SPUR GEAR TURNTABLE BEARING

Richard L. Dornfeld, BSME, P.E.
Staff Engineer
Walker Process Equipment
Division of McNish Corporation
July 2002

WPE spur gear drives incorporate a turntable bearing with replaceable raceway insert system. The Walker raceway inserts or liners are annealed, aircraft quality, vacuum degassed, AISI E4340 steel, which meets or exceeds the requirements of ASTM A331, MIL-S 5000, and Aerospace Material Specifications, AMS 6415 and AMS 2301. The raceway liners are ground and through hardened to 43 Rc minimum and 48 Rc maximum.

Raceway material hardness is a parameter in the bearing L_{10} life rating equations. The hardness of the raceways measured in the Vickers hardness scale is used to increase or decrease the bearing capacity and thus fatigue life of the bearing compared to the initial conditions set by Palmgren and expanded by ABMA.

The use of a bearing specifically designed for water and wastewater collector drives ensures optimal operation and service. The high hardness of 58-60 Rc common to most commercial bearing raceways increases the potential for stress corrosion of the raceway material in the presence of water. High humidity over collector basin surfaces in the region of the collector drive dramatically increases the potential for moisture to accumulate within the drive, thus increasing the potential for this type of corrosion in high alloy heat-treated steel races. This problem has been greatly reduced by the use of the medium hardness material as raceway liners, as found in the collector drive turntable bearing systems of the major drive manufacturers, such as Walker Process Equipment, EIMCO, and Envirex. Additionally, the replaceable raceway material is less susceptible to impact cracking than the more brittle higher hardness raceway material.

Bearing L_{10} Life is determined by equations based on bearing component materials and the bearing system geometry and loading. The resulting L_{10} Life rating of the insert raceway bearing system is of equal validity to the L_{10} life ratings for American Bearing Manufacturers Association, ABMA rolling element bearings. Both the ABMA rolling element ball and roller bearings and insert raceway bearing system are rated by equations developed from the basic equations of Lundberg and Palmgren for Hertzian fatigue life.

The raceway contour establishes the conformance of the raceway to the rolling element, in the case of the WPE turntable bearing, a 1 ½” diameter ABMA OK Gauge and ABMA Grade 50, AISI E52100 chromium alloy steel, with a hardness range of 60-65 Rc. The ball on the insert raceway establishes a conformance of the raceway to the rolling element for the insert race contour. The contour of any raceway is solely the geometry of that raceway, which may vary from flat to tightly curved without rendering the results of the rating equations inaccurate or invalid.

The extremely high L_{10} Life ratings that have been associated with collector turntable bearings in general indicate only that Hertzian surface fatigue is not the mode of failure or that the bearing may have been designed for an entirely different application. The misapplication of a bearing without regard to basic engineering principles of function and cost is not desirable.

Another more common and often ignored failure mode is abrasive wear. This type of failure is much harder to predict and is dependent on environmental conditions, lubricant function, and quality of maintenance as well as design parameters such as material properties, geometries, and loading conditions.

While difficult to predict, this type of failure can be considered in the design of the bearing and the potential for failure reduced by judicious choices. Abrasive wear is minimized by preventing the accumulation of hard particles in the region of the bearing. This accumulation is due in part to adhesive wear, which produces hard particles that result in abrasive wear. Another source of abrasive particles is infiltration from the environment and corrosion products. This includes air borne particles such sand and corrosion products such as those resulting from stress corrosion.

The accumulation of particles can be prevented or reduced by several methods. The housing can be tightly sealed to exclude air borne particles. This is not totally effective for rotating or moving equipment, as the particles tend to accumulate at the seal causing wear of the sealing surfaces over time. The products of stress corrosion can be reduced by using materials not subject to corrosion, most are unsuitable for this application; precluding entry of water or water vapor into the housing, this again is not totally effective due to seal wear over time. Reduction in adhesive wear particle production is obtained by the use of lubricants containing extreme pressure additives. As the additives are depleted over time, the adhesive wear increases as these bearing operate at low speed and are thus in the boundary lubrication regime.

