Inflatable seals for critical offshore applications

Bruno Rouchouze and Cindy Krishna, of Technetics Group, discuss the mechanics of inflatable seals and their applications.

Inflatable sealing technology is used in a number of critical applications including offshore production, storage and offloading (FPSO); anchoring drill rigs to the seabed; gas loading systems; pipeline welding; and watertight doors and panels.

Inflatable seals are the safest and easiest method of sealing components that move in relation to one another, and are frequently connected and disconnected. Capable of adapting to varying environmental and service conditions, these type seals can be expanded and contracted pneumatically or hydraulically to accommodate these changes.

The seals are available in different materials and high- and low-pressure configurations based on elongation and deformation of their profiles. Their hollow-molded shapes maintain consistency during expansion, conforming to the dimensions of the mating surface (Figure 1).

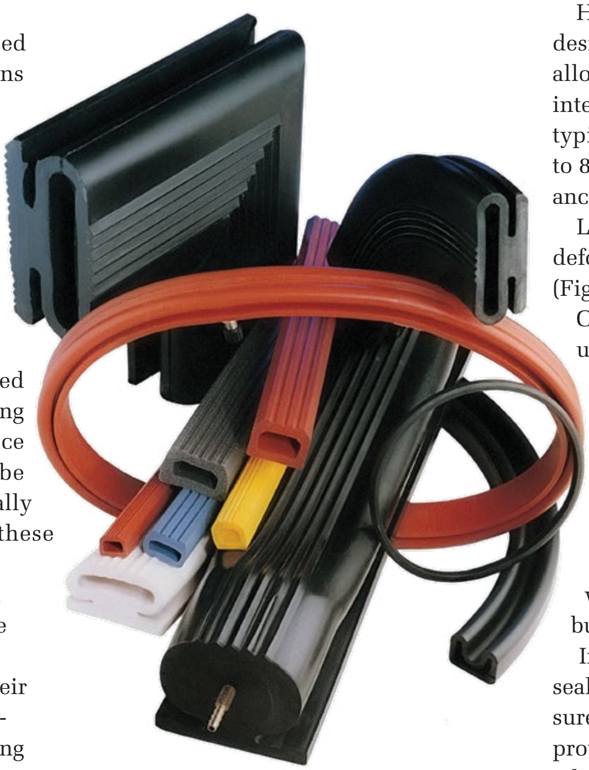

Figure 1: Inflatable seals.
Images from Technetics Group.

Inflatable seals can withstand a wide range of temperatures and pressures, providing a tight, durable and elastic solution to protect and keep equipment functioning during demanding drilling operations.

Background

Sealing critical applications in demanding environments used to be done with solid rubber profiles, which required extremely high compressive loads to seal effectively. They also required perfect machining of mating surfaces, since solid rubber is not sufficiently compressible to compensate for any irregularities or deformation that could pose potential leak paths. This machining is an expensive process, and not always possible.

The clearances to be sealed in any application can vary widely. A door or panel can have very different gaps to compensate for from one side to the other, i.e. a 2-3mm gap in one place and one much larger elsewhere. To close the widest gap, a very large load would have to be applied to a compact seal, over-stressing the main part of it in the process. An inflatable seal, by contrast, requires virtually no effort, since there is no contact during closing and expands to fill any gaps afterward.

To accommodate these variations, inflatable seals come in high-pressure and low-pressure configurations. The operating principal of high-pressure seals is elongation of the lateral faces of a squarish profile cross-section (Figure 2).

Figure 2: High-pressure seal profile

High-pressure inflatable seals are designed to fit in metal retaining grooves, allowing axial, external radial and internal radial expansion, These seals typically can withstand pressures of up to 8 bar, and are suitable for sealing clearances from 2-10mm.

Low-pressure seals work by geometric deformation of an omega-shaped profile (Figure 3).

Capable of handling external pressures up to 2.5 bar, they can be expanded 5-30mm to seal larger clearances.

Both types of seals can be inflated with compressed air or nitrogen, which will slowly leak through the material, necessitating occasional re-inflation. They also can be inflated with liquids such as water or oil, which will not leak through the seals, but will reduce their compressibility.

If the primary function is to provide sealing, it is advisable to use low-pressure, air- or gas-filled seals, which also provide better insulation and sound and vibration damping. If the function is to lift or lock something in place, a harder, liquid-filled seal is recommended.

For valves, molded cones provide better sealing, since the profile around the valve and the overall profile are molded in one piece, rather than fused together (Figure 4).

This precludes any areas of weakness or potential leakage. The valve therefore has greater damage resistance and good centering. Also available are expandable end plugs and end plug fixing devices.

The latter are used with flanges or retaining plates to avoid damaging seals during inflation, and to ensure they remain in the grooves when the seals are deflated.

