IMPROVING THE RELIABILITY AND PERFORMANCE OF A MELT PUMP APPLICATION IN A PETROCHEMICAL PLANT WITH BLOCK STYLE UNIVERSAL JOINTS

by

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ABSTRACT

A major chemical company has implemented a cost reduction and performance enhancement via universal joints on a melt pump application. The melt pump is used to push molten polyethylene through a die to produce pellets. The pump takes material at 30 psig and 200°C (390°F) and discharges at 3000 psig. Misalignment between the gearbox and melt pump gear centers is approximately one degree. The authors jointly studied the existing problems associated with the gear spindles (high angle gear coupling): primarily reduced life, high maintenance, and high repair costs due in large part to high operating temperatures and the seal design of gear spindle at high misalignment, and proposed block style universal joints to solve the problems. The universal joints replaced the gear spindles supplied originally by the pump manufacturer.

This paper demonstrates the block style universal joints were able to:

- Significantly reduce plant downtime.
- Eliminate high repair costs associated with gear spindles, for this chemical company.
- Reduce wear and tear on the melt pump compared to gear spindles.
- Improve yield (or production) through superior performance and reliability.
- Reduce noise levels.

These block type universal joints have been running for over five years now and have been inspected once after 24 months of operation with only general wear and tear from normal operation. The paper will also demonstrates how the universal joints will continue to improve performance in the long term.

BACKGROUND

Eastman Chemical Company, at their Longview, Texas facility, uses a FMP-70 Melt Pump (supplied by Farrel Corporation) driven by a motor through a dual output reduction gearbox. The equipment was originally driven by gear spindles that were breaking down every two weeks, resulting in lost production and associated higher maintenance costs. Eastman undertook the task to improve reliability and performance of the drive to reduce downtime and resulting lost production. The melt pump is used to push molten polyethylene through a die to produce pellets. The pump takes material at 30 psig and 200°C (390°F) and discharges at 3000 psig.

OPERATING CONDITIONS

The application is driven by a 1000 hp constant torque, DC motor with a speed range of 850 to 1150 rpm, driving through a dual-output gearbox with a 27.87:1 reduction (Figure 1). Each driveshaft is required to transmit 1,033,200 lb-in at 30.5 to 41.3 rpm, with a minimum service factor of 1.5. The driveshafts are located between the gearbox and the melt pump. The shaft separation is 60 inches, with a parallel shaft offset of 1 inch for each of the driveshafts. The center distance between gearbox output shafts is 17 inches, and the center distance between pump shafts is 15 inches. Both the gearbox and the melt pump have straight, keyed shafts.

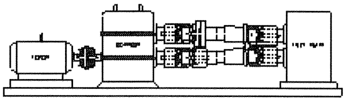

Figure 1. Melt Pump Drive Train. (Courtesy of Farrell Corporation)

As noted above, the melt pump was originally driven by gear couplings. Problems were experienced almost immediately with the gear couplings. Molten polyethylene is both extremely viscous (5000 Poise) and very hot (200°C, 392°F). This placed a high torsional load on the couplings. The heat from the melt pump shafts traveled into the grease cavity of the gear coupling. The grease was baked out, which produced tooth wear at a very high rate due to the high loading. In addition, damage to the melt pump itself was suspected to have been caused by thrust from the gear coupling. The teeth on an offset gear coupling move axially during a revolution to relubricate. If the lubrication is baked out from between the teeth, the resulting friction generates periodic thrust on the melt pump shafts. A plant shutdown had to be scheduled every two weeks to relubricate the couplings. During the two years of plant operation when gear couplings were in service, three couplings were worn beyond repair.

A study was launched to find a reliable, long-term solution for this application. The main concern was the operating temperature, specified as 250°F to 356°F at the outside of the melt pump. Due to this consideration, the driveshafts were required to be designed with either a provision for manual lubrication while operating, or with lubrication that would provide for a minimum of 18 months continuous, uninterrupted operation. Also, the top driveshaft was required to be designed with timing adjustment to allow the proper orientation of the top and bottom pump rotors.

DRIVESHAFT DESIGN

Universal driveshafts offer several advantages over gear spindles.

- *Universal driveshafts require less maintenance*—They require less grease for lubrication and lose less grease during operation than gear spindles, which commonly experience seal problems in tough applications.

- *Universal driveshafts have significantly less backlash than gear spindles*—Less backlash results in improved timing, reduced noise, and reduced wear and tear on the connected equipment versus gear spindles, which require a certain amount of inherent backlash that increases as the gear spindle wears.

- *Universal driveshafts are made up of fewer components than gear spindles*—The result is less inventory and lower storage costs.

Typical considerations in the design of universal driveshafts are torque capacity, misalignment, bearing life, and envelope (outside diameter) restrictions. For melt pump applications, high temperatures and timing adjustment must also be considered, as will be discussed later in the paper.

