

Universal joints can be the most efficient and cost effective method of driving mill rolls including applications in high-impact reversing roughers and Steckel mills.

Design and selection of universal joints for rolling mills

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THE application of universal joints has significantly increased in steel and aluminum rolling mills. It is generally known that the most unique feature of universal joints is misalignment capabilities of 15° or greater. While this is significantly higher than the 6° capability of gear couplings and spindles, there are other advantages for the high torque loads and almost continuous operation of today's mills. Universal joints resist lubrication loss and contamination in harsh environments because of their bearing and seal design. Simplicity and ease of lubrication can significantly reduce maintenance time. When compared to other types of high-angle couplings, universal joints operate with negligible backlash and radial clearance that can improve product quality.

Selection and retrofitting procedures of universal joints for mill gear spindles are discussed in this article, including a review of operating characteristics, bearing life, length compensating features, roll end support design and maintenance requirements.

Background

Universal joints are defined as a mechanical device that can transmit torque and/or rotational motion from one shaft to another at fixed or varying angles of intersection of the shaft axes. They are categorized by their motion characteristics as a single joint, which can be nonuniform or uniform. A uniform or constant velocity (CV) universal joint assembly transmits motion with an angular velocity ratio of unity between input and output members. The device commonly referred to as a universal joint transmits motion with various ratios of instantaneous angular velocity between driving and driven members when operating at angles greater than 0° and only a single joint is used. The average angular velocity is unity. This type of universal joint is normally referred to as either a Cardan or Hooke universal joint (Fig. 1). Placing two universal joints in tandem with proper phasing allows the velocity fluctuations of the first joint to be cancelled by the second joint, allowing for a constant output speed equal to the input speed.

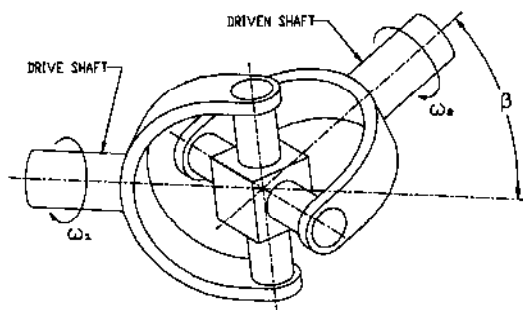


Fig. 1 — Cardan universal joint.

Historical evidence indicates the Greeks invented the universal joint approximately 300 B.C. The name Cardan was derived from the sixteenth century Italian mathematician Geronimo Cardano, who utilized a similar mechanism to suspend a ship's compass horizontal, regardless of the ship's movement. During the seventeenth century, Robert Hooke made the first application of a universal joint to a rotating shaft in a clock drive.¹ The development of the automobile accelerated the refinement of universal joints. Other uses include: marine; railway; aircraft; agriculture; and industrial applications.

Compared to high angle, low torque automotive applications, industrial applications, such as rolling mills, require high torques and relatively low operating angles for universal joints. Historically, the most common type of spindle used to drive rolling mill rolls were wobbler couplings (Fig. 2) and slippers (Fig. 3). Wobblers are typically cast pods and are not sealed to prevent lubricant leakage.

Heavy metal to metal contact produces high wear and high noise levels. A slipper coupling has the same rotating characteristics as a universal joint. In fact, a shaft can be made with a Cardan joint at one end and a slipper at the other. The slipper elements are normally made from bronze and, more recently, nonmetallic materials. Slippers wear through repetitive sliding of loaded metal to metal interfaces. Excessive tolerances inherent in the design cause loss of concentricity.² These characteristics can contribute to product flaws resulting from mill chatter. Additionally, lubricant is not contained and, in some cases, must be continuously supplied.

The inherent disadvantages of wobblers and slippers combined with market demand for greater productivity and improved quality of rolled products led to the application of

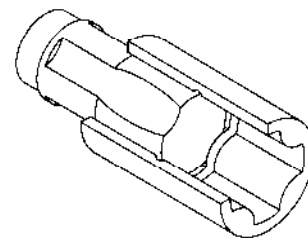


Fig. 2 — Wobbler coupling.

