

Miscellaneous

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MECHANICAL SEALS ON PROCESS PLANT

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Applications in process plant

Many types of chemical process plant need to seal a rotating shaft where it passes into a containment system for hazardous fluids. Most commonly this will be a pump, but a similar requirement exists on compressors, on agitator shafts associated with stirred vessels, centrifuges and other plant. Where hazardous liquids or gases are being processed, the seal will nearly always be a mechanical seal, which typically comprises a rotating ring shaped carbon element forced against a harder flat surface.

To handle hazardous liquids and gases safely, particularly where the plant operates under pressure, the whole of the containment system needs to be built to a high standard. There are detailed codes for pipework and pressure vessels, but there is less information about mechanical seals, although these are widely regarded as the weakest link in many containment systems. As the weakest link they deserve some attention during any assessment of the integrity of process plant. This note gives a summary of the technology, as it affects safety, experience of seal failures and suggests approaches to inspection of this common item of process plant.

Design types

The design of seals and sealing systems is complex, and there are very many different types on offer, from a comparatively small number of specialist suppliers.

Variations in type include seals described as balanced or unbalanced, those with or without one element attached to a bellows, and in the range of materials used for the various components, particularly the hard face and static seals. Proper selection requires close co-operation between seal maker and the user, but many users may have insufficient knowledge or experience to understand all the factors that need to be defined in order to make a sensible selection. There is inevitably a tendency to leave the selection to the seal supplier.

Parameters that will always be important are: service pressure, range of operating temperatures, any corrosive properties of the fluids involved, rotation speed, together with properties of the sealed fluid such as boiling point, and the presence of any dissolved gases or solids.

Hydraulic forces keep the sliding surfaces in close contact when the system is running under pressure, while springs or a bellows are provided to keep the system sealed when it is not pressurised.

The mating surfaces are machined to very close tolerances, to minimise the flow of fluid past them, but all mechanical seals are designed allow some flow between the surfaces, in order to provide lubrication, and remove frictional heat. Flow rates on seals performing as intended commonly amount to a few grams/hour, and this may not be detectable visually.

Manufacturers have internal guidance their engineers to help them recommend particular types of seal, but this is often not available to the user. Some manufacturers offer training to users on correct installation of their seals.

Failure modes

Operating experience across the oil and chemical industries suggests that early failures, from poor selection, installation or operation dominate the overall failure data, and that very few mechanical seals actually wear out. Some American data analysed failure modes as follows:
40 % operating problems (e.g. operating outside the design intent)
24% assembly errors, misalignment
19% faulty design of the lubrication circuit, this leads to overheating and degradation of the seal faces
9% poor selection of seal components, e.g. failure of polymeric static seals by chemical attack
8% miscellaneous
Failure may not create a serious safety risk, as it is often a gradual process and there are a range of ways to reduce the consequences, and many failures do not give rise to a gross leakage.

Approaches to limiting the leakage

In many circumstances a single seal is sufficient, and gradual deterioration in performance can be tolerated. If this is not the case, the simplest option is to fit some type of auxiliary seal, which may be described as a throttle bush, a floating carbon bush, an abeyance seal or a lip seal. The space between the seals may be ventilated to a safe area, as an additional precaution.

A higher level of integrity is provided by double or tandem seals. A tandem seal has two similar seals, orientated to face the same direction, and a barrier fluid circulates between the seals. The outer seal is capable of taking the full duty of the inner seal, and any leakage is contained in the barrier fluid. Usually the pressure in the space between the seals is approximately half the pressure to be withheld, and any product leakage is out from the system into the barrier fluid.

If the product is a very poor lubricant, or any leakage is unacceptable, double seals are used. These face in opposite directions, and the fluid between them is held at a pressure higher than the pressure in the main plant. Flow between the seal faces is then from the barrier fluid into the containment system. Some contamination of the product by the barrier fluid must be acceptable with this type of arrangement.

In principle such double or tandem seal systems offer a very high degree of reliability, but they may in practice be vulnerable to common mode failure. For example both seals could be affected at the same time by excessive vibration, loss of barrier fluid leading to overheating, or faulty assembly.

