Seal selection for rotary plant

The choice of what is the best seal for the job often comes down to personal preference as much as objective decisions. For many the choice is between a packed gland or mechanical seal – soft and conformable or hard and rigid. Here Andrew Goulding of James Walker & Co Ltd presents an overview of sealing options for centrifugal pumps.

Figure 1. A few rolls of compression packing in the maintenance store will solve gland problems on most centrifugal and reciprocating pumps, and valves, at a site.

The predominant role of fluid seals in rotary plant such as centrifugal pumps and mixers is to retain pressurised fluid media within a process. Unless a vacuum is involved, the seal rarely needs to prevent the ingress of external contaminants, as the positive pressure differential will achieve that naturally. Two types of rotary sealing device effectively contend for this form of dynamic duty, namely, the simple packed gland (typically containing five rings of pliant material) and the somewhat more complex mechanical seal. Another favoured sealing device for rotary shafts, the elastomeric lip seal, will efficiently protect bearings, but rarely holds a pressure greater than 4bar or works at under-lip temperatures above 200°C.

Although compression packing is a traditional sealing device that predates the industrial revolution, constant advances in materials technology, lubricant systems and manufacturing methods over the past 100 years have kept it at the forefront for both OEM and maintenance applications.

Some 20 years ago, a sharp decline in the use of asbestos-based materials, from which most packings were then made, combined with the increased popularity of mechanical seals to force traditional gland products out of favour for a time. This inspired high levels of research to produce low-friction compression packings from materials such as exfoliated graphite, graphite yarn, PTFE, and new synthetic fibres.

The aim was to provide better chemical compatibility, abrasion resistance, temperature characteristics and service life than obtained from asbestos packings, at a comparable price. Within just a few years, and a decade before the UK government's ban on white asbestos came into force in November 1999, new packings of advanced design were exceeding the performance of top-of-the-range asbestos types.

Before discussing in detail the many aspects relating to seal selection, an overview of pros and cons of both compression packing and mechanical seals is needed (see Table 1).

From this table it can be seen that both packings and mechanical seals have their own specific benefits on rotary duties. The mechanical seal is usually considered a fit-and-forget device, until its maintenance period is due. A packed gland, however, needs occasional adjustment to take up wear and compaction whenever the drip rate of fluid becomes excessive (ie, more than one drop every few seconds).

Table 1: Compression packing versus mechanical seal for rotary duties

Initial cost	One unit of cost	Approximately ten units of cost.
Reliability	Ample warning of impending failure with good possibilities of correction.	Little or no warning of end of working life -possibility of sudden failure.
Installation	Essentially very simple - needs no special skills if correct procedure is followed as prescribed by packing manufacturer.	Skilled fitting and defined environment often required for correct assembly and precise alignment.
Running maintenance	Extended service life is achieved by gland adjustment at regular intervals.	None between seal refurbishment intervals.
Spares	Length form packings and pre-formed sets are relatively low cost and readily held in stock. Also, one size/grade of packing can suit many different makes of pump on the same site - and possibly some valves.	Specific seal components must be readily available for maintenance purposes. Cost of holding stocks can be substantial. Seal parts may not be interchangeable between units on different makes of pump.
Shaft wear	Can be significant with highly abrasive slurries. Shaft sleeves and clean flush systems reduce these costs	None.
Operating costs	Friction losses slightly higher with packing. Slight media leakage (one drop every few seconds) needed for fluid film lubrication.	Usually, very low leakage of fluid media. Clean filtered fluid is often needed at the seal faces for satisfactory performance.

Figure 2. Arasele is a new soft and white packing from James Walker that can outperform tradition aramid products and reduce shaft wear.

Figure 3. Mechanical seals have a valuable role to play in centrifugal pumps, but original costs and refurbishment prove expensive for larger units.

Trained personnel are needed for the adjustment procedure: the machinery will be running, and it is easy to over-tighten a gland and lose the fluid film that is needed for lubrication. When gland follower adjustment fails to reduce the leakage to the required level, the time has come to repack the gland. At this stage it is usually possible to run with slightly excessive leakage until it is convenient to take the plant off-stream for maintenance attention.

With mechanical seals, the on-site assembly and installation can be a lengthy, complex task demanding clean working conditions and precision adjustment. Moreover, a mechanical seal gives little or no warning of a premature failure. The result can be serious in terms of fluid loss, pump damage, plant downtime and the cost of replacement or refurbishment. Periodic maintenance usually involves the removal of the complete unit to replace rotating faces and/or seats, as well as any elastomeric or polymeric components such as 'O' rings or bellows. Full refurbishment often comes to 50 per cent of the original purchase price of the seal - and as refurbishment is usually performed off-site, a replacement seal is needed in the short-term to keep a process running.

Gland packing is often far more cost effective than a mechanical seal of equivalent duty. A cost-wise factor of 1:10 is frequently quoted, although this varies considerably either way, with small diameter (ie up to 25 mm shaft size) mechanical seals priced about the same as a packing installation.

