

**Recurring Failure of Slurry Pump due to Angular Contact Bearing Problems.**

**Introduction-**

A large Vacuum Evaporation Plant was using a belt driven Slurry Pump in part of the process handling a super saturated slurry solution.

The pumps never ran more than six weeks between overhauls and often much shorter.

This was leading to an unacceptably high maintenance spend on this part of the plant.

**Plant and Machinery details -**

Originally there was two pumps installed on this duty as a typical duty and standby pair.

However, since the pumps had proven so unreliable, the manufacturer was rewarded with an order for two more pumps.

A third pump was installed as a second standby pump and the fourth pump was the spare.

In fact the pumps were so unreliable and so difficult to repair that often there was two pumps being worked on at any one time.

The pumps are a typical single entry centrifugal process pump each driven by a flat belt transmission from its motor.

The pumps had packed glands sealing the shafts and the bearings are oil lubricated.

**Background Investigation-**

There was found to be a good record of documented failures of the pumps.

The plant had a good record of the pumps from installation to the present time detailing all the problems and various meetings with the pump manufacturers trying to resolve the unreliability.

The pumps are overhauled by an offsite specialist workshop with very high standards of workmanship and they too have excellent records of the failures.

In fact it was the recurring nature of the failures that prompted the workshop to contact the author in the first instance to look at the failures.

The process plants own maintenance staff installed and commissioned the pumps to a high standard.

**Stephen H Shakeshaft Consulting Ltd**  
**75 Mere Bank, Davenham, Northwich, Cheshire, CW9 8NB.**  
**Tel- 01606 331558 Mobile- 07779 190087 Email- [steve@shs-consulting.co.uk](mailto:steve@shs-consulting.co.uk)**

Investigation of the plant records revealed that the pumps bearing arrangement was originally a pair of back to back Angular Contact Bearings.

This is a common enough arrangement in a pump bearing casing.

The manufacturers had proposed to add a third Angular Contact Bearing to the arrangement in order to stiffen the shaft assembly and provide extra load carrying capacity.

The theory being that the belt drive needed an extra bearing to work satisfactorily.

These modifications had been carried out but had proven not to be as effective in dealing with the problems as had been predicted.

At this point, the manufacturers sold the customer two more pumps and effectively said that they wanted nothing more to do with the pumps since it was in their opinion something that the customer was doing to damage the pumps.

Unfortunately in such cases, this sometimes happens but the manufacturer continues to be “rewarded” with a high demand for spare parts from the beleaguered client.

The main causes for concern were in the area of the three angular contact bearings.

Without fail a pump was coming into the workshop with all three bearings completely destroyed.

The balls would be completely blackened, the cage disintegrated and the races likewise blackened and melted in areas.

There was clearly quite obviously something drastically wrong with this bearing arrangement as designed and executed.

Conversations with the repair technicians revealed one feature which was completely overlooked in the design of the bearing housing.

The bearings were located axially at the inboard end of the casing against an internal circlip.

This is a common method of axial bearing location, but one that the author believes is flawed in anything other than light duty applications.

There were a couple of problems with the circlip implementation.

Firstly, the circlip groove was so far down inside the pump bearing housing that it was almost impossible to insert the circlip and ensure it was definitely properly seated.

**Stephen H Shakeshaft Consulting Ltd**  
**75 Mere Bank, Davenham, Northwich, Cheshire, CW9 8NB.**  
**Tel- 01606 331558 Mobile- 07779 190087 Email- [steve@shs-consulting.co.uk](mailto:steve@shs-consulting.co.uk)**

The shaft with the non-drive end bearing already on the shaft, had to be passed into the housing, held halfway in and the circlip inserted.

Given that the shaft diameter for the bearings was 55mm, the bearing outside diameter around 120mm, the circlip was both difficult to compress and extremely awkward to insert with the shaft in the way.

Furthermore, there was no way to check that the clip was securely seated in its groove.

The other major problem with the circlip solution for axial location is that every time there was a bearing failure, it was very likely that the circlip groove would be damaged.

The axial location of the bearings by a circlip is not a good idea under such circumstances.

**Further Investigation-**

A detailed examination was made of several of the failed pumps.

Without exception the actual bearings were so badly destroyed that little could be determined from them except that they had failed catastrophically.

It was noted that the stack of three inner bearing races was held against a shoulder on the shaft by a circlip.

The outer races were located axially by an end cover, but the cover had a thick rubber gasket under it.

Looking at this arrangement it became obvious that there were a few very serious shortcomings in the design.

On bearings of the size used there is width tolerance such that the variance in thickness of a stack of three bearings can be significant.

Therefore, a circlip cannot positively locate the inner race against the shaft shoulder.

Likewise on the outer race, the end cover having a rubber gasket underneath means that the outer race is not clamped axially.

These oversights in the design mean that the balls in the bearings are free to skid and roll in any direction except the way they were designed to.

Additional shortcomings were noted in the design. The shaft used a slip on wear sleeve to take the abrasion from the packed gland assembly.

**Stephen H Shakeshaft Consulting Ltd**  
**75 Mere Bank, Davenham, Northwich, Cheshire, CW9 8NB.**  
**Tel- 01606 331558 Mobile- 07779 190087 Email- [steve@shs-consulting.co.uk](mailto:steve@shs-consulting.co.uk)**

This means that the overhung portion of the shaft from the bearing to the back of the impeller is thinner than it could be.

