GEARLINK – A QUANTUM LEAP IN DRIVE TECHNOLOGY FOR THE NEXT GENERATION HEAVY- PLATE MILLS*

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Abstract

In steel mills universal joint shafts, slipper spindles and gear spindles are used to overcome the design- and process- related offset between the axis of the motors and the work rolls. At the roll side the available space for the couplings is limited by the minimum work roll diameter. This leads to extremely high loaded components of the universal couplings especially at the roll side joints. Furthermore modern steel mills continuously strive to roll larger plates and materials with increased strength. This requires drive solutions with even higher torque capacity. For these applications conventional design joints are not sufficient anymore. Even alternative solutions such as hybrid- or offset- designs fall short. Therefore the companies Voith and BUMA Engineering developed together the new GearLink drive concept in close cooperation with the Voestalpine Grobblech GmbH. A completely new combination of universal joints and gear couplings offers an up to now unique solution enabling the use of 1,35- times bigger joint with a 2,5- times higher torque capacity and a 20- times longer lifetime. The GearLink system was first time successfully taken into operation at Voestalpine Grobblech in December 2013 and is up to now working without issue.

Keywords: Universal-joint shafts; Slipper spindles; Gear coupling; Torque capacity.

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1 INTRODUCTION

Mill operators require higher and higher torques for their plate mills. Forced by their competitors they have to produce more efficient and forced by the market they have to develop new steel grades with higher strength and improved microstructure. The components of the whole drive train need to be extremely reliable, since an unexpected downtime leads to tremendous costs. The components at one side need to have high fatigue strength for normal operation, at the other side they are expected to absorb extreme loads due to the very rough application. Besides they have to be low in maintenance costs. Varying demands in torque capacity require specific drive line solutions.

2 REASONS FOR HIGHER TORQUE DEMAND

2.1 Increase of Production

Operators of steel mills tend to maximize utilization of their drives capacity. Using bigger deformation degrees for each rolling pass, can reduce the total quantity of required passes of certain materials, thus increasing throughput and production. The win in time, however comes at the price of increased work- loads for the rolling mill. The operating schedules are closely oriented to the power balance of the motors with regard to rolling and idle time.

2.2 Development of High-Strength Products

In the last decades the production portfolio of a modern plate mill has shifted from normal rolled commodities to thermo- mechanical rolled high strength specialty metals. Shifting of the production mix has also resulted in the specific load of the mills being increased.

2.3 Requirement for Wider Plates

With the economic boost at the beginning of the century the requirement for wider plates occurred. To meet this requirement wider plate mills were put into operation throughout the world. With the increasing of the length of the work roll in direct contact the demand of rolling torque was increased even further. In the following, drive line concepts with different torque levels will be introduced. Beginning with standard solutions, alternatives for successively higher torque demands will be discussed and finally a completely new drive concept will be presented.

3 RESULTS AND DISCUSSION

3.1 Rolling Mill Main Drive Shafts

In almost every plate mill so called joint shafts are installed between the work rolls and the main motors. In general they consist of two joints connected by an intermediate shaft, which enable a homo- cinematic deflection of the power flow (figure 1).

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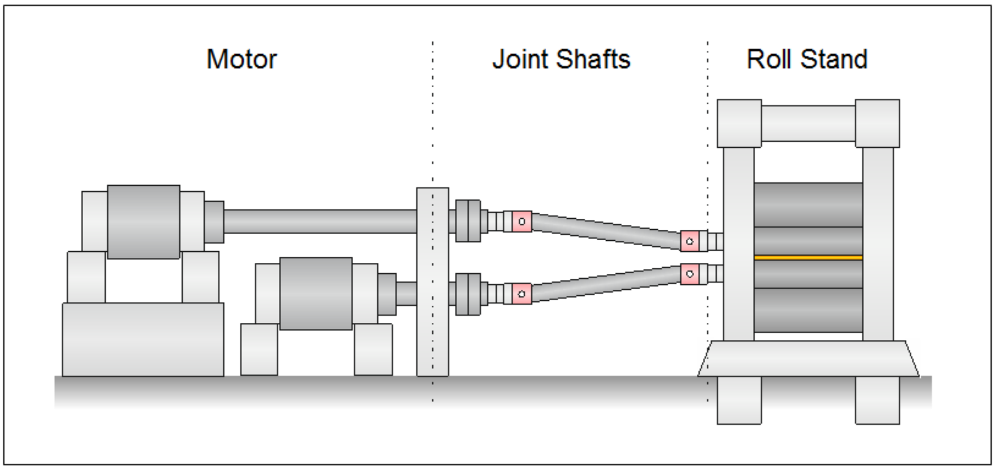

