TAKING THE MYSTERY OUT OF MECHANICAL SEALS

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ABSTRACT

Mechanical seals may seem like a mysterious black box that only sealing experts can grasp. While there is some truth to this, technicians and plant operators who have adopted their use, have become increasingly confident in their application, allowing them to discuss mechanical sealing issues with experts comfortably. Whether you want to learn how a mechanical seal works or how the operating conditions of the equipment affect the seal, this paper aims to demystify mechanical seals. Discover technical details on sealing technology and the role of seal piping plans commonly found in the Water and Wastewater industry. While you may not become an expert overnight, you will certainly feel more confident in making business decisions based on their use.

1.0 INTRODUCTION

Although small in size, mechanical seals are an incredibly important and ingenious engineering product. They're not—as is often mistakenly believed—an immovable part. Instead, they function dynamically, adapting to fluctuating temperature and pressure during use. These stresses must be intricately balanced for optimal performance. This is achieved by using the correct design and ensuring the seal is operated in a manner that provides sufficient lubrication and cooling between the faces.
The aim of a seal isn't – perhaps somewhat surprisingly – to create a wholly leak-free interface. Instead, a small gap is formed between the rotating and stationary faces of the seal. As pressure increases during operation, the lubricating fluid (sealed product) migrates into the tiny gap (often less than 1 micron) between the faces. As the fluid travels across the seal faces, the pressure drops until it reaches atmospheric pressure.
Along the way, it picks up heat, and, in some cases, the fluid vaporises completely – in others, typically higher viscosity fluids (oils); this is noticeable as either a wetted surface or small droplets. Both scenarios are normal and explain why a small amount of leakage is necessary for proper operation. Another misconception is that seal faces are completely parallel to one another. The stresses seals encounter during operation mean there is always some distortion. A sealing mechanism is important in reducing this as much as possible. This is achieved by working with the thermal and pressure forces the seal is exposed to during operation and with the lubricating and cooling effect of controlled leakage between the faces.
Therefore, the goal of a mechanical seal is to:

- Ensure the opposing faces are as close together as possible to allow fluid to move between them but limit the leakage level.
- To overcome loading forces and keep the opposing seal faces as parallel and flat as possible.

2.0 DISCUSSION:
FIVE KEY FEATURES OF GOOD MECHANICAL SEAL DESIGN

More than just two seal faces are necessary to form a mechanical seal. Drive and energising mechanisms with springs and static seals (elastomers) comprise the remainder of a basic component seal. Combining the basic components into a pre-assembled preset cartridge using a. gland and sleeve creates a cartridge seal. The combination of this hardware must work to maintain the seal faces in place and cope with the operating conditions of the equipment into which it is mounted. While there are several different types of mechanical seals, each must focus on five vital fundamental design elements.

2.1 Protected Springs

The placement of rotary springs within a seal has historically been problematic. This is because the earlier designs positioned the spring on the rotating part of the seal. This puts them directly in the firing line of the process fluid, with a high potential for degradation due to chemical attack and/or becoming clogged. Placing the springs on the stationary face is also beneficial in high-speed applications and integral in coping with angular misalignment. Cutting-edge designs overcome this issue by isolating the springs from the process fluid, thus reducing the risk of spring damage, which can result in premature failure (Figures 1 and 2).

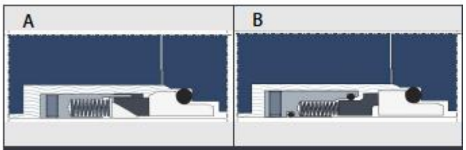

Figure 1. Springs inside pumped fluid (A) and springs outside pumped fluid "protected" (B).

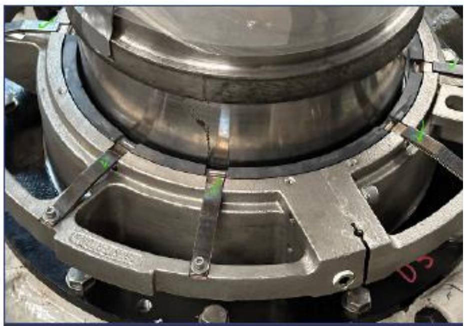
Figure 2. A split seal with Springs (finger type) mounted external to the seal for ultimate protection.

