Performance enhanced cardan shaft drives for cold rolling mills

Advantages

+ High torque capacity, even at large deflection angles
+ Low life cycle costs along with reduced sensitivity to vibrations
+ Maximized efficiency through the use of roller bearings
+ Minimal maintenance
The drive shaft diameters typically used range from approximately 350 mm to 550 mm. With these dimensions the welding-yoke and flange driver are typically designed as die forgings in order to minimize expenditure. The base design however severely restricts or can prevent further optimization, which is required in particular applications.

With your needs and requirements in mind: Voith offers the standard version, the R-Series, as well as the specialized CH-Series, which is optimized for the particularly high torque requirements in cold rolling mills.

Reliable torque transmission from input to output at the highest torque capacity is the most important characteristics of Voith cardan shafts. However the drive configurations of cold rolling mill stands vary, ranging from reversing single stands on tandem drives to one-way operated five-stand production lines, for these configurations we provide special solutions meeting the highest demands!

The different cardan shaft ranges available:

Type R cardan shaft (standard version)
- Torque range: 32 kNm to 1,000 kNm
- Flange diameter: 225 mm to 550 mm
- High torque capacity
- Optimized bearing life
- Flange in friction and positive locking design
- Length compensation with an involute profile – SAE profile starting from size 350; available on demand
- Optimized torsional rigidity and deflection resistance in a low-weight design
- Well suited for use in high-speed drive applications
- Optional: Low-maintenance length compensation using plastic-coated (Rilsan®) involute profiles

Type-CH cardan shaft (high load design)
- Torque range: 140 kNm to 20,690 kNm
- Flange diameter: 350 mm to 1,460 mm
- Very high torque capacity
- Optimized bearing life
- One-piece flange yokes (integrated)
- Flange yokes (neck / neckless)
- Flange with Hirth coupling to transmit maximum torque
- Length compensation with SAE profile
Planned according to your requirements –
Voith Universal joint shafts are highly efficient in operation

*Based on 8,000 kW at 2°
Staggered arrangement of the drive shafts

Consequently, the universal joint shaft needs to overcome the torque demands within the given constraints, i.e. limited space and high engine power. In some cases, this can lead to a slower than desired service life, especially on the roller-side joints. The joint diameters on the engine side, are often reinforced beforehand due to the larger existing center distance.

Offset designs are well-known and were established to increase the joint-diameter, winning the required space by use of an intermediate shaft with a shaft diameter at the opposite drive side. With the standard R-Series only smaller diameter growth differences of approximately 15% are possible. The decisive factor here is the aforementioned limited geometric optimization range with the use of a conventional die for the welding yoke and flange yoke.

Advantages and disadvantages of the conventional design

Advantages
- Same and identical parts for both shafts
- Minimal deflection angle for both shafts, thus minimal possible service life of the universal joint bearings
- Low forces on the connecting hub (wobbler) connection
- Avoid unbalanceability of the work roll possible when using shafts with length compensation

Disadvantages
- Due to the often very high rolling torques, the bearings life of the universal joints can be shorter than desired
- Motor and roller-side joints are not the same size and have different lifetimes, as a nearly different journal cross assembles are required, which increases the number of spare parts

Advantages of an optimized offset design

Advantages
- Drive shafts are identical on the upper and lower shaft
- Higher torque capacity of the other side. Additionally uses higher torque capacity compared to gear spindles
- Significant increase in bearing life (> factor 9) of the cardan shaft bearings
- Identical journal cross assemblies and thus lower spare parts expenditure

Disadvantages
- The upper and lower shafts have different roll end sleeves. Furthermore, a compensation adapter is needed at the flange connection
- The longer lever between the work roll and the joint on the drive shaft results in higher forces at the connection point for torque and thus higher shaft stresses. A hydrodynamic roller bearing support is, so called sparingly required, so recommended to compensate for additional forces. At the same time this is also helpful in reducing the support forces onto the work roll, which are possible with a conventional universal joint shaft design
- Harmonic deflection angle. As a result, the bearings undergo longer rolling distances, which increases their service life slightly

Offset arrangement of the cardan shafts

Conventional cardan shaft solution

For conventional rolling mill drives, the joints of the upper and lower shafts are arranged directly above one another. The maximum possible roll-side joint diameter is obtained based on the minimum work roll diameter. For highly loaded drives, the work roll diameter and joint diameter are generally the same. The selection of the work roll diameter is subject exclusively to rolling process related parameters. Technical performance dimensions of the drive shaft are normally not considered.

