

**Failure of Cooling Fan Shaft Bearings.**

**Introduction-**

A facility manufacturing intermediate compounds for plastics manufacture has a large number of air cooled systems where there are many fans driven by electric motor and speed reducing pulleys.

Over the years they had been suffering many premature bearing failures on the fan shafts.

**Machine details-**

The process and service fluids are cooled through banks of finned tube air coolers.

There are long banks of these coolers arranged as cells in an elevated steelwork structure.

The cooling fans are installed vertically underneath blasting air upwards into the coolers.

Despite all the fans suffering premature bearing failure at one time or another, there were in fact two different types of arrangement installed.

One arrangement used spherical roller bearings fitted to the shafts on taper sleeves, with the bearings installed in plummer block housings.

A second type of arrangement used deep groove ball bearings manufactured integrally with the bearing housing. This is a lighter duty arrangement that is fitted to the smaller of the fan coolers.

**Initial investigation-**

This plant had lived with having a high number of coolers under maintenance for a long period of time.

Comprehensive maintenance records were not available, but the operating and maintenance management's both confirmed that there were regular breakdowns. Historically, the situation had been managed due to the plant operating well below its maximum capacity so regular breakdowns were not a problem.

However, a change in the market led to the plant having to run at high capacity. This combined with a period of unusually warm weather meant that fan breakdowns suddenly became a high priority and were limiting production.

Inspection of failed bearings in the local plant workshop showed that the two

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arrangements were suffering from different failure modes as maybe expected from two quite different bearing types. However, as will become clear later, there are certain similarities in how the problems arose.

The spherical roller bearings are of 65mm bore and are fitted to the shaft with taper sleeves.

Failures of the bearings were characterised by overheating of the races and breakage of the plastic cages. The bearings are not located axially against a shoulder on the shaft. The axial position is set by measuring the correct position and tightening the taper sleeve. Axial location of the bearing is set in the top plummer block with a locating ring, whilst the lower bearing is allowed to float axially in the housing.

The drive pulley was below the lower bearing outboard of the bearing housing. It was noted that the bearings were standard clearance.

The deep groove ball bearings are of the type made with an integral housing so they could be easily bolted in position. The shaft diameter is 50mm. The bearing inner race is extended axially and incorporates a grub screw for locking the inner race to the shaft.

The failures of these bearings was characterised by overheating but with fatigue spalling of the races as well.

When the bearing was sectioned it could be clearly seen that the wear track was offset from the centre of the races. This condition indicated a high axial loading and the fatigue of the races showed that the bearing was suffering an overload in the axial thrust direction.

The axial location of both the top and bottom bearings was set by the inner race butting against shoulders on the shaft.

It was noted that the bearings are fitted with integral seals and are lubricated for life.

#### **Further investigation-**

It was agreed that I would work with the maintenance technicians whilst they were repairing some of the fan coolers.

Firstly I worked with the technicians on the units fitted with spherical roller bearings.

The installation of these units was characterised by a large amount of grease spilling out from the plummer blocks. The bearings were lubricated by grease gun from a remotely positioned grease nipple connected to the plummer blocks by plastic piping.

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Looking at this it was obvious that the operations team were resorting to regular greasing of the bearings in an attempt to keep them running longer.

In fact they were completely filling the bearing housings with grease and the excess was being ejected through the seals.

What was also obvious from the grease spilled was that this was a high specification grease with solid lubricants since the colour of the freshly ejected grease was dark grey. This level of dry lubricant package shouldn't really be needed for this kind of duty.

The maintenance supervisor confirmed that they had upgraded the grease to a type with a high level of extreme pressure (EP) and solid lubricant additive in an attempt to lengthen the life of the bearings. The plant was paying a significant premium for this type of grease.

Inspection of the shafts where the bearings were locating showed a high degree of scoring which in turn was effecting the diameter of the shaft.

The technicians were aware of this and were also aware that the axial location of the fan assembly was secured purely by the friction of the taper sleeve onto the shaft. When fitting the bearings the technicians were making sure as best they could that the shaft assembly was located firmly by tightening up the taper sleeves as much as they could.

They also packed as much grease into the plummer blocks as they possibly could. This was to make sure that the bearing had "plenty of grease".

When the fans were put back into service the bearings ran hot straight away. I was told that "they always run like that".

There were certain things that stood out during this exercise-

The technicians understood the need to secure the shaft axially and that the scoring caused by previous failures to the shaft compromised this security.

The technicians had been given no information on how to fit the spherical roller bearings properly.

Due to the above facts they over tightened the taper sleeves reducing the bearing clearance to zero.

The technicians thought they were doing a good job by getting as much lubricant into the bearing housing as possible.

As a result of the above findings the following actions were taken-

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New shafts were obtained for the fans to make sure there were no security issues with the taper sleeve. However, it is not really good practice to rely purely on friction for axial security on a heavy duty assembly. It was agreed that this issue was to be pursued as a redesign of the shafts.

