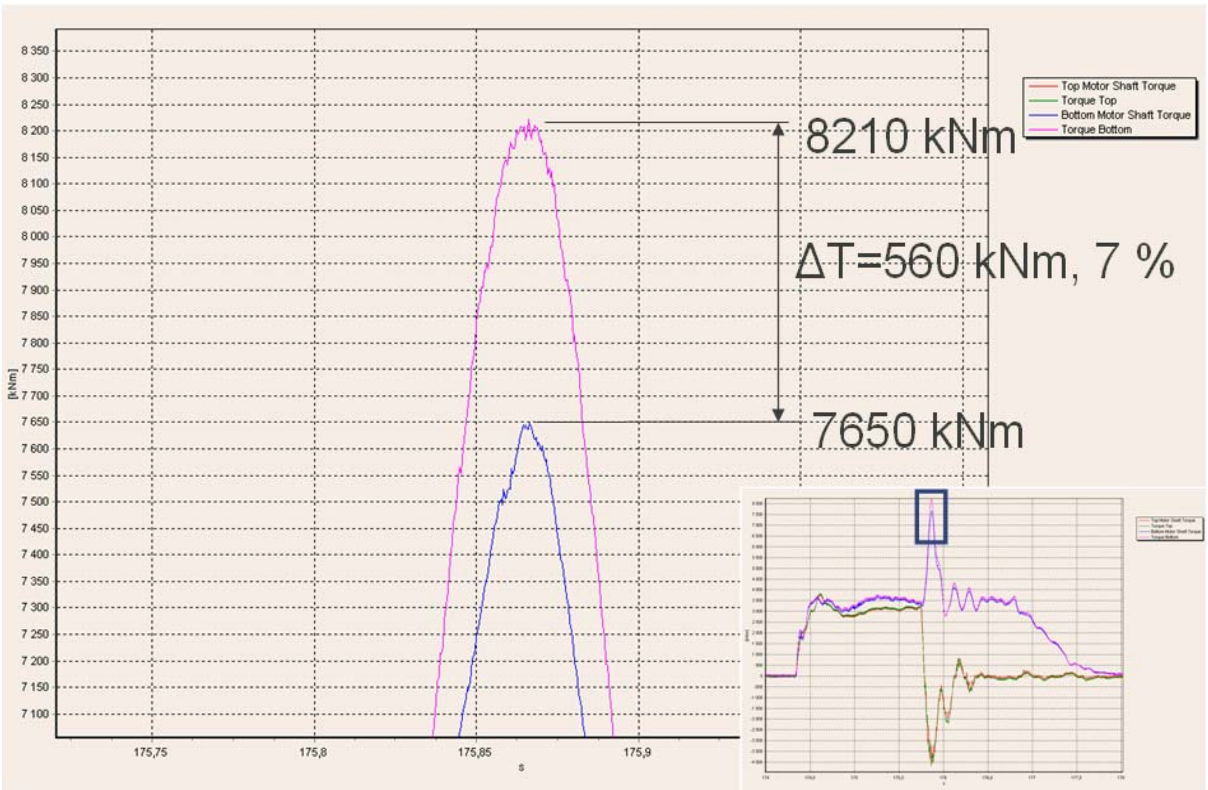


Figure 21. Torque measurement close-up from a top motor cut event.

5.3 High Gradient and Varying Torque Dynamics

Another HPM was studied when a varying torque event took place (Figure 22).