Figure 3: Low-pressure seal profile

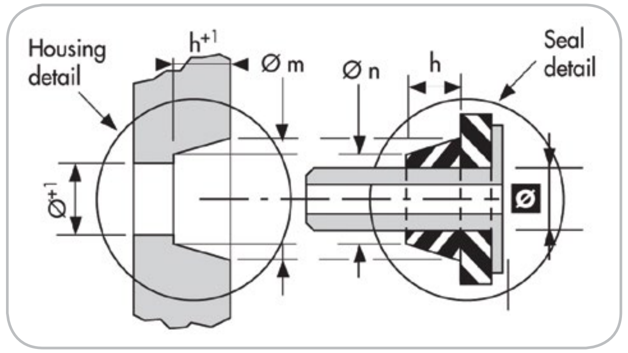

Figure 4: Molded cone profile

Deflatable seals

An important advance in inflatable seals is their ability to operate with either pressure or vacuum. This allows them to be deflated, for example, when a watertight door is opened. Even if there is no internal pressure remaining, they will seal a door tightly when it is closed. The seals also can be re-inflated to atmospheric pressure or more if stormy weather conditions are anticipated.

Inflatable seals are available in a wide range of extruded, molded and profiled materials to meet the requirements of diverse applications. Silicone rubber (Q) has good thermal properties, remaining stable in terms of compressibility across a wide temperature range (-30°C to +100°C and up to 250°C for short durations). Being mineral-based, it has better aging properties and UV resistance than organic materials, which can oxidize in air and degrade with exposure to UV radiation. However, it is not a particularly robust material, with little abrasion resistance.

Nitrile rubber (NBR) is impervious to oil and some other hydrocarbons and temperatures of up to +100°C (+150°C for hydrogenated nitrile rubber or HNBR). Neoprene rubber (CR) is fire-resistant and has good aging properties, but is limited in temperature capability (0°C to +100°C). Styrene butadiene rubber (SBR) is less permeable than silicone, and is seawater-resistant. It has good tear and abrasion resistance, and a temperature range of -20°C to +100°C.

Fluorocarbon rubber (FKM) has low permeability, and can withstand contact with oil or gas, but is quite expensive. Fluorosilicone rubber (FMQ) is a fragile and expensive material, used primarily to seal aromatic applications such as kerosene and other fuels, making it suitable for certain oil and gas applications.

Applications

Inflatable seals are being used successfully in a number of oil and gas applications. For example, large-diameter seals are used in the connection between the riser buoy and ship turret for a rig working off the coast of Greenland (Figure 5).

Twenty meters in diameter, soft, low-pressure seals made of SBR material are inflated with air, allowing them to be squeezed without damage by wave action between the buoy and ship. The temperature is 10°C, and the seal is submerged to a depth of 30m.

Another application is anchoring offshore platforms to the sea floor (Figure 6).

In this application, the pressure of an 800m water column embeds a pipe anchor in the seabed. Inflatable seals that function independently of the water depth create a differential pressure when installing or pulling up the anchor. This application also features low-pressure SBR seals, 5m in diameter.

A single seal provides a pressure barrier of 2.5 bars, but when two or three seals are installed in parallel from the outside to the inside of the anchor, 10 bars of pressure can be achieved.

In addition, FKM seals inflated with oil, water or gas are used to seal toluene and benzene vapors in gas loading systems (one major producer uses silicone rubber seals that are impervious to vapors and protected against high- and low-pressure extremes).

Inflatable silicone rubber seals also are used to seal neutral gas areas in inert gas chambers for pipeline welding, as well as in devices for testing welded parts. In these applications, the seals are inflated with nitrogen gas, leaks of which will not pose a welding hazard.

Conclusion

Inflatable seals make it possible to overcome difficult challenges. They can be used in a wide range of applications, including buoyancy-aided sealing, gas containment, and clamping/unclamping. Among their principal advantages are flexibility in profiles, compounds, working loads and operating environments, i.e. the level of sealing and flexibility in extreme conditions including availability of custom seals for special applications. Inflatable seals minimize open/close stresses, and provide pressure and vacuum capabilities, a broad temperature range (-30oC to +250oC), large selection of materials, and configurations for valves and flanges. OE

Figure 5: FPSO application

Bruno Rouchouze *is a senior product manager with the Technetics Group, a unit of EnPro Industries, Inc. Based Montbrison, France, he has been with the company 34 years, where he has been involved in the design and development of inflatable seals and rubber sealing devices. He is a graduate of the Universities of Saint-Etienne and Montpelier.*

Figure 6: Anchoring drill rigs to the sea floor.

Cindy Krishna *is senior oil and gas market manager with the Technetics Group based in the UK. Previously she worked for Emerson in instrumentation products management for 17 years. For the past 10 years she has focused on the oil and gas market, including control valves, subsea equipment installation and FPSOs. She is a chartered engineer and holds a Master's degree in engineering and an MBA from the University of Liverpool.*