The technicians were given a training course explaining the approved methods of fitting spherical roller bearings to taper sleeves. Two methods were discussed, the “drive up” method where the distance the bearing is driven up the sleeve is measured and the internal clearance check method.

A laminated card was issued to each technician explaining the methods with an instruction to use the drive up method by counting the turns applied to the lock nut and then double check the internal clearance of the bearing with feeler gauges.

The bearings were re-specified to C3, increased clearance. This meant that the bearings could be secured on the shaft with the taper sleeve but there would be a definite amount of measurable clearance in the bearing to check for with feeler gauges.

The importance of not filling the plummer block with grease was explained to the technicians.

The re-greasing facilities were removed and blanked off so that the bearings couldn't be over greased after fitting.

The grease was re-specified as a NLGI2 Lithium complex grease without any of the extreme pressure additives or solid lubricants. This specification is more than adequate for the duty.

An automatic greasing cartridge was installed with a setting to top up the bearing housing over a one year period.

The results of these changes were immediate and dramatic. The bearings settled down over few days, running only about 10 to 15 Celsius above the ambient temperature.

The installations also were much quieter.

It was immediately obvious that there had been a step change in the running condition of the bearing installations.

Attention then turned to the smaller bearing arrangements fitted to the remaining fans.

With the success of the larger spherical roller bearing installations behind us the maintenance team were very keen to get to the root cause of the failures on the

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smaller deep groove ball bearing installations.

Again I worked with the technicians on several of the fan assemblies to look at the underlying causes of the axial overload condition causing failures of these installations.

On the shaft of the 50mm bearing assemblies, the inner race of the bearings were located axially against a shaft shoulder.

The bearings were threaded onto the shaft and the inner races were abutted against the shoulders and a grub screw tightened up to secure the inner race to the shaft.

The flanges of the bearing housing were then bolted down to the steelwork frame.

The pulley and fan then secured and the belts fitted.

The assembly was in fact very simple and the technicians had been carrying out the work for years.

However, there are a couple of fundamental problems with this arrangement.

Both bearings were located against shoulders giving a fixed distance between the bearing housing flanges.

The shafts, naturally, were all slightly different giving slightly different distances between the flanges. In addition of course, the steelwork frames were all slightly different too.

So whatever happened, when you located the bearings against the shaft shoulders, secured the grub screws and then bolted the assembly to the steel frame, you were absolutely guaranteed to have an axial preload on the bearings because all the assemblies were slightly different.

Once this was pointed out to the technicians and their supervisor they were extremely keen to resolve the issues.

In fact once the problem is understood, the solution is very simple-

The locating shoulder was machined off the upper bearing location on the shaft.

This meant that the axial location and axial load from the fan is carried on the lower bearing (the fan blows upwards so the thrust is downwards).

The bearing housing flanges are then fastened down before the inner race grub screws are tightened.

These simple modifications and change in the fitting procedure were documented and a procedure given to each technician.

As with the larger spherical roller bearing installations, the effect was immediate and stunning.

Quieter operation, less heat generation and a much more satisfied operations management.

### **Conclusion-**

In both cases installation of these fan shafts was introducing an overload condition into the assemblies.

The bearings really had no chance at all to perform correctly, yet looking at the shafts installed one would be forgiven for thinking that the assemblies were so simple that nothing could possibly go wrong.

In the case of the spherical roller bearings the maintenance team were focused on the aspect of axial security.

This was a focus given to them by the original designer not understanding that on a heavy duty fan assembly it is simply not good enough to rely on shaft sleeve friction to secure the axial position of the fan.

The maintenance team being well aware of this shortcoming did their best by tightening the bearing as tightly as possible.

For many years they coped with this strategy until fan failures became a limiting factor on the plant. Once the root cause of the failures was explained to the maintenance team they were very enthusiastic to implement the required changes.

On the smaller units, the original design of the shaft assembly provided axial location for the bearings, but the designer hadn't understood that when the assemblies are built in the field, it is impossible to exactly match the centre distance between the bearing flanges and the steel work locations.

In both cases, simple and straight forward modifications solved long standing reliability problems.

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The cost of the solutions was as close to zero as makes no difference. But the consequential savings in the maintenance budget, the gains from resources redeployed on more important tasks and the increased production run into tens of thousands of Dollars annually.

#### **Follow up-**

The plant is now operating these fans without breakdown maintenance.

Re-lubrication of the spherical roller bearings is carried out as an annual planned maintenance task.

The bearings are changed every three years, but presently it is being considered whether to make the PM change out at five years, considering the lack of failures to date this seems a good strategy to consider.

The 50mm deep groove ball bearing assemblies are sealed for life with lubricant and are changed every three years.

To date there has been not a single breakdown of the fan drives and the memory of the unreliability once caused by these units is fast disappearing into history.

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#### **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.

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