The following figure below illustrates the minimum roll diameter of 350 mm combined with an R-joint, which by the axial offset compared to a conventional arrangement already has a significantly larger joint diameter of 420 mm. Taking into account that the torque in relation to the joint diameter is increased exponential under the power of three, this equates to an approximately 40% higher torque capacity.

Advantages and disadvantages of the staggered arrangement

Advantages
- Identical drive shafts of the upper and lower shaft with at least the same torque capacity compared to gear spindles
- Significant increase in bearing life (> factor 6) of the cardan shaft bearings
- Motor and roller-side joints are identical and have the same long service life – normal replacement possibilities
- Identical journal cross assemblies and thus lower spare parts expenditure

Disadvantages
- The upper and lower shafts have different roll end sleeves. Furthermore, a compensation adapter is needed at the flange connection
- The longer lever between the work roll and the joint on the drive shaft results in higher forces at the connection point for torque and thus higher shaft stresses. A hydrodynamic roller bearing support is, so called sparingly required, so recommended to compensate for additional forces. At the same time this is also helpful in reducing the support forces onto the work roll, which are possible with a conventional universal joint shaft design
- Harmonic deflection angle. As a result, the bearings undergo longer rolling distances, which increases their service life slightly

Optimized offset design with special Voith joints

The performance and design potential of the flange drives in the CH-Series result in further performance-enhancing possibilities for the powertrain. Especially when compared to the standard R-series universal joint shaft range. The optimized offset design makes it possible to realize a joint and work roll diameter difference of up to 30%, which corresponds to a jump of about two series size. The torque capacity is doubled and the bearing life of the joint bearings is increased annual tenfold.

To keep the-bearing diversity of the components low and thus ensure optimal availability, the journal cross assemblies of the CH-/R-Series are kept the same. These joints have been tried and tested in tens of thousands of proven installations.
Project selection

The values provided below are intended to give a rough idea and a basis for orientation purposes. Starting with a given roller diameter, the corresponding CH joint with the corresponding Mdw values can then be selected; intermediate values being possible. Please be aware that a design assessment must however be carried out in all instances.

Selection of the cardan shaft size

<table>
<thead>
<tr>
<th>Minimum working roll diameter [mm]</th>
<th>CH-Series</th>
<th>min. CH flange yoke neck diameter [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>275</td>
<td>350.8</td>
<td>272</td>
</tr>
<tr>
<td>310</td>
<td>390.8</td>
<td>306</td>
</tr>
<tr>
<td>360</td>
<td>440.8</td>
<td>355</td>
</tr>
<tr>
<td>400</td>
<td>490.8</td>
<td>395</td>
</tr>
<tr>
<td>455</td>
<td>550.8</td>
<td>450</td>
</tr>
</tbody>
</table>

Our broader portfolio offering includes:

- Project consultation services
- Maintenance, service advice and planning
- Complete solutions from a single source
  - from spindle supports, spindle head clamps through to special connection flanges
  - new, low-wear connection hub technology \(\rightarrow\) FlexPad

For any project, upgrade or modernization project, our wealth of experience and knowledge will assist you in bringing about the most functional and cost effective operation.

Contact us at: UJSshafts@voith.com

Or your local Voith representative for more information.

For the analysis and development of an improved drive concept, we will request further information:

- Heights and distances from the gearbox to the working rolls
- Connection of the wobbler to the working roll and connecting flange to the gearpin
- Current drive shaft and the actual service life
- Motor data, gearbox data, rolling data (speed, TAF, operating hours per annum)
- What possible improvements could be made?