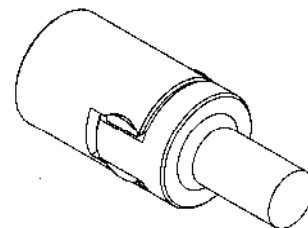


Fig. 3 — Slipper coupling.



Fig. 4 — Mill gear spindle.

Advantages of universal joint

Universal joints have always been recognized for their inherent advantage of large misalignment capabilities upward of 15° compared to a maximum of approximately 6° for typical gear-type spindles. In recent years, research and improvements in design and manufacture have contributed to substantial increases in the torque capability of universal joints. Achievement of power transmission densities that allow universal joints to meet rolling mill diameter limitations has increased their competitiveness with gear spindles. Today, U-joints are generally available with power densities equal to or greater than geared spindles, especially when operating misalignment angles exceed $1\frac{1}{2}^\circ$. The advantages of universal joints include:

- Consistent operating characteristics.
- Reduced backlash and runout.
- Reduced maintenance.
- Elimination of possible mill chatter.
- Lower operating costs.

Operating characteristics — U-joints utilize a cross and bearings instead of engaging gear teeth for the flexing component.

Gear spindle teeth are constantly sliding and wearing during their operational life, which can have significant effects on the life and capacity of the gear spindle.

U-joint bearings roll and have minimal and relatively predictable wear during their operating life.

The torque capacity of gear spindles decreases as misalignment increases because fewer teeth are in full contact to share the load.

U-joint torque capacity is not significantly influenced by the misalignment angle, and reduction in bearing life is statistically predictable regardless of operating angle.

Backlash and runout — Gear spindles, by design, must have 0.020 to 0.100 in. of backlash in order to flex—this backlash increases as the spindle wears.

U-joints typically have less than 0.003 in. of backlash, which does not increase until after complete bearing failure.

Gear spindles typically have 0.020 to 0.060-in. runout as a result of heat treatment distortion (which will increase due to wear).

U-joints are assembled with virtually no radial runout.

TABLE I Typical 7-stand hot finishing mill with 26-in. OD gear spindles and U-joint lubrication man-hours

Coupling type	Lubrications/year	Man-hr/stand	Total time, hr*	Total cost/year, \$**
Gear spindle	48	3	1008	80,640
U-joint	12	1	84	6720

* 7 stands

** \$80/hr

TABLE II Typical 7-stand hot finishing mill with 26-in. OD gear spindles and U-joint lubrication quantity and clean-up costs

Coupling type	Lubricant, lb/unit	Lubrications, number/year	Lubricant,* \$/year	Lubrication clean-ups, \$/year	Total, \$/year
Gear spindle	20	48	13,440	57,600	71,040
U-joint	1	12	168	720	888

*\$2/lb, 7-stands

Universal joint designs

Cardan joints for industrial applications consist of variations using a cross and bearing design. All designs (except for plain or composite bearing types) transmit torque through anti-friction bearings, two forged or cast yokes and a forged cross member. Heavy-duty lip seals that are not subject to eccentric loading prevent lubricant leakage and contamination. This allows operation in contaminated atmospheres such as caster applications. Since crowned rollers are typically used, the U-joint life can be statistically determined. Hardened precision tolerance raceways are used with the bearing-steel rollers for optimum life.

Mill universal joints can be categorized as one of the following five types:

- Closed eye (1-piece) yoke design (Fig. 5)—A 1-piece yoke surrounds the bearing housing.
- Split yoke design (Fig. 6)—Yokes are split axially to produce a 1-piece bearing housing with a solid bearing end cap whose yoke halves are held together with a tie bolt during assembly, shipping and installation. After mill assembly, the halves are held together by the bolted connection to the drive shaft flange.
- Split bearing eye (Fig. 7)—Bearing bores are split into two sections and retained by a combination of serrations and bolts.