Variable speed drive pumps
and mechanical seals

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The widespread use of electronic Variable Frequency Drives (VFDs) includes machine tools, production machinery, conveyor systems, fans, ventilation systems and pumps. The VFD controls the frequency of the electrical power supplied to an AC (Alternating Current) electric motor so that the motor's rotational speed is controlled. When a VFD is installed in
a motor-driven system, such as a centrifugal pump, the potential benefits include:-

- increased productivity
- improved product quality and process control
- reduced maintenance, energy consumption and downtime.

Today, VFDs are used with centrifugal pumps because they enable pump capacity variation, without adversely affecting the discharge control valve. Changes to the discharge control valve can alter the pumped head. As a result, this can have a negative consequence for the pump's Best Efficiency Point (BEP). It should be noted however that consequences can extend beyond such inefficiency.

The use of VFDs with centrifugal pumps is a preferred option where the system head is dominated by friction in the piping plan. Alongside flow flexibility, VFDs can eliminate the need for a throttling valve, thus negating the need for a bypass line and the maintenance of this. The most significant operational benefit of a VFD controlled pump is the potential to reduce heat which can occur from pump discharge throttling. This heat can cause the viscosity of the sealed media to change, the fluid to convert to coke, to vaporise (or flash) or to crystallise.

Unintended consequences with mechanical seals

With the increasing use of VFD controlled pumps, a key component which should not be overlooked is the mechanical seal. Likened to a fuse that can fail due to problems elsewhere within an electrical system, the mechanical seal is one of the most vulnerable components of a pump. Heat generated in the pump can change the condition of the fluid film between the seal faces, which is of critical importance to the reliability and performance of the seal.

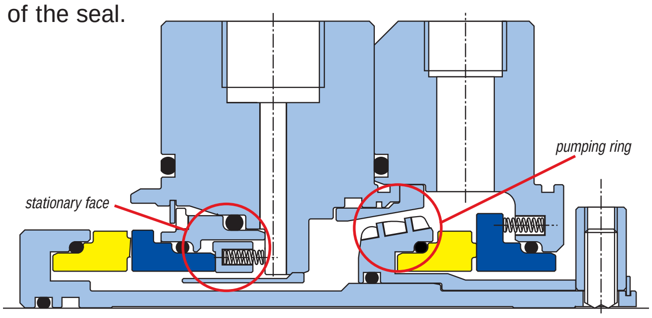

Fig. 1

Face flatness is another primary concern. Virtually all mechanical seals have counter-rotating seal faces. These faces are precision lapped to be extremely flat (typically better than 0.000022 of an Inch). Excess heat can distort faces: the level of flatness during operation is critical to the reliability and performance of the seal.

While the majority of mechanical seals use contacting seal faces, some seal designs use non-contacting face technology. This is typically achieved through hydrodynamic lift, which is created by a series of grooves in the faces.

Seal face separation is a requirement of such designs, which as per design, occurs at a given shaft speed. Below this, separation is either minimal or does not exist. At this point, the potential for increased face wear and indeed failure is a major concern. To avoid this, the speed required to achieve 'minimum lift' is a key concern prior to installing a VFD to rotating machinery. Furthermore, shaft speed fluctuations will affect the conditions seen at the seal faces and increase the likelihood of faces contacting, which can have profound consequences.

The opposite is true for contacting mechanical seal technology typically found in wet-based applications. It is generally accepted that the constraint is the PV (Pressure-Velocity) limits of the seal face materials used. Therefore, contacting designs are more susceptible to conditions prevailing near the upper speed limits of VFDs. Assuming that seal faces are selected in accordance with the appropriate seal face material PV limits, PV should not be a limiting factor for contacting mechanical seals. Two areas of mechanical seal design, however, should be considered.

The first is the 'configuration' of the seal. At high shaft speeds, typically greater than 23m/s, it is common practice to select a 'stationary' mechanical seal. This is where a seal flexing component is not rotating – see Fig. 1. This is in contrast to a 'rotary' mechanical seal, where the rotating component is flexing – as per Fig. 2.

At elevated shaft speeds, it is generally accepted that the force necessary to maintain face closure is so great, it adversely affects seal life. This is recognised by the Standard for the Oil and Gas Industry: API-682, 3rd Edition, Section 6.1.1.5.

Rotary seals, as per Fig. 2, have a greater tendency to experience spring fatigue and / or elastomer fretting when the seal chamber mounting surfaces are not perpendicular to the shaft. This is highlighted in Section 6.1.2.13 of API682, 3rd Edition.

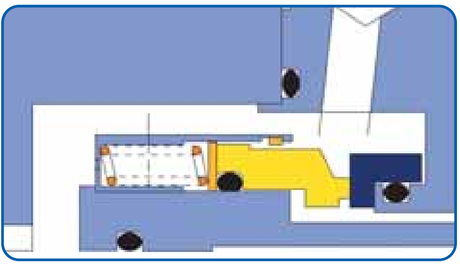

Fig. 2

Today, best practice is that a stationary seal design is more appropriate with a VFD controlled pump, proving a more robust sealing solution for higher shaft speeds.

The second issue concerns the ability of the seal to circulate barrier or process fluid during shaft speed variation. Many double mechanical seals have an integral pumping ring designed to circulate barrier fluid between seal faces and a seal support system. This is a closed-loop barrier system with the barrier fluid cleansing and cooling the seal faces, thus extending seal life. Fig. 1 shows the position of a tapered-vane pumping ring above the outboard rotary seal face. Some single mechanical seals also have pumping rings. These are typically used with API 682 Plan 23 Arrangements, as shown in Fig. 3. Similarly, the purpose of a pumping ring is to circulate barrier fluid around the closed-loop system.