A size 350 D block style universal driveshaft was selected (Figures 2 and 3). The block style was selected due to its compact design. Block style universal driveshafts provide high torque capacity in a design that minimizes the diameter of the cross and bearing assembly (Figures 4 and 5). Also, the distance from the end of the shaft to the centerline of the cross and bearing assembly is minimized, increasing the distance between flex points in the driveshaft assembly, which reduces the operating angle. A reduced operating angle results in increased bearing life.

Figure 2. Block Style Universal Driveshaft.

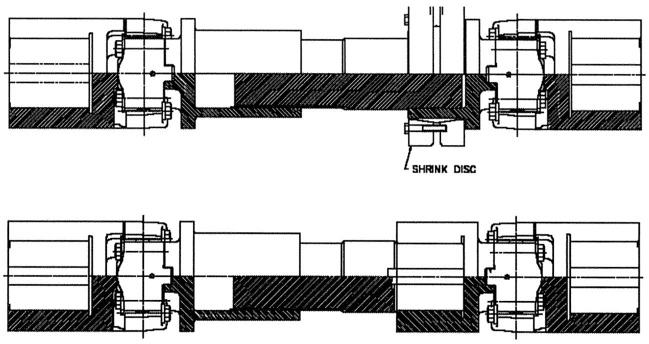

Figure 3. Top and Bottom Driveshafts for Melt Pump Application.

For this application, the size 350 D block style provides a 1.9 service factor and a calculated bearing (B10) life of 35,000 hours based on combined service at the resulting 1.2 degree operating angle.

HIGH TEMPERATURE CONSIDERATIONS

The temperature range of 250°F to 356°F was well beyond the limits of the standard bearing seals and greases used in typical driveshaft applications.

Block style universal cross and bearing assemblies are designed with a patented multilip seal design to keep grease in and contaminants out, a slinger to keep out fluids and contaminants, and the area is sealed using silicone rubber to further prevent contamination.

The standard cross and bearing assembly was modified to be used in high temperature applications. The standard seal was replaced with a fluoride rubber seal of special design with a temperature limit of 400°F, and the thrust washer was changed to a

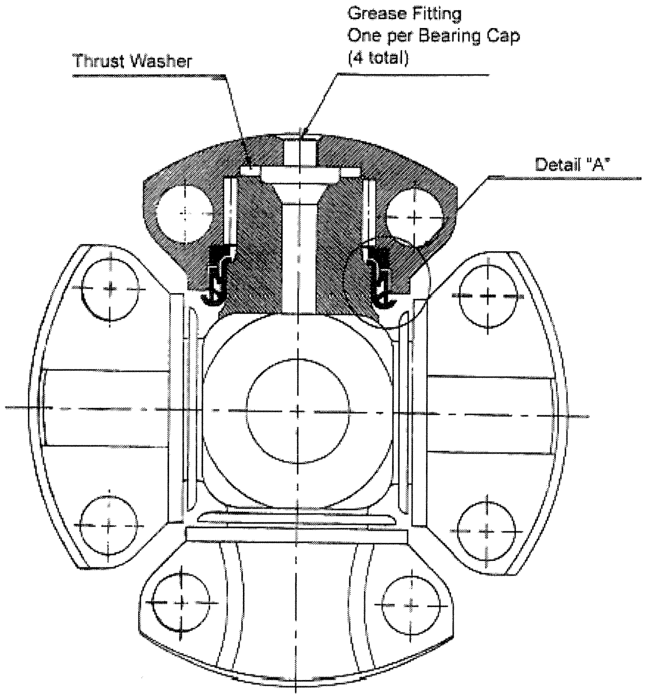

Figure 4. Block Style Cross and Bearing Assembly.

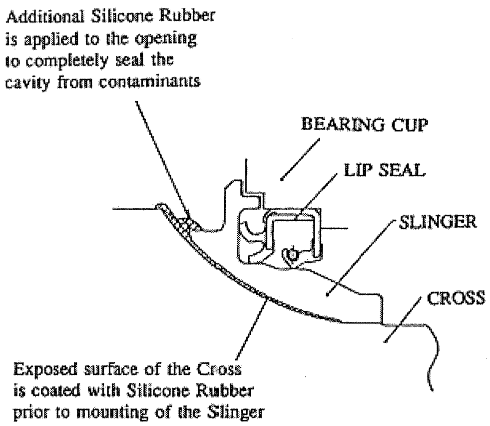

Figure 5. Detail of Block Style Cross and Bearing Seal.

special, high molecular plastic with a rating of 500°F. The standard bearing grease was replaced with a special bearing grease for high temperature applications, with a polyurea thickener and a temperature rating of 400°F.

TIMING ADJUSTMENT

Similar to the existing gear spindle, the top driveshaft was designed with a shrink disc connection. The shrink disc clamps the connecting hub to the shaft and transmits torque through the keyless hub to shaft connection. The keyless connection allows the ends of the driveshaft to be rotated relative to one another.