This leads to shaft flexing and premature leakage of product which in turn will contaminate the lubricant and shorten the life of the bearings still further.

The seals at the ends of the bearing housing were simple single lip seals. These are used for cheapness and availability, but the author believes they have no place in a serious process plant. Lip type seals cause scoring to the shaft and both allow contamination into the bearing frame and let oil readily leak out.

Following the detailed investigations, the following modifications were carried out to the pump-

1. A new pump shaft was designed and the three angular contact bearings were located against their locating shoulder axially by a standard nut and locking washer chosen from the SKF catalogue. The shaft tolerances were made such that there would always be a positive load on the inner races irrespective of the allowed thickness tolerance on the bearings.
2. Angular contact bearings from FAG were specified since these were the only manufacturer that had brass cages readily available ex-stock for their angular contact bearings. It was felt at the time that neither plastic nor steel cages were the ideal solution for this particularly arduous duty.
3. The overhung portion of the shaft was increased in diameter, the sleeve no longer being used. This considerably stiffens the assembly.
4. A cartridge type mechanical seal that wouldn't damage the shaft was chosen instead of gland packing. This reduces the likelihood of product leakage contaminating the lubricant.
5. The non drive end of the bearing housing had its deep groove ball bearing replaced with a brass caged single row roller bearing. The inner race of which was secured to the shaft axially with a nut and locking washer.
6. The end cover at the drive end and non drive end of the bearing housing were redesigned to ensure positive axial location of the outer races.
7. The lip seals were also disused and labyrinth seals used. In turn, this allowed the standard breather of the bearing housing to be replaced with a plug since breathing of the housing would be accomplished via the labyrinth seals rather than through the housing vent. This further reduced contamination from splashed product, the plug only being used to fill the lubricating oil.

**Stephen H Shakeshaft Consulting Ltd**  
**75 Mere Bank, Davenham, Northwich, Cheshire, CW9 8NB.**  
**Tel- 01606 331558 Mobile- 07779 190087 Email- [steve@shs-consulting.co.uk](mailto:steve@shs-consulting.co.uk)**

However, the most radical design was the assembly of the shaft and the angular contact bearings. Fortunately, the bearing housing was heavy duty with a very thick wall.

The housing was bored out by around 30mm and the shaft/bearing assembly was engineered into a separate cartridge that could be assembled separately and inserted into the main pump bearing housing as one sub assembly.

This meant that all the intricate assembly work could be carried out on the bench in an easily handled assembly and also meant that the troublesome circlip locating design was engineered out.

As a finishing touch, the rotating assemblies were all balanced to G2.5 or better.

### **Conclusions-**

The original vendor of the pumps appeared to have supplied a standard pump designed for direct electric motor drive but adapted to belt drive.

The shortcomings of this were immediately apparent in short mean time between failure (MTBF). MTBF's of three to six weeks being typical.

The vendor then made matters considerably worse by designing a modified bearing assembly that was so badly engineered, ignoring basic fundamentals of bearing design, such that the pumps became an operators nightmare.

Possibly the worst aspect of situations like this is that the vendor often gains considerable spare parts business as a "reward" for supplying inadequate equipment.

A critical re-appraisal of the design showed flawed engineering in every aspect of the bearing arrangement of these pumps and it was not difficult to improve the design significantly.

However, with many months of poor operating experience behind them and a hugely overspent maintenance budget, the client agreed to a complete custom design of bearing arrangement being designed.

It was an agreed objective that the pumps would continue in use (because they pumped well) but in a way that would free the user from going back to the original vendor for anymore spare parts or technical support.

The redesigning of the pumps proceeded and the pumps were successfully re-commissioned several weeks later.

**Stephen H Shakeshaft Consulting Ltd**  
75 Mere Bank, Davenham, Northwich, Cheshire, CW9 8NB.  
Tel- 01606 331558 Mobile- 07779 190087 Email- [steve@shs-consulting.co.uk](mailto:steve@shs-consulting.co.uk)

**Follow up-**

The first pump to be converted to the new design operated for three years without maintenance.

All the pumps have been converted to the new design and to prevent degradation of the standby pumps (which are really no longer required) only a single operating pump is installed at any one time.

In between three yearly overhauls the only attention required by the plant staff is to periodically wash any crystallised product away from the mechanical seal since the duty being a saturated solution tends to form crystals at the seal/shaft interface.

The pumps continue to operate completely trouble free and the days of regular panics over these pumps is long since forgotten about.

Stephen H Shakeshaft IEng MIMechE MIET MIIE

© **Note-** This paper is copyright of Stephen H Shakeshaft Consulting Ltd. It may be reproduced or used by third parties provided permission is first sought from the copyright holder.

**About the author-**

Stephen H Shakeshaft is a Mechanical Engineer based in the United Kingdom. He is the Principal Consultant and Director of Stephen H Shakeshaft Consulting Ltd., an engineering consultancy specialising in optimisation of existing assets and engineering design of new build projects.

Stephen has over 30 years experience of working at the “sharp end” as well as the “back room” of manufacturing industries with clients in the chemical, utility, metals, industrial gases and pharmaceutical businesses.

Stephen is a registered professional engineer in the UK and is a corporate member of both the Institution of Mechanical Engineers and the Institution of Engineering and Technology.

Stephen H Shakeshaft Consulting Ltd. can be found on the internet at the following URL-

[www.shs-consulting.co.uk](http://www.shs-consulting.co.uk)

The consultancy welcomes contact from all who are interested in plant and machinery maintenance, systems and development.