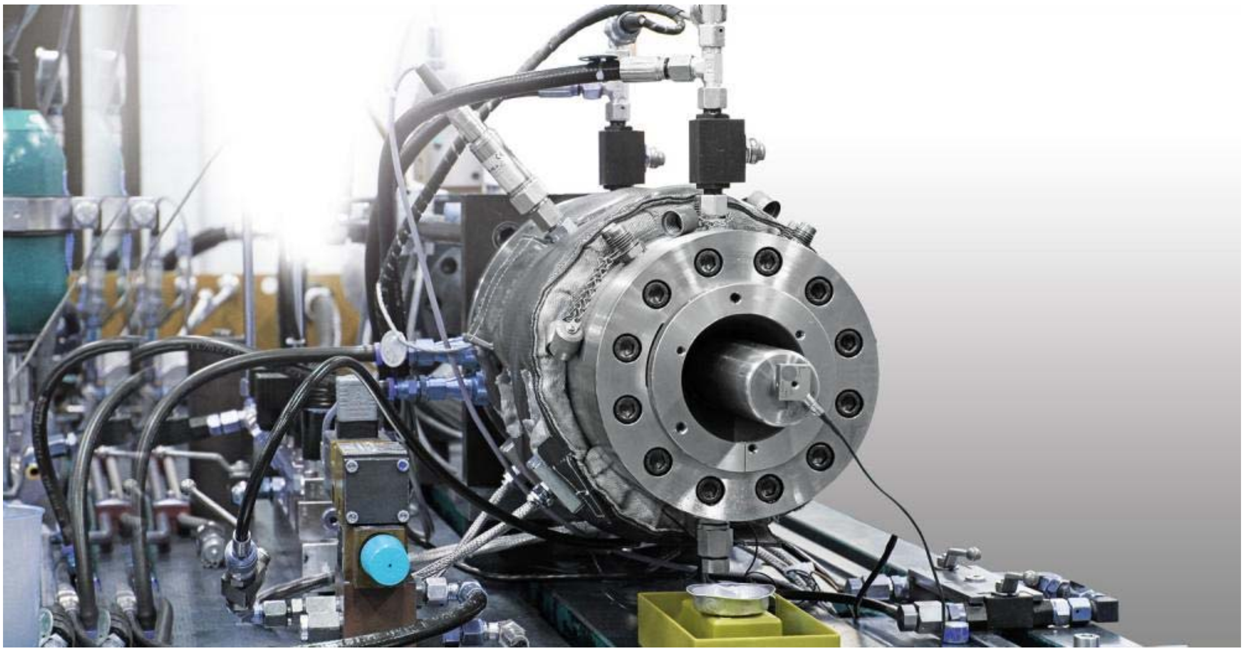
Hydraulics & Pneumatics



This test rig uses a three-dimensional accelerometer to measure vibrations from stick-slip operation between a rod seal and a piston seal and their respective mating surfaces.

Reduce Vibration and Avoid Stiction in Seals

If not addressed, stick-slip can potentially degrade performance and can cause damage in hydraulic applications.

Seals run smoothly in most hydraulic applications, especially when the piston rad has a surface finish that retains a light film of oil. However with little or no rod lubrication, stick-slip motion (stiction) between the seal and the piston rod can cause vibration or noise.

Stick-slip, in general, can be described as two surfaces first adhering to and then sliding over each other, with a corresponding change in the friction force. When applied to a seal, stick-slip occurs at low velocities or when a large change in friction force occurs relative to a small change in velocity, as may be found in hydraulic cylinders, often after a period of rest.

Stick-slip is not always a big issue, but sometimes it can significantly degrade performance. Potentially, it can cause damage, such as cracks in steel work and strength loss, and even health problems for operators. Typically, this can be the case in lightweight hydraulics, industrial robots, mobile cranes, and lifting equipment. We look at solutions to combat stick-slip to lower vibration as well as to create damping solutions.

The peripheral conditions affecting friction in the contact area of a dynamic seal are complex. These include the structure of the counter (piston rod) surface in combination with the lubricating fluid, the design and the material of the seal, and the operating conditions. For example, temperature affects oil viscosity, while also influencing the modulus of the seal material. Over time, changes will also occur to the surface roughness values at the contact areas and, when combined, these factors directly influence the friction behavior of the seal.

Selecting the Seal Material

Many seal materials exhibit elastic behavior, which enhances their performance due to contact forces that ensure sealing effectiveness. Selecting the appropriate material in terms of its elastic properties can normally compensate for cycling pressures or even deflections. To extend a seal's capabilities to damping, it is not necessary to develop new materials, but to use existing compounds and seal geometries differently.

Transferring the principle of a spring and a damper to the application of hydraulic seals, we first have to consider the values of the elastomeric materials, including the ratio between the loss and the storage modulus during elongation and tension. These characteristic values can be used to describe the damping properties of the material; on the one hand the *stored energy* and, on the other, the *absorbed energy* created by the relative movement of the molecular chains.

In the case of stick-slip at the sealing contact area, micro-movements can be controlled by making good use of the damping characteristics of an elastomeric material to eliminate vibration and noise. Seemingly simple, the solution proposed was a damping disc combined with proven seal designs. To understand how this works, a review of the testing process is necessary.

Test Setup for Rod and Piston Seals

To measure the vibration frequencies in rod seals, a three-dimensional acceleration sensor was adapted on a test rig to measure vibrations that were expected to be multidimensional due to the play in the bearing of a rod within a housing.

The vibration frequency was calculated from the accelerations measured during the movement of the rod at different velocities while varying the pressure load. The test parameters were varied according to the defined test procedures. To produce the stick-slip effect, the measurement was made using a critical counter surface.

It became clear under constant testing conditions that the design and material of the seal exerts the main influence on the vibration frequencies. The sealing system tested consisted of a single-acting O-ring energized piston seal with a damping disk and radial pretension by way of an elastomer O-ring. The damping element was compressed by the seal when pressurized. Vibration with and without a damping element at O bar and 0.02 m/sec showed that the elastic behavior of the damping element in the sealing system significantly reduced vibration.

In piston seals, very smooth roughness profiles with a very low reduced-peak height—in combination with certain hydraulic fluids—can result in stick-slip and lead to noise. The same principle (as used in the rod seal) of adding a damping element can also successfully be applied to piston seals.

The proposed solution underwent extensive testing with successful results in reduction of noise and vibration. The new damping seal's technology enhances the performance of hydraulic actuators (especially those of lightweight construction) while improving the user experience.

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