Figure 1: Rolling mill drive line

At the motor side there are a few limitations regarding the available space for the joints. The drive components at the roll side have to cope with extremely harsh operating conditions. However available space is very limited. The maximum size of the roll side joint is constrained in dimension by the minimum work roll diameter. When designing rolling mills, the work roll diameter needs to be kept as small as possible, because this reduces the rolling forces required. When revamping drivelines, very often only the motors and gears are increased whereas the work rolls remain unchanged. As a consequence the size of the joint shafts and especially the roll side joints often operate well above their fatigue limit. In these cases the lifetime of the universal shafts is limited, maintenance costs are high and there is risk that parts fail due to fatigue or overload. To solve this problem, in the next chapters, solutions with successively increased performance will be presented.

3.2 Standard Solutions

Due to deflection angles of 3 up to 10 degree mainly universal joints and slipper joints are used (figure 2). In modern mills universal joints are often preferred since the housed roller bearings need less lubricant, have higher efficiency and lower wear. Moreover universal joints are virtually clearance-free (no backlash), thus reducing the dynamic effects and increasing product quality from the mill. Modern universal joints have a similar torque capacity when compared to slipper spindles.

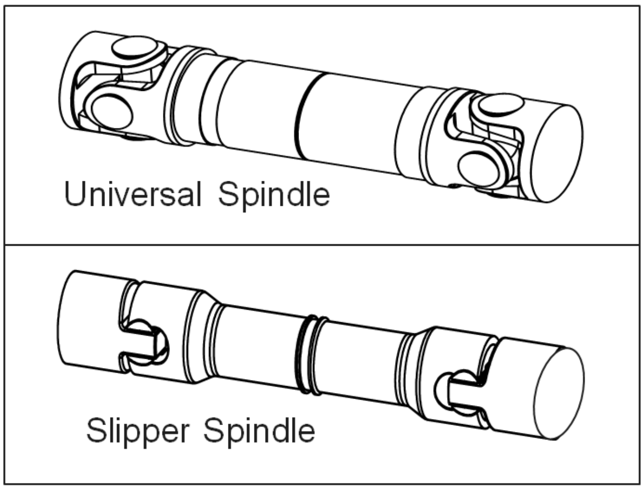

Figure 2: Main drive spindles

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For both, universal joints and slipper spindles, increases in torque capacity can be achieved by the use of materials with higher strength and by optimizing the design of the highly loaded components. Bearings need specific consideration, particularly the sliding bearings in slipper joints need optimization of tribology and in most cases the grease lubrication is replaced by an oil-air lubrication system. For universal joints the bearing capacity is achieved by the use of bigger, special designed cartridge bearings. Figure 3 illustrates the different kinds of joints in principle.