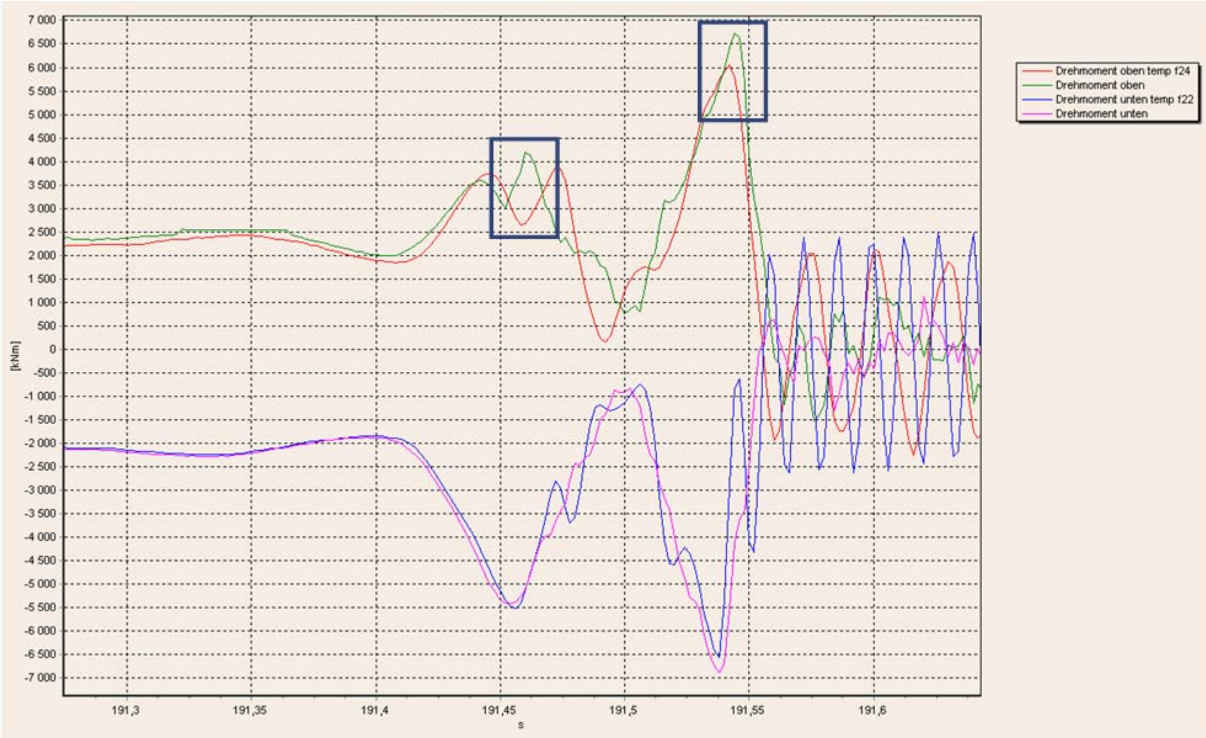


Figure 22. Torque measurement in a heavy plate mill.

In the first peak the motor fail to follow the roll torque and a dynamic phenomenon takes place. The relative difference between the two measuring points is very high since the event is at a quite low level to begin with (Figure 23).

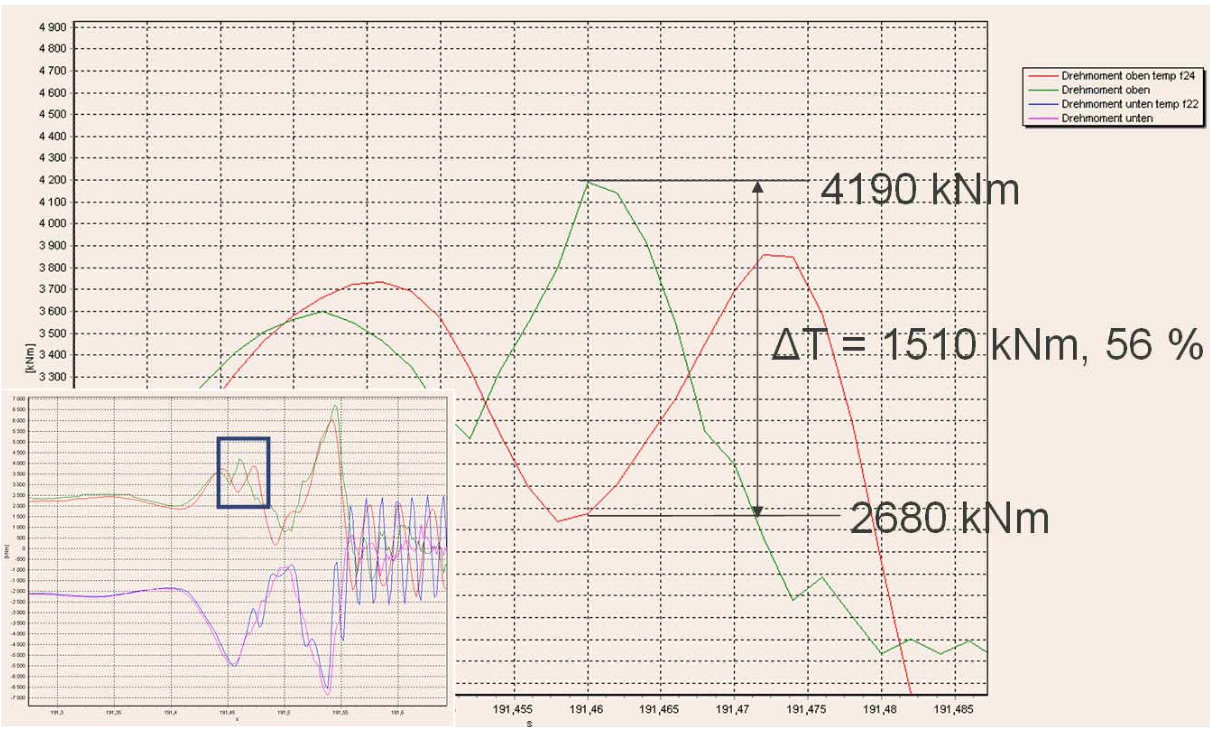


Figure 23. Torque measurement close-up from a varying torque event.

ISSN 1983-4764

At the very top of the peak the difference between the two measurement positions in the bottom drive is found to be 11%, as shown on Figure 24.