A book published by the Institution of Mechanical Engineers gives advice on the use of these secondary sealing techniques, based on a crude rating of the toxicity of the contained fluid. It also suggests that for flammable liquids or gases, an auxiliary seal is the minimum requirement, and often a secondary mechanical seal will be required.

The selection scheme in the I Mech E book cannot be wholeheartedly recommended, as it does not address the consequence issue. It is clear for example that a small leak of some toxic gas is likely to create a greater risk if it leads to an occupied area indoors than in an open air plant. What matters more is that the plant operators have attempted to address the risks in a coherent fashion, and have adopted high integrity systems where even a moderate leak would create a high risk.

Ignition risks

Mechanical seals generate significant heat, even when running normally. In badly designed systems, this can contribute to early failure if the liquid film between the mating faces starts to boil. It is difficult to measure directly the surface temperatures that can be reached, but the temperature rise can reach 200°C. Power losses within the seal are often a kilowatt or more, but with large seals on high pressure, high speed duty, power losses can reach 20 kW. Technically, seals would seem to fall within the definition of equipment under the ATEX

directive, and when power losses of this order are possible, it is hard to argue they create no risk of ignition. So far this issue has not been addressed by the manufacturers. It is very hard to quantify either the probability of seal failure, or the leak that might be expected from some major failure, but single mechanical seals should generally be seen as secondary sources of release giving rise to a zone 2 hazardous area. Actual examples of fires caused by seals are hard to identify from the accident literature, as often seal failure is a consequence of bearing failure on the same pump and either may have provided the ignition source.

Maintenance

Mechanical seals do not normally need routine maintenance of the critical components, and it is generally advised that the running faces are not separated until they have to be replaced. Maintenance is more likely to be limited to ensuring that the barrier fluid in a double or tandem arrangement is uncontaminated, and is circulating properly as intended. The fluid may need to be topped up, or replaced, and filters in the circuit may need to be cleaned. Misalignment of shafts and seals as a result of excess vibration or mountings working loose may usefully be checked in any planned preventative maintenance programme. Increasingly pump maintenance is undertaken by specialist contractors, and they will make choices about replacing or repairing seals. It is clearly important that for critical applications the plant operator chooses a competent contractor, and that the contractor understands how and where a pump they are servicing will be used.

Defining the point at which seals should be replaced is not simple. The I Mech E book suggests that a leakage rate of 250 times the expected value for a new seal may be the point at which a seal can definitely be said to have failed, but much depends on the fluid being sealed and the location of the plant.

Manufacturers have tried to reduce the frequency of early seal failures by selling cartridge seals, which require much less on-site assembly. The use of such seals should be encouraged, and American Petroleum Institute codes require their use for some applications. Mechanical seals will inevitably need replacement at some point, and they are difficult to flush completely clear of the product being contained. Maintenance instructions should assume that the fitter will be exposed to the product fluid, and specify suitable protective clothing and a safe system of work.

Sources of further information

The most comprehensive reference is published by the Institution of Mechanical Engineers, 'Mechanical seal practice for improved performance', 2nd ed 1992. The American Petroleum Industry Codes API 682 and 610 are also widely used though these do not cover all applications. Both the I Mech E book and API 610 have a check list for users, intended to help them correctly specify the type of seal to be supplied by a manufacturer.

Approaches to inspection

From the point of view of safety, the following factors need to be considered.

Is the fluid to be sealed toxic, flammable corrosive or some combination of these?

Is it a gas, that will disperse on release, or a liquid that could accumulate around the seal in the event of large leak?

Has any hazardous area been assigned around the seal?

Is there a policy to help plant designers decide where single seals need to be supplemented by auxiliary seals, or where double or tandem seals should be used?

Does this policy consider the location of the plant as a factor, where the consequences of any release are likely to be greater indoors than outside?

How would any failure be detected? In the case of gradual deterioration, at what point would the plant be taken out of service and the fault repaired?

Have the staff who undertake maintenance work on seals been suitably trained, and are they given adequate instructions when they have to dismantle seals which have contained hazardous fluids?

Where pump/seal maintenance is subcontracted, what information is passed to the contractors?

If seals have failed after a short service time, have the causes been investigated?

Feedback on operating and maintenance experience with mechanical seals in the chemical and gas industries would be welcome.