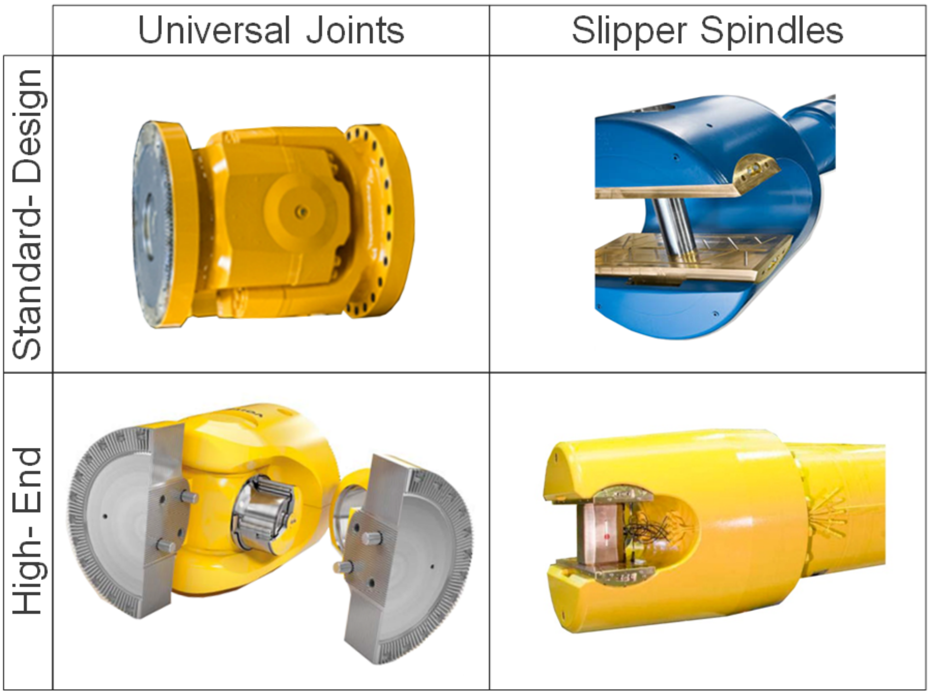

Figure 3: Joint types for rolling mill main drives

3.3 Improved Concepts for Higher Torque Demands

In case torque requirements exceed the specification of standard design drive shafts, different ways to increase the diameter of the joints need to be considered. Figure 4 illustrates a hybrid solution where a gear coupling is utilized for the bottom mill spindle, and the top mill spindle utilizes a universal joint. Because of the tube- like shape, gear couplings are able to transmit higher loads when compared to universal- or slipper- spindles with the same diameter. So in combination the gear joint on the bottom spindle can be chosen with smaller diameter and thus allowing for a larger universal joint size on the top spindle. A prerequisite is the positioning of the geared shaft with a low deflection angle (i.e. <1°). The universal joint dia. on the top universal spindle can be increased by a factor of roughly 1.1, what leads to an increase in torque capacity of up to 30%. Since the gear couplings can transmit only small deflection angles, nearly the whole misalignment is shifted to the top universal joint.

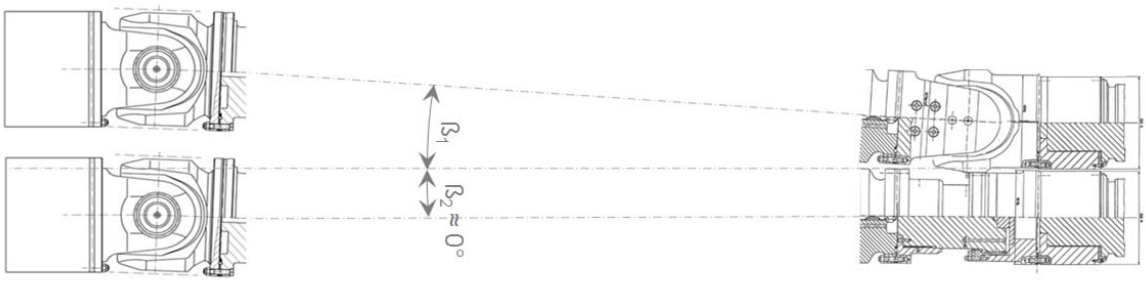

Figure 4: Example for a hybrid solution at the roll side

Another solution to cope with high torque loads is shown in figure 5. The joints are arranged by an axial offset. The compact design of the spacer on the bottom spindle provides additional space which can be used for larger joints on the top spindle. Using offset arrangement the joint size can be increased by a factor of roughly 1.25. Hereby an increase in torque capacity of up to 200% is achievable and particular for universal joints the bearing- lifetime can be increased favorably by up to 10 times. The only disadvantage of this solution is the longer distance between the roll side joint and the roll end hub at the bottom spindle due to the spacer. The long lever generates higher bending loads at the neck of the work roll, so in many cases a spindle support system is used to take over the weight of the shaft. If work roll shifting is required then the spacer length has to be increased by the corresponding shifting length, which is a further small handicap for this drive solution.