At shaft diameters above 100 mm, compression packings represent far better value in terms of initial outlay. Then, when you get to the high capacity pumps typically used in the power generation, metallurgical and mineral industries, the cost of packings is almost negligible compared with that of massive mechanical seals.

Operational parameters

On pressure and surface speed ratings, a top-of-the-range mechanical seal will often have a slight advantage over a packed gland on rotary applications. Whereas high grade graphite-based packings can work efficiently at up to 25bar or 25m/s, specific types of mechanical seal will match that speed and operate at pressures of over 35bar – although this is not often required on rotary sealing applications.

Chemically aggressive or abrasive media can be readily handled by both

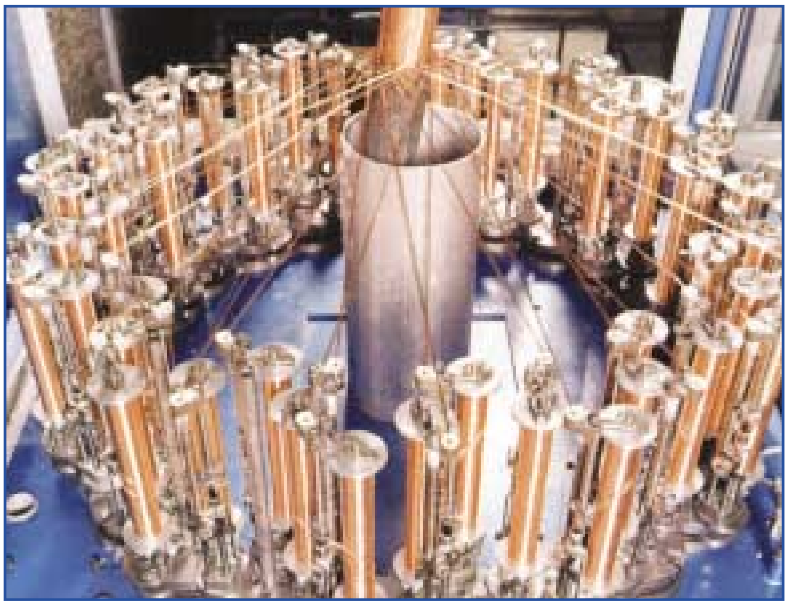

Figure 4. Compression packing manufacture is a complex task, but the products offer exceptional value for money.

Rotary face/seat materials	Metal components	Elastomeric/polymericcomponents
Carbon: antimony impregnated	Stainless steel: 304	Chloroprene (CR - neoprene)
Carbon: pressed	Hastelloy B	Ethylene propylene (EPDM)
PTFE: graphite filled	Hastelloy C	Fluoroelastomer (FKM)
PTFE: glass filled	Monel	Perfluoroelastomer (FFKM)
PTFE: virgin	Titanium	Silicone (VMQ)
Stellite	Incoloy 825	Fluorosilicone (FMQ)
Chrome oxide		Butyl (IIR)
Tungsten carbide		FEP
Silicon carbide		PTFE: virgin
Silicon nitride		PTFE: glass filled
Various other ceramics		

types of sealing device, as can foodstuffs and potable water when the products are suitably approved by FDA, WRAS, etc. Many PTFE or graphite-yarn based packings offer chemical compatibility in the pH range 0-14, and mechanical seal components can be specified to accommodate chemical action at these levels.

For example, mechanical seal face and seat materials range from resin-bonded carbon or doped-PTFE compounds to the most chemically- and abrasion-resistant ceramics. Seal bodies are manufactured in high performance alloys to suit the application (see Table 2).

When using a packed gland with highly abrasive media and slurries, it is advisable to protect the shaft from wear by using 'sacrificial' sleeves and/or by introducing clean flushing fluid into the packing ring system to prevent the abrasive medium reaching the main sealing rings. The flush should be around 1 bar higher than system pressure and fed through the housing into a lantern ring on the shaft. The fluid is distributed around the circumference and beneath the packing rings to prevent the ingress of abrasive particles.

A similar technique is used to prevent the leakage of toxic or noxious media. Harmless barrier fluid introduced via a lantern ring, at above system pressure, provides fluid film lubrication and prevents the pumped medium escaping to atmosphere – but the system must be able to accept low level dilution by the barrier fluid. When necessary, a liquid coolant can also be introduced this way.

Temperature limitations

The working temperature ranges of packings and mechanical seals are almost entirely imposed by their materials of construction. The limiting factor for a mechanical seal is usually its elastomeric or polymeric-based components – typically 'O' rings or bellows. The upper limits of high performance elastomers are typically in the +150°C to +250°C range, with perfluoroelastomers rated up to +315°C, whereas the safe upper limit of PTFE is +260°C. Compression packings based on PTFE fibres, and those using yarns braided over elastomeric cores, obviously have similar temperature limits.

Modern compression packings, however, are constructed from a wide range of synthetic and natural materials, with advanced lubricants incorporated (see Table 3). Whereas PTFE-based packings and those containing both PTFE and graphite fibres are limited by the upper temperature limitation of PTFE, both types will usually operate efficiently at down to minus-100°C. At these low temperatures, mechanical seals will need their springs formed from exotic alloys for efficient operation.