Speed variations will have a direct effect on the flow rate and head produced by the mechanical seal pumping ring. At low shaft speeds, resultant flow from the pumping ring may be insufficient to overcome resistance from inherent flow constraints within the seal management system. This could lead to increased heat seen at the seal faces and consequently reduced seal life.

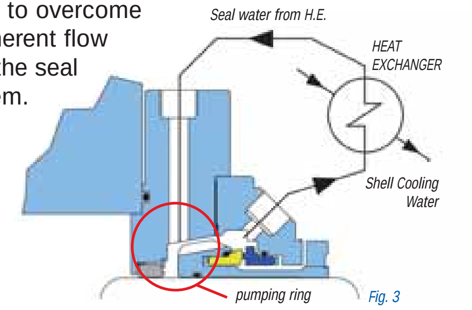

Fig. 3

The more efficient the seal pumping ring is at circulating fluid, the greater the scope to enable effective flow with a VFD pump. Design differences lead to some pumping rings being more effective than others. Some have close radial clearances between the stator and rotor which may touch, or even seize when using a VFD.

Best practice as prescribed by Section 8.6.2.3 of API-682 3rd Edition stipulates that radial clearances between the stator and rotor should be at least 1.5 mm (Fig. 4).

The effect of radial clearance

Close radial clearances between counter-rotating surfaces can lead to component contact and 'galling' or binding of the material.

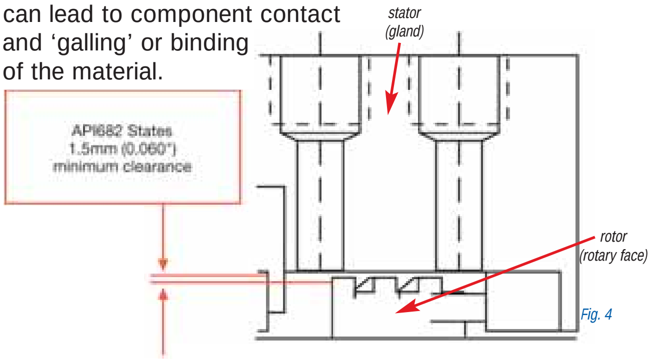

Fig. 4

By way of example, if a stainless steel rotary component contacted a stainless steel stationary component, 'galling' would occur. Notwithstanding this, some double mechanical seals are designed with radial clearances between 0.25mm and 0.5mm. This is in contradiction to API-682 (3rd Edition), which is technically correct as shafts are known to deflect.

The tapered vane pumping ring depicted in Fig 5 consistently delivered more flow and head compared with all other pumping rings when tested by AESSEAL®. This tapered vane pumping ring design has been featured in the design of over 20,000 double mechanical seals sold since 2000. Importantly, but unlike some other designs, it conforms to Section 8.6.2.3 of API-682 (3rd Edition). Furthermore, it is specifically advantageous for VFD applications, ensuring that the mechanical seal pumping ring continues to circulate fluid throughout the speed envelope of the pump.

In summary, VFDs will become increasingly popular as Plant Engineers strive to generate process improvements and reduce energy consumption. Mechanical seals used in such applications need to be carefully selected against operating conditions (considered throughout the life of the pump). Some seal designs are more capable than others of withstanding the associated speed envelope. Such a mechanical seal should have key attributes and capabilities. These include:

i) Contact seal face technology. This is better suited to the wide range of shaft speed applications.

ii) Stationary mechanical seals which have springs in the stator part of the seal rather than the rotating part of the seal are better suited to high shaft speed applications. Stationary mechanical seals are often found on VFD duties.

iii) Mechanical seal pumping rings which comply with API-682 (3rd Edition) specification and deliver the highest amount of fluid flow.

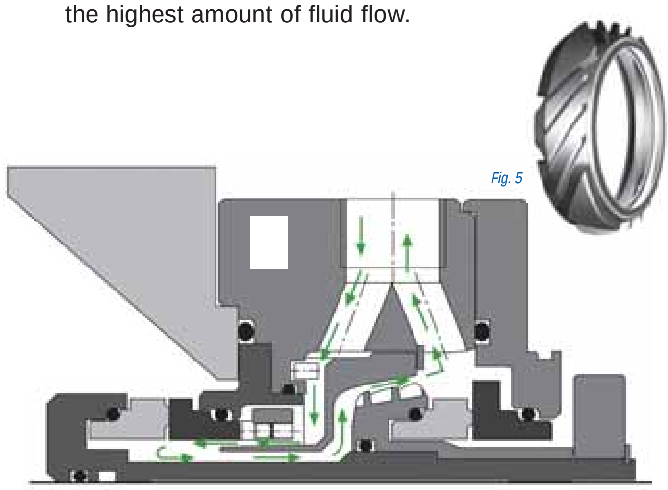

Fig. 5

Figure 1: A dual stationary mechanical seal - source: AESSEAL plc (Design: CAPI A1 dual).
Figure 2: A conventional rotary mechanical seal.
Figure 3: A single stationary plan 23 mechanical seal – source: AESSEAL plc (Design SMSS23™).
Figure 4: The radial clearance requirement between the mechanical seal rotor and stator, as outlined by API-682 Section 8.6.2.3.
Figure 5. Top: view of a typical tapered vane pumping ring; Bottom: typical position of a bi-directional tapered pumping vane device within the dual seal barrier/buffer cavity of a pump (source: AESSEAL plc).