New Ways of Gas Bearing Sealing In Bulk Powder Handling

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New Way Air Bearings

Bulk solids are a challenging media to seal against. Powders are insidious and work their way into the smallest crevices and gaps through seals and bearings. Contact type seals often combined with buffer or barrier gases have been one of the few solutions for decades. Contact seals such as packing require regular maintenance. More advanced mechanical seals are often plagued with squealing noise or high temperatures, and wear from the heat resulting from the contact pressure or speed. We are all familiar with the problems.

Hopefully, the take away ideas from this article will be new ways of solving your old problems. The basic idea is to use externally pressurized gas bearing compensation techniques to: (1) increase the pressures that can be sealed against, (2) reduce the flow of buffer gas, barrier gas, or shop compressed air, and (3) eliminate friction, heat, and wear in seals and bearings for bulk powder processing.

First let's cover a bit of gas bearing technology. There are two main types of gas bearings: aerodynamic gas bearings and externally pressurized gas bearings. Dry Gas Seals (DGS) often used in high-speed compressors are an example of aerodynamic technology. It would be great if DGS worked in powder applications, since dry and frictionless seals are just what the powder industry needs. Aerodynamics seals like DGS generate lift only when you have the relative surface speed that allow the hydrodynamic features to operate properly. Unfortunately, in most powder applications, the motion is relatively slow compared to gas compressors where the seals are most frequently employed.

Aerodynamic bearings depend on relative motion between the bearing surfaces and usually some type of spiral or "T" grooves to pump air pressure between the bearing lands. This bearing action is very similar to hydroplaning in your automobile when hitting a puddle of water at high speed, which is why we have tread in our tires. At a lower speed, your tire would cut through the water to the road. In just this way, aerodynamic bearings require relative motion between the surfaces - when there is no motion or when the motion is not fast enough to generate the air film, the bearing surfaces will come into contact. Aerodynamic bearings are often referred to as self-acting bearings. Other examples of this type of bearing would include read-write heads flying over a spinning memory disk, or in oil, crankshaft, and camshaft journals. Another issue with aerodynamic seals is that the flow is from one side of the seal to the other, <u>across</u> the seal face. So this doesn't work well when there's powder on the higher pressure side.

Aerostatic bearings, though, are a category of gas bearings that have not been applied to sealing technology, and there is a great deal of promise for improved sealing in bulk solids. They are also dry and frictionless. Aerostatic bearings require an external pressurized air or gas source. This air pressure is introduced between the bearing surfaces by precision holes, orifices, grooves, steps or porous compensation techniques. It is this idea of compensation that is key but not yet well appreciated. Compensation enables bearing faces to run very close together without touching, because the closer they get together, the higher the gas pressure between them gets, repelling the faces apart. The other great advantage is the gas pressure in the gap can be almost as high as the source pressure, enabling the ability to completely seal process pressure up to the pressure in the gap. With the flow being a cubed function of that gap, flow is dramatically reduced by the small gaps that become possible.

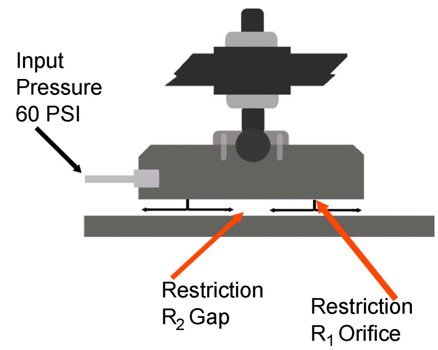

Figure 1: This is a cutaway side view of a typical orifice air bearing found in a coordinate measuring machine (CMM). If a pneumatic system is to be considered an "air or gas bearing," it needs to have a restriction upstream of the bearing gap restriction.

So what is Compensation? Compensation is a story of restriction, of holding back source pressure in reserve. Think of the restrictor as a throttle between the source pressure and the pressure in the gap. In a gas bearing the average pressure in the gap will equal the total load on the face divided by the face area; that is the unit loading. So if the source gas pressure is 40psi and the seal face has 10sq in of area and there is 200 lbs. of preload or closing force, there will be 20 psi in the bearing gap. Nothing less than 20 psi will enter this gap; it would be like water running up hill. So there is no flow across the seal face, only the flow from the porous media will be in the gap. If you increase the preload, the pressure that can be sealed against increases proportionally and the gap gets smaller, with the flow (already a small fraction of a SCFM) reducing as cube of the gap. The increase in preload is free though of the usual friction, heat, and wear that would normally come from increasing preload. This allows for a lot of flexibility. For instance, a light preload and low source pressure would minimize source consumption in applications with small pressure differences. Alternatively, high preload with higher source pressure increases the pressure that can be sealed against. So for 100psi source pressure, up to 90 psi can be sealed, with 1000psi source, 900psi could be sealed, providing the preloading force or balance is available.