To set the timing of the pump rotors, the shrink disc connection is loosened and the shaft rotated within the connecting hub until the timing is correct (Figure 6). The shrink disc is then retightened on the connecting hub.

However, unlike a gear spindle that is infinitely adjustable for timing, universal driveshafts must be assembled with their two joints in phase within an acceptable tolerance in order to operate properly. A single joint does not transmit uniform angular velocity from input to output shaft. The output shaft accelerates and decelerates as it rotates through 360 degrees, based on the angle of misalignment.

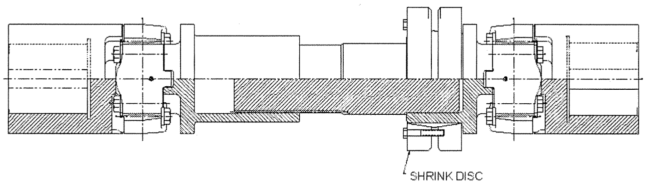

Figure 6. Shrink Disc for Timing Adjustment.

By using a universal driveshaft assembly with two joints installed in phase and operating at the same angle of misalignment, the second joint effectively negates the angular acceleration caused by the first joint, and the result is uniform transmission of angular velocity through the universal driveshaft assembly. Simply put, the output speed is the same as the input speed. When the joints are not in phase, however, the second joint will not compensate for the angular accelerations caused by the first joint.

The acceptable amount of phase difference for installation purposes is three degrees for this application (Figure 7). The top driveshaft was marked with indicators to show the proper orientation of the connecting parts and tolerance zone for proper installation when setting the timing.

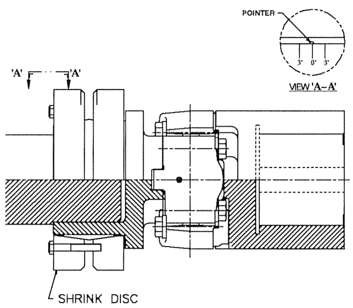

Figure 7. Timing Adjustment Range.

Since this was an existing application, and it was originally designed with gear spindles in mind, the keyways of the gearbox shafts and the melt pump shafts were not machined in any particular orientation. (New applications designed for driveshafts have all four keyways machined in a particular orientation to allow the driveshafts to be bored and keyed prior to shipment to the equipment manufacturer.) Therefore, the keyways were required to be machined onsite with the timing set as closely as possible to be certain that the driveshafts were nearly in phase when the timing was set and the driveshaft assemblies were installed (Figure 8).

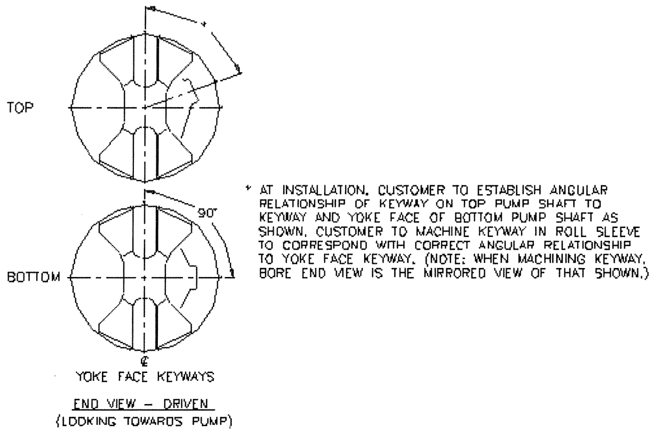

Figure 8. Final Machining of the Driveshaft Keyways.

The final fine adjustment of the timing was accomplished using the three degree tolerance allowed on the timing adjustment of the top driveshaft.

RESULTS

The universal joints have been in continuous operation for five years with no problems. After two years in service, the hottest, most highly loaded cross and bearing assembly (pump end) was removed for inspection. Only normal wear was present. The universal joints are lubricated quarterly during scheduled plant downtime for other reasons, whereas a forced shutdown every two weeks was required with the old gear couplings. This has resulted in an operational savings of $1 million over the five year period. An additional $0.5 million savings has been realized since the plant does not have to be shutdown to replace failed gear couplings every one to two years. It is also believed that improved melt pump reliability has been realized due to the elimination of the gear coupling thrust loading on the melt pump shafts.

It is clear that universal joints provide the best overall solution for melt pump drive applications for the following reasons:

- Rolling friction in bearings is superior to the sliding friction of gear couplings,
- Cross and bearing design limits heat travel into grease cavities,
- Grease retention is far better with a universal joint, and
- Power transmission to the melt pump is smoother and is thrust-free.

ACKNOWLEDGEMENTS

Melt Pump and Drive 3-D schematic provided by Texas Eastman from Farrell Corporation's operation/installation manual.