2.2 Balanced Design

As mentioned, creating the necessary hydraulic balance between the seal faces is crucial. At the most basic level, an advanced seal must overcome the load it is subjected to during use. As operational hydraulic force increases, so does the heat and distortion between the opposing faces. Therefore, utilising a design whereby only a small element of the sealing interface is under stuffing box pressure is key. This sensitive balancing act dramatically affects the seal's performance and is rooted in robust seal face geometric design. The less hydraulic load this adds, the better the seal's performance and suitability for higher temperature, pressure and speed (Figure 3).

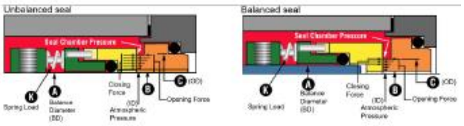

Figure 3. A graphical representation of how a mechanical seal diverts a portion of a system's hydraulic pressure to substantially reduce or "balance" the hydraulic pressure acting to close the seal faces.

2.3 Fretting and Non-Fretting Design

The placement of the dynamic elastomer of a seal plays a large part in reliability. Rotary seal operation has to overcome non-concentricity and out-of-square– nothing is ever perfectly aligned. Over time, this will cause fretting wear as the elastomer shuttles back and forth in compensation. While this could be moved into the seal itself, this causes wear in a different place. This is a self-fretting design. Instead, moving it to a location where it doesn't ride on a metallic surface largely removes the issue. This is known as a non-fretting design (Figure 4). While mounting the O-ring on the seal face does not eliminate fretting 100%, protecting costly shafts and sleeves by doing this certainly makes for a more repair-friendly seal (Figure 5).

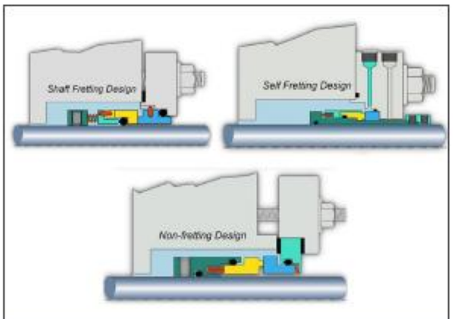

Figure 4. Fretting, self-fretting, and non-fretting.

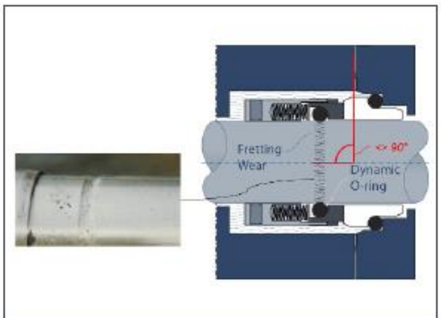

Figure 5. Typical fretting damage caused under O-ring on a stainless-steel shaft.

2.4 Monolithic Seal Faces

Old school (first and second-generation) seals were commonly designed with a sealing material within a metal holder. This is known as composite seal face technology. A third-generation design was introduced at the latter end of the 20th century. It was revolutionary because the entire seal face was made of a single material. Typically, this was graphite/carbon, tungsten or silicon carbide. This is called a monolithic seal face technology (Figure 6).

The major advantage is that the use of a single material means that there's no difference in expansion under temperature. In other words, both parts of the seal would thermally expand at the same rate. This dramatically helps control leakage, reducing seal face distortion (Figure 7).

Figure 6. Shrink-fit seal faces and monolithic seal faces.

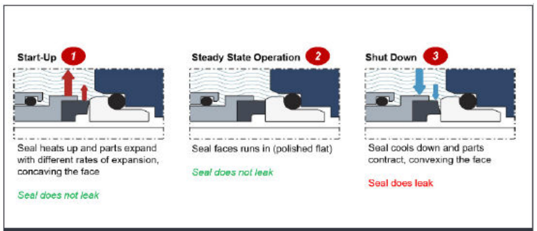

Figure 7. Seals with shrink-fit faces used in cyclic applications tend to leak when shutdown.

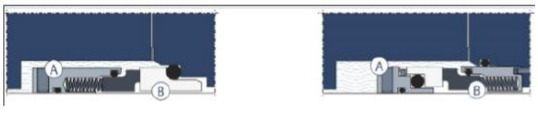

Figure 8. Rotary sprung seal design and stationary sprung seal design.

