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APPLICATION OF THE CERAMIC BALL BEARING IN HOFFER TURBINE FLOWMETERS

BACKGROUND

Several design elements are critical to the operation of the turbine flow meter. These include the number, angle and shape of the blades on the rotor, the flow conditioners used to develop the fluid's cross-sectional velocity profile, the moment of inertia of the rotor, the magnetic drag (if any) between the rotor and proximity sensor and the type and quality of bearings used to facilitate rotation of the rotor about the fixed shaft (or axis). Of all these elements, the bearings have garnered the most attention and criticism as being a potential failure point in the turbine meter design. The bearing types most commonly used in turbine flow meters include ball bearings, journal bearings and jewel bearings.

Of these three, the journal bearing is generally the most robust design and jewel bearings the least; often restricted to very low flow applications in the lab or pilot plants. Though inherently rugged, the journal bearing can only be used on lubricating liquids. The ball bearing has enjoyed the widest success in the turbine meter because of its combination of relative ruggedness and capability to be used on non-lubricating liquids and gases. This last feature is accomplished by constructing the bearing with a lubricating compound built-into the ball and race area. A molybdenum di-sulfide compound is typically used as the lubricating material. The balls, races and shields in these bearings have traditionally been built of a heat-treatable stainless steel such as 440C. These steels are generally a compromise between hardness for wear resistance and chemical resistance. They are not as resistant to chemical attack as austenitic stainless steel such as 304 or 316. The fact that the balls and races are built from the same material also increases the rolling coefficient of friction between the two components. Over time or under extreme conditions of load and/or ambient temperature, this fact will cause the bearing to deteriorate due to mechanical wear or galling. Exposure to corrosive fluids in the flow stream will act to accelerate this process. The normal expected life for a set of conventional ball bearings in a turbine flow meter operating under continuous is anywhere from 1 to 4 years without the presence of corrosives.

The Ceramic Ball Bearing Alternative:

Beginning in the mid-1980's, the Miniature Precision Bearings Group at Timken Company began development of ball bearing components made from non-ferrous ceramic materials. Various combinations of all ceramic and ceramic and 440C bearing components were tested in an effort to produce bearings that could withstand extreme operating condition and loads. One of the products that came from this development program was a self-lubricated, hybrid ceramic ball bearing. This design replaced the 440C ball in the bearing with ceramic balls while

retaining the self-lubricating compound and the 440C shields and races. In 1996, Hoffer Flow Controls began testing this bearing in turbine meters under extremely harsh conditions in an attempt to solve a bearing life problem. The application was the measurement of what turned out to be a wet landfill gas with substantial amounts of hydrogen sulfide. This combinations of wet gas and hydrogen sulfide caused conventional all 440C ball bearings to fail after only a few days of service. Field testing of the ceramic ball bearings produced outstanding results. The bearings performed flawlessly under these conditions for more than 3-years at last check. The initial success with this application led Hoffer to test the ceramic ball bearings on a number of other applications that produced similar results under extreme operating conditions. The bearings were tested on more conventional applications and the benefit derived from their use was an improvement in bearing life by factors of 2-to-5-times the norm. These successes have led Hoffer to decide to migrate away from the all 440C self-lubricated bearing to the self-lubricated ceramic ball bearing as the standard bearing offered in most of its turbine meter product line.

Technical Advantages of the Ceramic Ball Bearing:

Behind these successes are specific technical reasons why the ceramic ball bearing provides the customer with improved performance. These reasons include the following:

- Ceramic ball bearings are molded and finished to fine surface finishes. The smooth rolling surface of the ceramic balls reduces the friction between themselves and the 440C races. Reduced friction means decreased wear rates and increased life for the bearings.

- Ceramic ball bearings have extremely high compressive strength. In point of fact the limit for compressive loading of a ceramic bearing is a function of the steel races rather than the ceramic ball. The ability to resist higher compressive loads means the ceramic balls better resist any shape change deformation that would lead to uneven rolling action that will lead to bearing failure.

- Ceramic balls are twice as hard as a steel ball. Hardness is the critical property of a bearing's ability to resist wear. In general, the harder the material the greater its wear resistance.