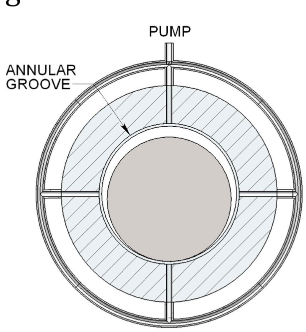

Figure 2A: This is an end view of a shaft through a throttle bushing with an annular groove, centered axially in the ID of the bushing. There is no force to center the shaft in the bushing, as the barrier gas just follows the groove to side with the largest gap.

This sounds simple and attractive but is not yet the usual case in bulk solid sealing. Common for the bulk industry would be a throttle bushing with a center annular groove (Figure 2A). With the bushing on the shaft, and plumbing the buffer gas into the groove, it is hoped that higher pressure can be maintained in the groove, with flow from the groove to both the process and to atmosphere sides. But because the flow through a gap is a cubed function of the gap, nature prefers one large gap to two smaller gaps, and so the bushing ID and shaft will touch from this decentering or destabilizing force. Flow will need to be high to maintain even a small percentage of the source pressure in the groove.

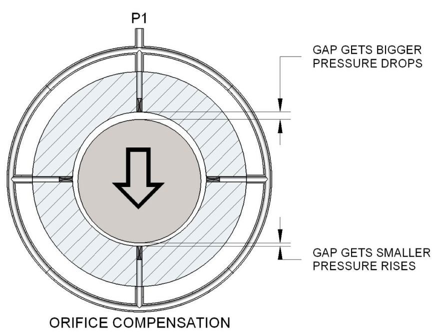

Figure 2B: In the same case as 2A, except there are restrictive orifices inserted in the ID holes, and there is no annular groove. There is now a centering and stabilizing force. As the shaft moves toward an orifice, the restriction in the bearing gap increases relative to the orifice restriction, and so the orifice lets in more of the supply pressure, pushing the shaft back to center. There is an equal and opposite complimentary change in pressures on the opposite side. This is compensation.

Alternatively, without an annular groove, an orifice-restricted compensation can be used (Figure 2B). Note that as the shaft moves toward an orifice, the gap gets smaller, and so has more restriction. Subsequently, the lower flow means the orifice allows higher pressure from the source to build in the gap, pushing the shaft back to center, while on the opposite side the gap has increased, reducing restriction and pressure and allowing the shaft to find center again. An annular groove would short circuit this, allowing all the gas to escape from one side.

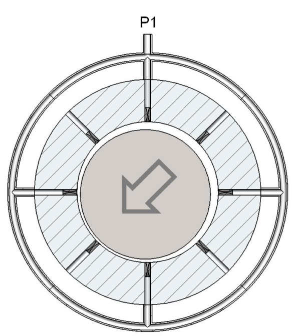

Figure2C: Still, this restoring force should be equal around the 360° of the base. Many expensive orifices may be required to achieve this with orifice technology.

But if the load happens to have a vector between orifices it can be hard to encourage the gas to the higher load area, so what do designers do? They add more orifices (Figure 2C). This is a solution but it is expensive as holes for inherent compensation need to be drilled very accurately, or jeweled orifice are used (the hardness of Ruby or Safire are needed to keep the hole from enlarging due to high velocity dust erosion over years of operation).

Out of all the compensation techniques orifice compensation is the most popular or widely used. Orifice compensation typically uses precisely sized orifices that are strategically placed on the bearing face and often combined with grooves to distribute the pressurized air across the bearing face. However if the bearing face becomes scratched across a groove or near an orifice, the volume of air that escapes through the scratch may well be more than the orifice can supply causing the bearing faces to contact or crash. Orifice bearings also can be plagued by contamination plugging the orifice and starving the face for pressure and flow. Orifices are typically 100 to 250 μm (0.004 to 0.010in.) in diameter and so can be readily plugged by Teflon tape or material sloughing off of the inside of the tube or some other particulate contamination.

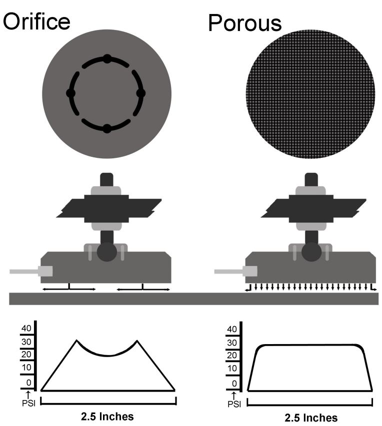

Figure 3: When air pressure bleeds evenly from the entire surface area of the face, the whole surface area develops pressure even when grounded. Orifice bearings have only the area of the orifices and any grooves for the pressure to establish initial lift. The even pressure profile of porous gas bearings makes them more suited for application to sealing technology.

Finally orifice bearings experience collapse at very small gaps. As the face of the bearing gets closer to the guide surface, the inflow around the feed hole becomes choked and is not enough to provide pressure and flow for the rest of the face. This collapse can be seen in reverse during initial lift off. By slowly increasing the supply air pressure from "0" to an orifice bearing that is grounded by a load, it can be seen that a high percentage of the supply pressure is needed before the bearing will pop up as flow is established across the face of the bearing. This is because a flat orifice bearing on flat surface has only the area of orifices and grooves to establish initial lift (Figure 3).