2.5 Stationary Sprung Seal Design

So, finally, the use of a stationary sprung design over a rotary sprung design reduces the number of times a spring must compensate per operational rotation. Remember, since nothing is ever perfectly aligned, ensuring a seal can cope with angular misalignment is important. Whilst trying to compensate for misalignment between the stuffing box face and the shaft centreline, the latter cycles once per rotation. This can and often leads to increased fretting and spring fatigue and the onset of early failure. Excess leakage occurs on equipment with significant misalignment as seal faces struggle to track closely at speed. Any separation of the faces can also allow small, suspended particles to migrate between the seal faces, causing damage to the sealing surfaces (Figure 8). The former and preferred designs cause the stationary face to take an initial angular set, which is determined by the amount of angular misalignment. This allows the seal to sit in this one position permanently for its installed life. The springs do far less work, and the seal faces track each other far better, resulting in better sealing.

3.0 SYDNEY WATER CASE STUDY

Sydney Water provides water and wastewater services to the Sydney metropolitan, Illawarra and Blue Mountains regions. Its area of operations covers approximately 13,000 square kilometres and comprises water and wastewater treatment facilities, distribution/collection network assets, and stormwater assets. In July 2020, Sydney Water launched its new infrastructure and delivery model – P4S: Partnering for Success – designed to simplify procurement, optimise value throughout the supply chain, and deliver $4 billion of construction works and services between 2020 and 2030. Water and wastewater specialists and Chesterton partner FITT Resources successfully tendered to undertake work in three main areas with the new delivery model: the repair and overhaul of submersible pumping units, centrifugal pumping units and positive displacement pumping units, with work commencing in April 2021. This included upgrading and maintaining raw sewage pumps using Chesterton 442 Split Mechanical Seals. These pumps had been initially fitted with packing and then later with cartridge seals. A decision was made to replace these with split mechanical seals to benefit from reduced maintenance time and costs.

Figure 9. Vertical split case sewage pump with Chesterton 442 split seal, ceramic hard face, vent drain and API plan #13 flush arrangement.

Sydney Water benefited from:
Using a split seal solution provides several advantages that make them well-suited for the water and wastewater industry. These benefits include:

- Equipment disassembly is not needed. With split seals, the only item that needs to be removed from the pump is the seal itself, which increases the safety of maintenance crews.
- Heavy lifting equipment is not required, which saves time and costs while improving safety. It also eliminates Pump Alignment, as heavy pump frames, bearing housings, and electric motors do not need to be moved.
- Reduced wear and leakage. Split Seals eliminate sleeve wear and leakage better when compared to packing.
- Visual indication when it's time to service. Split seals help reduce equipment maintenance and operating costs by visually indicating wear. This makes it easier to tell when servicing is required.
- Reduces or eliminates flush water usage. This can result in significant savings where precious potable water is traditionally used to flush packing and mechanical seals, including water reheating costs.
- Minimises production loss and downtime.

For more information on this case study, scan the QR Code:

3.0 CONCLUSION

Seal design is incredibly important. While commonly used equipment will often be suited to off-the-shelf seal design, oftentimes, equipment requires a bespoke solution. These five design principles apply to standard products as much to engineered seals (Figure 10). Spending some time defining the optimal seal/s to use brings multiple benefits. These include mechanical longevity, production efficiency and reduced leakage. A basic understanding of a seal's operation is crucial to choosing the right design. Spending some time getting this right by considering the five key design features can dramatically affect performance and, ultimately, production costs.If necessary, getting a sealing specialist to assess and recommend the optimum sealing package is a sure way to improve the bottom line and create a cleaner, safer environment.

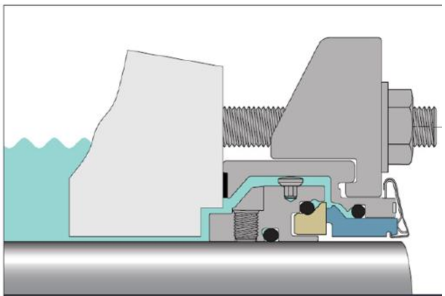

Figure 10. Example of a design that incorporates all five of the key design features.

4.0 ACKNOWLEDGEMENTS

Thanks to Fitt Resources and Imatech, our trusted distributor partners.
A 140-year-old A.W. Chesterton Company brand has a proven track record of enhancing critical industrial equipment and structures worldwide.

5.0 REFERENCES

1. The Fundamentals of Mechanical Seals, Part 2 by Alan Evans, A.W. Chesterton
2. "FITT Resources keeps Sydney Water pumping" Case Study by Jorge Mellado, A.W. Chesterton, in collaboration with our distributor partner FITT Resources.