Failures of Mechanical Seals: Part 2

Mechanical seals are commonly used in many industrial areas, including pumping units, agitators, separators, etc. They provide leak tightness and, thus, cleanliness and process efficiency for a reasonably long period of time, often reducing the power consumption of a machine. Unfortunately, mechanical seals are also components, which can be easily damaged.

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Mechanical damage

Mechanical damage arising from bad equipment condition or incorrect assembly has been described in part 1 of this article, while in this part, mechanical damage that may result from seal operation in working conditions that are unsuitable for a given seal type will be discussed. There are many kinds of this type of damage. One of them is the cracking of the sliding rings arising due to high adhesion forces generated between the sliding rings, which result from the accurate adhesion of the flat faces. This phenomenon takes place especially after the equipment downtime — this is often connected with viscosity change or even solidification of some sealants. This occurs in conjunction with the temperature change or time lapse. At the time of start-up of the equipment, the starting torque may be so high that it may cause damage to the rings or the seat in the place of torque transfer between the ring and the body (so-called pins or drivers) (figure 10). If the same failure associated with gluing of the sealing rings occurs repeatedly, it is important to verify the equipment starting conditions (e.g. the need for heating the sealing area before starting). If it is not possible to change the sealant properties, e.g. by heating, the use of a system with a double seal and barrier liquid may be a good solution. Maintaining the suitable overpressure of the barrier liquid over the process medium causes the sliding surfaces to be "lubricated" with this liquid.

Wear of the working surfaces of the rings is the only proper operation symptom, provided that it occurs after a period not deviating significantly from the hourly durability of the seal.

Premature damage to the sliding surfaces may take place due to the occurrence of abrasive particles between the sealing surfaces (e.g. crystallized working medium) or insufficient lubricating film between the ring faces. The situation wherein insufficient lubrication results in excessive wear of the seal may have several causes. These are, e.g.: "dry" running of the seal (if it is not adapted for that), partial evaporation of lubricating film and excessive viscosity of the medium that forms the lubricating film. All mentioned causes result in catastrophic consequences in connection with the occurrence of dry running. This leads to the destruction of the sealing ring faces (figure 11), often with elastomer overheating at the same time. If the seal is not adapted for "dry" running, its operation without a sealant is unacceptable. The "dry" running of the seal is one of the most frequent causes of mechanical seal failures; therefore, in a number of currently produced machines, in which such risk exists, the systems for detection of "dry" running are used.

Figure 10: Pair of mating sealing rings damaged due to excessive adhesion forces on the working surfaces.

The situation in which abrasive particles enter between the seal faces or crystallization of medium occurs, becomes a significant problem if one of the sealing rings used has been made of material with considerably lower hardness than that of abrasive particles (e.g. resin impregnated carbon graphite materials. As a result, hard particles get stuck in the material of which the ring was made. Abrasive particles destructively "grind" the sliding surface of the mating ring made of hard material (e.g. SiC), leading to the state similar to the one in figure 12.

In this situation, using the seal with two rings of hard material results in the fact that crystallisation of the particles, present in the lubricating film, causes enlargement of the gap between the sealing surfaces, thus leading to the increased leakage. It is another example (as with viscous liquids) when the use of a double seal with barrier liquid protects against this type of failure.

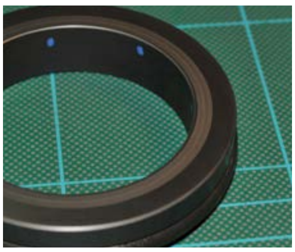

Figure 11: Damaged sealing surface of the ring of sintered silicon carbide SiC due to mating with another ring of the same material with insufficient lubricating film between the surfaces.

Figure 12: Damaged sealing surfaces due to crystallization between the sliding ring faces; left, the ring of SiC with considerably recessed sliding surface, right, mating ring of resin impregnated carbon graphite material.

Mechanical erosion

Mechanical erosion is caused by the action of solid particles existing in the process medium, which degrade the sealing component material surface during the side-wall turbulent movement of the liquid around the seal (figure 13).