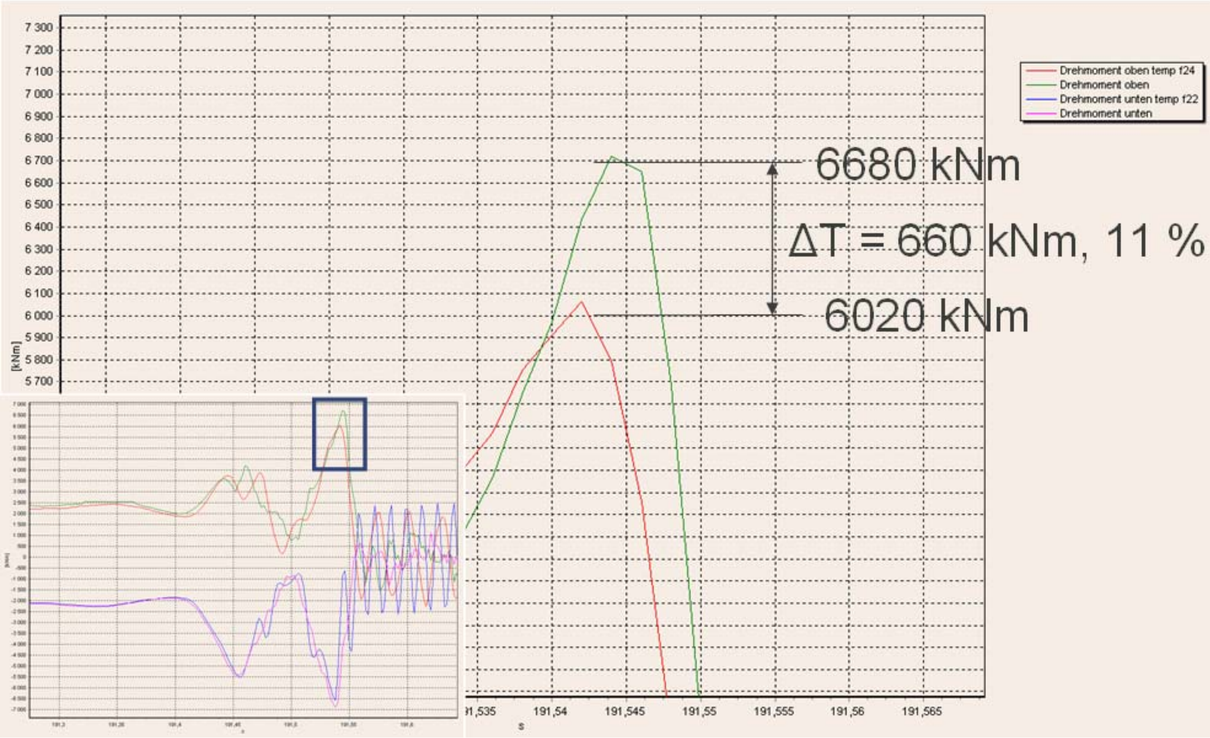


Figure 24. Torque measurement close-up from a release event.

6 CONCLUSIONS

- Any torque measurement is only valid for the measured position. It can not always be considered as valid for the complete drive;(3)
- torque can vary throughout a rolling mill drivetrain. It is seen in both simulations and real life measurements that toque dynamics is an existing phenomenon that needs to be included when designing a rolling mill drive;
- the dynamic torque difference depends on both the drive itself and the characteristics of the torque peak. Rapid torque peaks gives more dynamics;
- when designing a new rolling mill drive it is wise to put the torque limiter as close to the weakest point (roll neck) and the source of over-torque peaks (roll) as possible;
- both SafeSet SR-F and SafeSet SR-C are performing well and give reduced torque in the drive. They are not the source of dynamics. It is the drivetrain itself;
- the SafeSet SR-C is possible to mount closer to the roll and therefore recommended for heavy plate mills with low safety margins;
- the SafeSets will not release without an over-torque;
- trust the SafeSet! In the case of a deviating torque measurement the big picture including the drive design, drive parameters, measured curves etcetera has to be examined to find the explanation.

ISSN 1983-4764

Gratefulness

We would like to thanks our R&D and sales teams which supported us all the time providing the necessary information from both customer and product.
Our appreciation also for our Asian customers where we could develop most of this research and that all the time believed on our product.

REFERENCES

1 MACKEL, J., FIEWEGER, M., ASCH, A. Maintenance and quality related monitoring of rolling mill main drives, SARUC, Vanderbijlpark, 2002.
2 Dipl.-Ing. Martin Fieweger (Acida GmbH): "Investigations of drive trains under dynamic loads", AKIDA 2008, Aachen, Germany
3 Dr.-Ing. Jerry Mackel, Dipl.-Ing. Martin Fieweger: "Condition monitoring in steel industry", POHTO 2010, Oulu, Finland