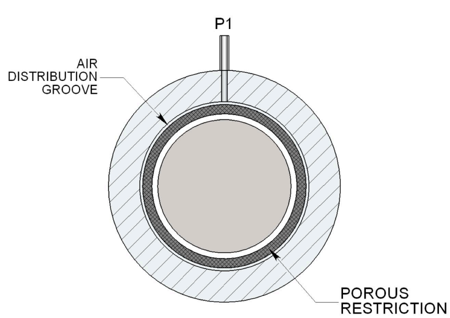

Figure 2D: By positioning the annular groove under the porous media, it feeds millions of submicron-sized orifices that are formed naturally and very evenly distributed across the face.

There is a more elegant method for providing this compensation. The ideal air bearing design would supply pressure equally across the whole face of the bearing and automatically restrict and dampen the flow of air to the face at the same time. This can be achieved by diffusing air through a porous bearing or seal face (Figure

2D). The stability of porous media compensation is due to the damping effect from the torturous passageways the gas must flow through to reach the face. This damping effect makes it difficult for the volume of air in the gap to change quickly, resulting in a naturally stable gas film that cannot be plugged by particulates. As even with the supply tubes and/or ports completely full of particulates (sand, dust, etc.), it still does not create as much restriction as the porous media itself. In the case there is contact, graphite is an excellent plain bearing material.

This also works well for very small gaps and so small flows. With porous bearings, a low initial lift is achieved with a low percentage of supply pressure, and the gap increases with increasing supply pressure. This is because the whole face contributes to lift, much like the exposed area of a hydraulic cylinder, as again illustrated in Figure 3. Again, this makes porous bearings easier to use then orifice bearings.

This porous gas bearing technology is applied in both bushing and face type seals. The face type seals are easier to achieve very small gaps with, as the air gaps are set by relative loads, preloads, or pressures; whereas the fixed geometry and hoop stiffness of journal bearings means bearing clearances need to be match machined closely and ambient temperature should be somewhat consistent. Still, the convenience and tight radial package make the bushing approach appropriate for many bulk powder applications.

In summary, the use of porous media technology in bulk powder processing should provide the industry with three key advantages: sealing against higher pressures, reduced flow of buffer or barrier gases, and the elimination of friction, heat and wear for seals. These seals are envisioned as being used for powder, bulk solids and wet mixture handling equipment such as screw conveyors, paddle/ribbon mixers, rotary valves and other similar equipment vented to the atmosphere. They are also appropriate for seals and bearings in fans and blowers. High-speed applications are also a strong suit for gas bearings, especially in dusty environments. Visit Flowserve at booth #2726 at this year's Powder & Bulk Solids Exhibition to observe this technology up close.

Figure 4: Submersed underwater with 60 psi input pressure, 3 SCFH bleeds evenly out of the face of a 2.5-inch diameter New Way porous bearing. This bearing carries 150 lbs. of load at 0.0002-inch air gap.

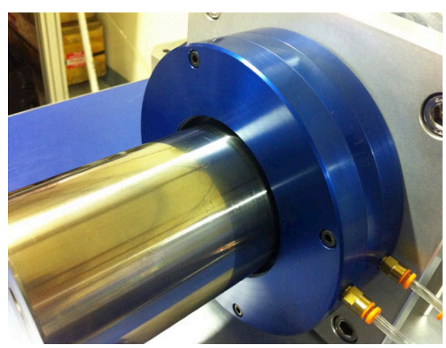

Figure 5: Porous gas bearing seal designed as a double opposed isolation seal in a very compact package. It can completely contain 30 psi with 0.5 SCFM of barrier gas @45 psi.

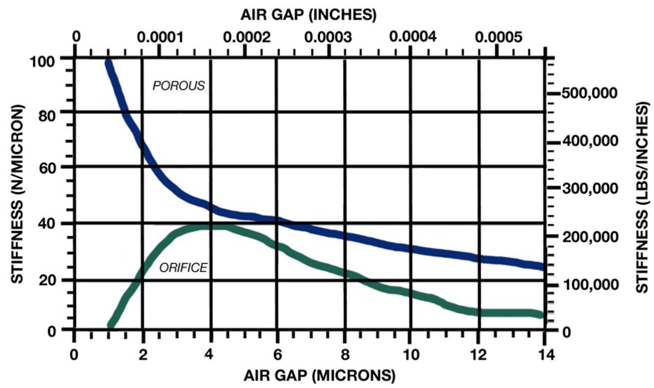

Figure 6: It is well known in the Dry Gas Seal industry that small air gaps have very high stiffness. Since flow through a gap is a cubed function of the gap, small gaps are great for reducing flows. Porous compensation in gas bearing technology has shown the best results in low fly height application.