The most effective method to prevent the accumulation of abrasive particles in the region of the bearing is periodic or continuous removal of the particles from that region. The bearing lubricant must accomplish this function in most designs. In the case of grease lubrication, the particles are held in place by the thickener base. The admission of new grease to the bearing cavity should expel the depleted grease from the region of the bearing. The depleted grease thus carries the abrasive particles away from the bearing. Unfortunately, the configuration of a turntable bearing does not lend itself to the effective displacement of the depleted grease by the admission of new grease. This condition results from the volume of the bearing cavity and the lack of a means to preferentially mechanically force the depleted grease away from the bearing as is found in other types of mounting configurations, which can be purged such that the depleted grease is forced from the bearing cavity. Similarly water removal is also ineffective.

In order to purge the turntable bearing of depleted grease, the path of the grease from admission point to purge point must be restricted so that the new grease pushes the old from the cavity. This cannot be accomplished in the turntable-bearing configuration. Both new and depleted grease can escape the cavity at any point around the seals and thus short circuit the purge. This failure to transport depleted grease from the bearing results in continued contact of abrasive particles and sequestered moisture with the bearing surfaces.

The configuration of turntable bearings in general precludes a systematic sampling program and indeed may prevent any samples of the purged grease from being obtained without disassembly of the entire drive. Disassembly of the spur gear drive is required in order to remove all depleted grease from the bearing and housing and repack the bearing to perform proper relubrication of the bearing. Disassembly would also require the removal of the collector bridge and any other structure above the spur gear housing for turntable bearings of the solid ring design.

Oil lubrication eliminates these problems by moving the particles and any moisture from the region of the bearing through fluid circulation. This type of circulation is not found in grease even for NLGI Grade 000. Further, the moisture will coalesce and settle through the oil to the bottom of the oil reservoir. The heavier particles will also settle out while the lighter particles will be dispersed in the oil volume thus reducing their concentration in the region of the bearing. Both the water and the entrained particles will be removed from the sump when the oil is drained. A substantial portion of the settled particles will also be removed with the drained oil. Flushing the housing will remove addition quantities of settled solids. The recharging of the reservoir with oil will provide clean lubricant to the entire system.

An additional benefit of the oil lubrication is the potential to draw samples in a systematic manner allowing for predictive maintenance. The oil samples can be analyzed and the results recorded or charted to establish any wear or contamination trends.

Based on the inescapable presence of contaminants, the life of grease lubricants used in turntable bearings is greatly reduced over the ideal predicted life of grease in general. This is shown by the work of Sachs cited in Erwin Zaretsky's Rolling Element Bearing Technology Course Notes – Univ. Wis. Milwaukee CCEE. The relubrication interval for greased ball bearings for speeds below 250 rpm is based on lubricant life, which is generally taken as 5 years. Factors such as temperature, contamination, moisture, vibration, position or orientation, and bearing design, in this case ball elements; tend to reduce this ideal life expectancy of the grease. For temperatures below 150 ^{o}F, light abrasive dust contamination, occasional condensation, and neglible vibration in a ball turntable bearing, the ideal life of grease is reduced from 5 years to 0.24 years or roughly 88 days. For heavy abrasive dust and occasional water in the housing, this relubrication interval drops to just 11 days. This either greatly increases maintenance time for relubrication or increases the likely of drive failure if the relubrication interval is not adjusted.

Besides reducing the life of the grease and shortening the relubrication interval, this contamination reduces the bearing L_{10} Life. Such authorities as the Society of Tribologists and Lubricating Engineers, STLE recognize this. In the STLE Life Factors For Rolling Bearings, Second Edition, ©1999, Erwin V. Zaretsky editor, in chapter 6, Application of Life Factors, by E.V. Zaretsky, in section 6.6.9, Lubrication, it is shown that the L_{10} Life adjustment factor a_3 is reduced to 0.9 to as little as 0.4 due to the effects of moisture, humidity, and wear contaminants. This reduction in L_{10} Life is seldom taken into account by those extolling grease lubrication for clarifier drives.