Probably the best combination of operational capabilities in a gland packing will be found with plaited ribbons of exfoliated graphite. With a typical working temperature range of minus-200°C to +850°C in non-oxidising environments (+450°C in oxidising conditions), such products can often work at 25m/s or 25bar with chemicals of pH range 0-14, although strong oxidising agents should be avoided.

For general services, the grades of packings developed to replace asbestos, and the natural-fibre based products, offer highly reliable service and best value for money. The former are often based on glass fibre and other synthetic yarns giving temperature ranges around minus-40°C to +350°C, with various combinations of shaft speeds, working pressures and chemical compatibilities suited to multiple duties.

Andrew Goulding is one of Europe's top experts on gland sealing technology. He joined James Walker in 1965 as a chemist in the research laboratory working on improved designs of compression packing. In the 1980s, he developed a complete range of asbestos-free packings to meet industry's changing needs. He is currently responsible for compression packing development, marketing and manufacture at James Walker's Cockermouth plant in Cumbria.

Packing type	Shaft speed (m/s)	System pressure (bar)	Maximum temp (°C)	Minimum temp (°C)	pH range
PTFE yarns	22	10	+260	-100	0-14
Graphite yarn	20	25	+400	-50	0-14
Exfoliated graphite (plaited ribbons)	25	25	+450 to+850	-200	0-14
Graphite rings (moulded)	25	10	+650 to+1000	-200	0-14
Aramid fibre	20	25	+250	-50	2-13
Glass yarns + graphite particles	10	10	+350	-40	4-10
Natural fibre: Flax	9	25	+95	-40	5-10
Natural fibre: Ramie	17.5	20	+120	-30	4-11
Natural fibre: Cotton	7	10	+90	-40	6-8
Lead foil	20	20	+260	-70	4-10

Traditional packings of natural yarns – such as cotton, flax or ramie – are renowned for their long life and low shaft wear on rotary applications with mineral oils or water-based media at up to about +100°C and 20bar. (Surprisingly, ramie, a tropical nettle plant, produces fibres of great strength and durability, allowing packings to work at extreme pressures in reciprocating plant: 250bar, extendable up to 700bar under certain conditions). As would be expected, the chemical compatibility of natural yarns does not extend to the far limits of the pH range.

Less than perfect conditions

Packed glands will always outperform mechanical seals when the going gets rough. By this, we mean when the rotary action is eccentric, due to worn shafts/bearings or inadequate support. Mechanical seals need to be set up very accurately (at the factory with cartridge designs, or on-site with most other types) so that rotary face and seat mate perfectly to provide an efficient seal. Off-centre or eccentric action places considerable loads on the sealing device, making it act as an alternative bearing for the shaft – a duty it is usually unable to perform for any period, with obvious results.

Specific designs of packing will absorb eccentric action. These types usually have a central core of high-temperature resistant elastomer that allows the packing to compress and recover very swiftly, keeping the braided sealing face in intimate contact with a fast-moving offset shaft.

Other compression packings that prove highly effective under less-than-perfect mechanical conditions are the ‘injectable’ types. These homogeneous blends of fibres/fillers (typically aramid, graphite or PTFE) and lubricants are pressure injected through a valve into a gland housing between two end rings of conventional packing. The gland follower is then adjusted in the usual manner to compress the material and form a seal.

As these ‘bulk’ materials readily conform to fill almost any void, they can overcome sealing problems caused by worn shafts and irregular shaped housings. In addition, the gland is swiftly repacked by pressure injection without stripping the housing - saving significant maintenance effort and plant downtime.

With so many advantages, there has to be a downside to injectable packings. It is the difficulty in ascertaining where and when to use them to best effect – for this the expert technical advice of the product manufacturer is essential.

Conclusion

The concepts of ‘best value’ and ‘total owning costs’ are yardsticks now applied across all sectors of commerce, industry and public service. The selection of sealing methods and products for rotary plant can be assessed in the same way.

The basic sums may be simple for sealing devices in relation to capital cost, installation time, running costs, operational life expectancy, and then refurbishment or replacement. However, fluid seals are relatively low-cost items in relation to the processes they protect. Therefore, other issues such as unscheduled plant downtime, the health and safety and environmental aspects of leakage, and the cost of any lost fluid media, must also be taken into account.

With all other factors being equal, if it is important to keep a plant on stream until the next scheduled shutdown and a low level of controlled leakage or media dilution is acceptable, then the packed gland is usually the most reliable and cost effective option. And remember, many length form packings can also be used on valves and reciprocating plant, which improves their stockholding value.

If the rotary plant is in perfect mechanical condition, and media leakage or dilution is unacceptable, then a mechanical seal is a realistic choice: so long as the mating faces are kept lubricated (a requirement with the majority of installed mechanical seals) and all components subject to wear are replaced well within their operational working limits. ■

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