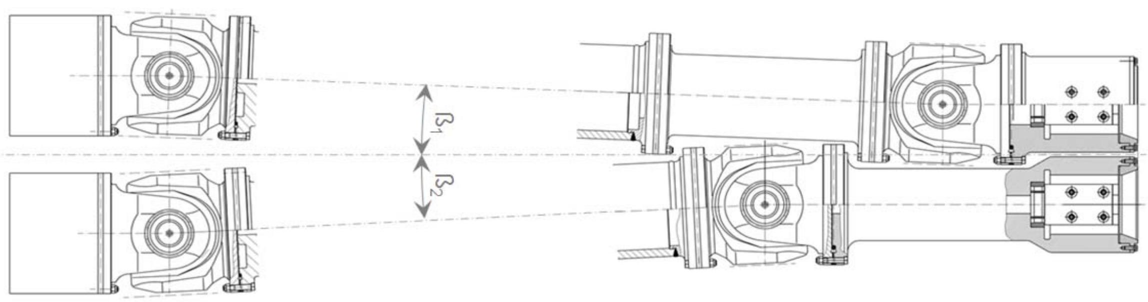

Figure 5: Example for an axial joint offset- solution at the roll side

3.4 GearLink, a Quantum Leap for Extreme Torque Capacity

As shown in section 5 a combination of gear couplings and universal joints as well as an axial offset design can provide a solution that enables transmission of significantly higher torques when compared to standard slipper spindles or universal joint shafts, but these systems have their limitations and disadvantages equally. For further torque increases and to overcome these constraints the engineers of Voith and Buma developed the new patent protected GearLink system (figure 6). As mentioned above the gear coupling is the drive element, which can transmit the highest torque in a defined space, compared to other elements but it is significantly limited by its maximum deflection angle. With increasing deflection, i.e. at deflection >1,5° the maximum permissible torque decreases significantly and wear increases beyond what would be acceptable in practice. With the combination of a gear coupling which allows the highest torque and the UJ-shaft which allows max. deflection, the benefits of both systems are combined in this new system, the GearLink. In state of the art mills work roll shifting is often implemented, which requires a telescopic element in the drive line. In the standard solutions this 'shifting' was integrated into the center section of the spindle. The GearLink is thereby characterized in that the telescopic function for the work roll shifting is located outside of the universal spindles and into the gear couplings close to the work rolls. Deflection between the axis of motors and rolls is mainly achieved by two fix length universal joint shafts. The top and the bottom universal joint shafts are supported in two separate bearings. The top bearing must be adjusted parallel to the movement of the top work roll to ensure, that the gear coupling always operates within the allowable range of max. 0.5°. This means that the GearLink system requires integration of the control of the hydraulic support system into the existing automation system of the mill. In addition another support system is required close to the gear hub which has the task to push the axially movable gear hub against the work rolls. Therefore additional loads on the flats of the work roll and the roll end sleeves can be prevented to the greatest possible extent. With this axial force also a perfect sealing of the gear coupling can be ensured. Due to the axial offset the roll side joints can be increased 1,35- times the work roll diameter, thus providing 250% higher torque capacity along with 20- times higher bearing lifetime rating when compared to a standard solution.