- Though they are significantly harder than 440 C balls the density of the ceramic balls is approximately 40% that of bearing steels. This reduction in mass leads to reduced radial loads on the races which contributes to increased bearing life.

- Ceramic balls running on steel races have a reduced requirement for lubrication as compared to conventional all-steel bearings. Lubricant failures in bearings are typically traceable to the micro welding of mating asperites between the balls and races. Such localized fusion between the steel race and ceramic balls does not readily occur. Bearing life can be dramatically improved with such a change.

- Ceramic balls are very dimensionally stable and do not undergo phase changes during operation. Conventional steel balls retain small amounts of austenite that can transform during operation resulting in dimensional changes to the ball. The degree to which this becomes an issue for steel bearings is a function of the base material, the heat treat process and the actual operating conditions.

- The ceramic balls are far more chemically resistant that 440C balls. Once the balls corrode, they begin to damage the races. Even though the races are made of 440C themselves, the running surfaces are less susceptible to corrosion because of the internal self-lubricant provides considerable protection to these surfaces. The lubricants do not provide nearly as much protection or resistance to corrosion to the 440C balls. Being inherently impervious to all but the most aggressive of chemicals prevents the ceramic balls from corroding and thus damaging the bearing race running surfaces.

- Finally the fatigue life of ceramic balls vastly exceeds that of the very best bearing steels. The crystalline structure of ceramics makes them all but impervious to fatigue. Care must be taken; however, with the steel races in order to keep loads to a level that does not accelerate fatigue life. In most hybrid ceramic ball bearing applications, the lighter mass of the balls will more than offset localized bearing loads on the steel races, resulting in significantly longer life.

Why Not Use an All-Ceramic Ball Bearing?

In addition to the ceramic ball bearings, Timken does also offer all-ceramic versions of these bearings. However, due to considerably longer lead times, much higher per unit costs and specific design limitations, all ceramic ball bearings are typically only used when no other suitable alternative is available. An example of where such bearings have been successfully used is in sensitive magnetic force and direction measurement instruments where their non-magnetic properties are critically important.

One of the design limitations on all ceramic bearings is their thermal properties. They are very sensitive to installation design due to the typically much lower coefficient of thermal expansion compared to most components into which they may be installed. Unless this issue is properly addressed, all ceramic bearings can loose contact between the outer race and the component into which they are installed with increasing temperature as the component expands and moves away from the outer race. Conversely, the bearing can be subjected to excess stress from components in which they are mounted when the temperature decreases and the components shrink around the bearing at a faster rate than the all ceramic bearing can contract. These nuances in the all-ceramic ball bearing preclude their ready use in turbine flow meters for the vast majority of applications.

Conclusions:

From the customer's standpoint, ceramic ball bearings provide a number of significant advantages that include the following:

- With their improved chemical resistance, ceramic ball bearings bring the advantages of low drag bearings to more corrosive fluid measurement applications than conventional all 440C bearings.

- Ceramic ball bearings consistently provide increases in bearing life over conventional 440C bearings. These increases in life expectancy have been demonstrated to be on the order of 2 to 5-times greater for ceramic ball bearings. With little of no increase in initial cost, these

bearings substantially reduce the long-term of ownership for the Hoffer turbine meter. This is of critical importance to many customers today who are facing decreased manpower plant maintenance including instrumentation. The ceramic ball bearings with their extended life expectancy reduce the annual maintenance burden and cost for the customer. Temperature range is -450°F to +550°F.

- The benefit of the ceramic ball bearing can be extended to existing Hoffer turbine meters the customer owns. As long as the existing meter is a ball bearing design, the new ceramic ball bearings can be readily interchanged with the conventional 440C bearings. These bearings may also be specified for replacement internals kits for Hoffer turbine flow meters.

To order the ceramic bearings in a new Hoffer turbine meter, use the designator “CB” in the meter part number section that designates the bearing type. The ceramic bearing is available of the HO Precision Liquid and Gas Meter Series, the HP Insertion Meter Series, the Mini-Flow Series, the API Petroleum Custody Transfer Series and the PG Premier Gas Meter series. For ordering details on replacement ceramic ball bearings or internals with ceramic ball bearings, contact the Hoffer Flow Controls factory.