

Failure of Cryogenic Gas Expander Thrust Bearings.

Introduction-

An Oxygen production plant inside a steelworks is using a gas liquefaction plant to take Oxygen gas produced during low gas usage periods and liquefy it for use during high gas demand periods.

Machinery details-

The liquefaction of Oxygen is a cryogenic process.

The refrigeration for the liquefaction of the gas is provided largely by gas expansion turbines (expanders).

The energy extracted by the expansion turbines from the gas as it expands and cools is used to drive a compressor.

If the expander and compressor share opposite ends of the same shaft, the unit is known in the industry as a “compander”.

This plant has two companders operating in parallel on a gas liquefier.

The companders are high speed rotating machines, running in this case at around 46000 rpm.

The machines have oil lubricated bearings of the tilting pad white metal type, with the lubricating oil fed by an electric pump on a separate skid assembly.

The plant is located in an area that is subject to periodic losses of power from the public electricity supply completely without warning.

Of course, when the plant loses power, the liquefier is instantly tripped and the companders run down without a supply of oil from the electrically operated lubrication pump.

Initial investigation-

The plant engineer and plant manager were concerned by the trends on the plant DCS system.

The trends showed that when the liquefier tripped, the axial thrust bearing of both the companders actually showed an increased temperature as the units came to rest and for a short time after they had stopped.

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

Initially it wasn't thought to be significant enough to be a major cause of worry.

However, I visited the site when the liquefier had been tripped and the plant manager suspected that both his companders had been damaged.

Simple checks made by the local staff confirmed that they had indeed got problems with the machines.

The axial thrust bearings had been destroyed in the trip. The first check was to remove the gravity fed drain off the units and look for signs of melted white metal from the bearings.

Sure enough, some fragments of melted white metal were found indicating a bearing problem.

Next the local technicians removed a housing and made a check on the axial shaft float.

This was larger than the specification and confirmed there was a problem.

At this stage it was decided to visit the site for further troubleshooting.

The companders are fairly compact machines weighing about 600kg each but are set-up such that they can be unbolted and replaced with spares supplied as "plug in" modules.

When I arrived at site the local technicians had prepared the machines for removal and the machines could be removed and partially stripped at site before returning them to the vendors overhaul workshop for complete overhaul.

When the machines were removed it could clearly be seen that there was a large amount of melted white bearing metal in the oil system return piping.

This indicated major bearing failure.

Further investigation-

Whilst the plant technicians were installing the spare companders several system checks were made including-

System non return valves.

System shutdown valves.

Correct calibration of seal gas pressures and checking filters for cleanliness. Seal gas pressures are used as partial thrust balance on these machines.

System cleanliness.

All control systems and vibration and speed measurement systems.

Lubricating Oil skid pipework, pump and filters.

During these checks no obvious faults were found. However, discussions about how the system shutdown safely on power failure led to a discussion about the rundown of the machines on power failure which obviously shuts down the oil pump as well as the rest of the plant.

The oil system is fitted with an accumulator. This is fitted so that it acts as a reservoir of oil pressurised by an internal bladder filled with nitrogen. The design is such that when commissioned it is to be filled with low pressure nitrogen to around 0.2 to 0.3 Barg.

When the oil system is operating, the oil pressure is between 2 and 3 Barg.

The oil will fill the accumulator vessel and push the internal bladder flat. When the electricity is lost to the plant, it is intended that the bladder will push the oil from the accumulator vessel to the compander bearings for a number of seconds after the plant has tripped.

The design intent is that the oil flow from the accumulator is sufficient to cool the bearings and lubricate them during the critical period just immediately after the loss of electricity to the plant.

The more this was thought about, the more it became clear that the accumulator had something to do with the failures.

It was suspected that the bladder had ruptured, since externally there was way to know.

However, when the pressure inside the bladder was checked it was found to be 3 Barg with the lubrication system shutdown.

This meant that the accumulator was entirely dysfunctional.

The bladder pressure was close to the oil system operating pressure and thus the accumulator held little or no oil.

When the companders tripped there was no reservoir of oil to provide protection while they were running down.

An inquiry into this revealed that a maintenance supervisor had thought that by increasing the bladder pressure of the accumulator, it would last longer. He thought

of the nitrogen pressure in the sense of the nitrogen being in a buffer tank and the higher the starting pressure, the longer it would last. Apparently, the supervisor went on to say that he thought the accumulator must be too small and he was going to fit a much larger one.

Of course, this logic was completely wrong since it is the volume of available oil that is important not the volume of nitrogen.

The bladder pressure was reset and the plant re-commissioned.

Conclusion-

A simple misunderstanding by a supervisor who didn't fully understand the consequences of what he was doing led to the oil accumulator vessel being over pressurised by a factor about 10 times.

He had done this with the best of intentions when the plant was first commissioned because he didn't think the bladder pressure was high enough.

This led to failures in the thrust bearings of the companders that would lead to repair costs of more than \$120,000 for the two units not including the costs of changing the units out.

When the thrust bearings failed it allowed components such as impellers to touch housings etc causing multiple components to have to be replaced during overhaul.

If the accumulator pressure had not been checked the failure would have happened all over again.

This failure again illustrates the need for all staff to be aware of the need for stringent completion of plant change control documents and strict adherence to the procedures.

Had such a system existed at this site and had it been initiated by the supervisor when he wanted to change the pressure in the accumulator, it is highly likely these failures could have been avoided.

Follow up-

Following on from the adjustment to the bladder pressure in the accumulator, the companders have performed faultlessly for a period of in excess of ten years at the time of writing this report.

The reliability of the public electricity supply has not improved, the increased reliability is entirely due to the accumulator functioning properly and supplying sufficient oil while the units run down following a trip.

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

Stephen H Shakeshaft IEng MIMechE MIET MIIE

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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.

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

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