Cardan shaft specifications

<table>
<thead>
<tr>
<th>Case</th>
<th>Propeller shaft assembly</th>
<th>Torques</th>
<th>Dimensions</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Standard arrangement R 390.8</td>
<td>Mw 160 kNm (100%)</td>
<td>Swing dia. 380 mm</td>
<td>Both variants necessary for telescopic shafts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M' 325 kNm</td>
<td>CxR 67.1 kNm</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Standard arrangement CH 390.8</td>
<td>Mw 190 kNm (116%)</td>
<td>Swing dia. 380 mm</td>
<td>Due to higher torque capacity of a CH flange yoke the offset performance can be increased.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M' 325 kNm</td>
<td>CxR 67.1 kNm</td>
<td>Smaller W-tube, not the R-tube</td>
</tr>
<tr>
<td>3</td>
<td>Offset R 440.8</td>
<td>Mw 250 kNm (156%)</td>
<td>Swing dia. 429 mm</td>
<td>Refer to the production drawing flange yoke from R and CH and forging blank contour (page 12).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M' 500 kNm</td>
<td>CxR 100 kNm</td>
<td>The reduced torque capacity is due to connecting flange limitations.</td>
</tr>
<tr>
<td>4</td>
<td>Offset CH 440.8</td>
<td>Mw 280 kNm (175%)</td>
<td>Swing dia. 429 mm</td>
<td>The reduced torque capacity is due to connecting flange limitations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M' 500 kNm</td>
<td>CxR 100 kNm</td>
<td>Special mid-section</td>
</tr>
<tr>
<td>5</td>
<td>Offset CH 490.8</td>
<td>Mw 280 kNm</td>
<td>Swing dia. 490 mm</td>
<td>The reduced torque capacity is due to connecting flange limitations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M' 500 kNm</td>
<td>Double flange</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CxR 130 kNm</td>
<td>Flange Q429 or H385</td>
<td></td>
</tr>
</tbody>
</table>

Cardan shaft analysis

As an example, thereafter the roll-side joint is considered at a minimum work roll diameter of 385 mm.

Cardan shaft analysis

The case study shows a variety of possibilities and the potential for improvement.

Case study
Flange yokes
The standard R-Series and the more sophisticated CH-Series have two different types of flange yokes for the rota sizes of 350, 390, 440, 490 and 550 mm. Both flange drivers are die forged, yet they have differences detailed below:

Due to the given geometry of the forging blanks of the flange yoke design, the R-Series has insufficient material space to machine to neckless design and accommodate the flange bolting threads.

When utilizing the CH-Series there is sufficient space for the flange bolting and hirth toothing. This is a result of the massive base material requirements for achieving the highest torques.

The transition from the yoke to the hirth serration is gentle, avoiding local stress spikes, despite the large difference in diameter (395 mm to 305 mm).

Appendix

Differences in flange yokes

<table>
<thead>
<tr>
<th></th>
<th>R-Series</th>
<th>CH-Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deflection angle</td>
<td>Maximum 15° deflection angle</td>
<td>Maximum 10° deflection angle</td>
</tr>
<tr>
<td>Material</td>
<td>42CrMo4</td>
<td>High strength quenched and tempered material with about 20% higher performance</td>
</tr>
<tr>
<td>Special features</td>
<td>Friction-, face-key-, hirth serration-flange</td>
<td>Only with Hirth serration</td>
</tr>
<tr>
<td>Suitability for welding</td>
<td>Suitable</td>
<td>Not suitable</td>
</tr>
</tbody>
</table>

Due to the given geometry of the forging blanks of the flange yoke design, the R-Series has insufficient material space to machine to neckless design and accommodate the flange bolting threads.

The CH-Series offset flange yoke

When utilizing the CH-Series there is sufficient space for the flange bolting and hirth toothing. This is a result of the massive base material requirements for achieving the highest torques.

The transition from the yoke to the hirth serration is gentle, avoiding local stress spikes, despite the large difference in diameter (395 mm to 305 mm).