The mechanical erosion destroys not only the seal, but also the machine in which this phenomenon occurs. The presence of solid particles is predominantly undesirable, and to limit the erosion, these need to be separated. Locally occurring erosion damage of the stationary rings (figure 14) operating in recirculating systems may be associated with excessive liquid velocity in the recirculation circuit. In this case, it is recommended to change the stationary ring material for a material that is more erosion resistant or to use an orifice in the recirculation circuit. This orifice mounted close to the flush liquid inlet causes reduction in the flow velocity at the outlet where the seal is placed.

Figure 13: Seal rotational unit of A1 type prod damaged by erosion.

Figure 14: Local erosion of the stationary ring caused by a stream of liquid in recirculation.

Chemical damage

Practical experience has shown that as in the case of exceeding the admissible thermal parameters, chemical damage usually refers to elastomer materials. However, it often happens that corrosion (e.g. ring of WC/Co figure 15) or chemical or electrochemical erosion lead to the damage of stainless steel components or sliding ring materials. When purchasing a seal, it is very important to inform the supplier of the working medium properties. This is key information in order to select individual seal components.

Using unsuitable elastomer leads to quick chemical degradation (figure 16) and, consequently, failure.

The future user should also give detailed information on all substances periodically occurring during the production process. The food industry may be used as an example here, in which the media occurring in the basic processing do not pose any hazard to most elastomers, while in the cleaning process of the CIP installation (Clean in Place), alkaline and acidic agents are used (e.g. nitric acid solution), which narrow the range of materials that can be used in the seal. In case of chemical damage to any of the seal components, it is necessary to change its materials or even design.

Figure 15: Corroded ring of cobalt bonded tungsten carbide as a result of contact with acidic medium.

Figure 16: Elastomer bellows of FKM material degraded chemically.

Decompression damage to elastomers

Rapid changes of pressure in the area where elastomers are present lead to their damage due to decompression, i.e. formation of cracks within the material (figure 17).

This problem can be easily eliminated by reducing the pressure changes near the elastomer sealing element or by changing the material into a different one that is more resistant to this phenomenon.

Blistering

This phenomenon occurs almost exclusively in sliding rings made of carbon graphite materials. It appears by the formation of characteristic spot damage to the sliding surface in the form of bulges surrounded by cracks (figure 18). These cracks extend to a small depth under the bulge surface, which becomes a "blister" detached off the ring. With time, chipping may occur in this area. There are currently several hypotheses about this phenomenon. Some of them say that it depends on several factors. The first of them is the type and viscosity of the sealant. The higher viscosity, the greater the risk of blistering, which most often happens when sealing viscous oil liquids. Another factor is the contact pressure on the sealing ring sliding surface. Both of these factors are highly important because they cause the formation of adhesion forces between the ring faces. The moment of start-up is critical when the greatest shear stress is exerted on the sliding surface area. This causes local exceeding of their admissible values for a given material, which results in the formation of characteristic subsurface cracks. The next factor that may favour the formation of defects is the local increase in temperature causing an increase in the volume

Figure 17: Cross-section of the O-ring of FKM material, which experienced decompression structural damage.

Figure 18: The sliding surface of the ring of carbon graphite material on which the blistering phenomenon occurred (right, enlarged view of the recess after chipping off the blister).

of the liquid trapped in the material pores (it usually has greater thermal expansion than the ring material) which consequently favours crack formation.

The solution to the blistering problem is to change the carbon graphite material of the ring. Currently, many carbon graphite grades substantially resistant to the blistering phenomenon are produced. However, the prices of these materials are high, and using them for a given application must be preceded by studies because currently, produced composites do not give 100% guarantee of the resistance to blistering in all conditions. If changing the carbon graphite to a more blister resistant grade does not solve the problem, it is necessary to use rings of ceramic materials.

Summary

The mechanical seal technology is currently at a very high level and it is continuously developed within the range of design solutions and materials used. Although the reliability of presently produced sealing systems is high, it should be remembered that its significant decrease can be affected by many factors. These may be both the quality of installing and the machine itself on which it is mounted but is primarily the proper selection of the design and material solutions for the actual operating conditions.

Part one of this technical article was published in the June issue of Pump Engineer on pages 13, 14 & 15.

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