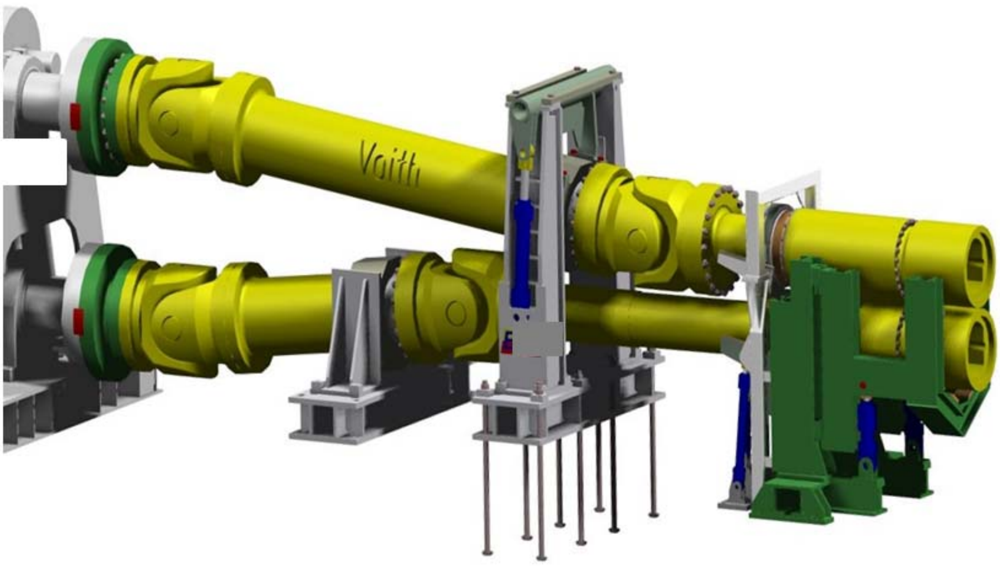

Figure 6: GearLink system

In case of extensive overload the roll end hub is designed as the weakest part of the system to secure the rest of the drive line.
The main advantages of the GearLink are:

- Higher torque capacity reduces the required production passes;
- Backlash free connection of the whole drive line reduces the TAF-Factor;
- Wear of the drive line is limited to the roll end hub.

The GearLink system was implemented into operation in December 2013 at Voestalpine Grobblech Plate. Since that time, plates of 4.2 m width have been rolled together with steel grades with significantly higher material strength. At the mill, a fatigue torque of two times 7500 KNm has to be transmitted at a work roll diameter of only 980 mm. Due to the new drive concept universal joints with a diameter of 1300 mm could be realized! From the first day of operation up to now the drive concept has been operating perfectly.

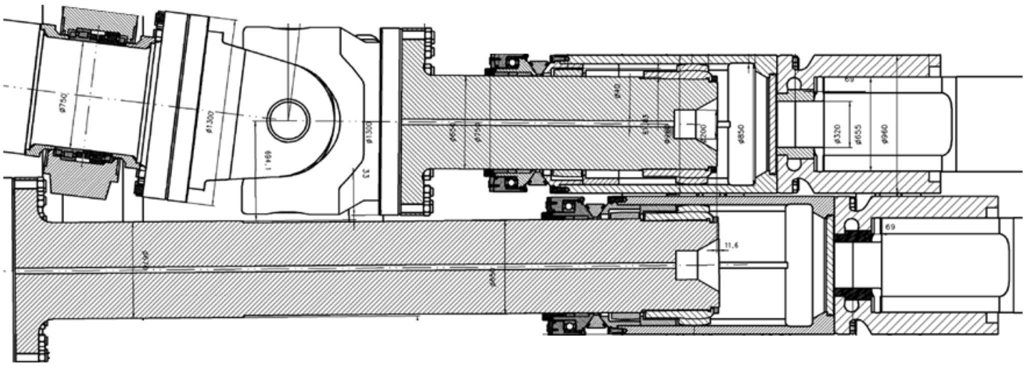

Figure 7: Detailed look into the gear couplings of the GearLink system

4 CONCLUSION

For a higher production efficiency and the possibility to roll modern materials with increasingly higher material strength, steel mills are requiring evermore powerful drive solutions. Referring to figure 8 the GearLink system enables an up to now unique solution for maximum torque and life- time at the limited space close to the work rolls. Compared to other solutions, additional loads to the roll end sleeves and the work roll flats can mostly be prevented. The combination of universal joint shafts plus gear couplings generates a drive system with reduced clearances and therefore low dynamic torque amplification at the beginning and the end of each roll pass. This enables a drive system with highest reliability plus highest availability! Even if the arrangement at a first look seems to be relatively complex, in practice the design elements work in unison, ensuring a problem free driveline concept.

	Standard universal joint	Combination of gear coupling and universal joint	Axial offset of the roll side joints	GearLink system
Size of the rollside joint	100%	110%	125%	135%
Torque capacity	100%	130%	200%	250%
Bearing Lifetime	100%	125%	1000%	2000%

Figure 8: Comparison of the performance of different drive line solutions

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