for speeds exceeding 150,000 rpm, ElringKlinger Engineered Plastics has developed the new ElroSeal sealing system module, TABLE 1, to meet these difficult conditions for specific applications. All seals can be optimized specifically for customers and adapted to the required speeds and direction of rotation. Spiral structures on the shaft, or special profiling of the sealing lip, can generate a hydrodynamic transport effect that further improves dynamic oil sealing behavior. The benefit is that this is possible with very low radial sealing lip contact pressure and low frictional losses. Combined with ElringKlinger’s alternating spiral design, the sealing function can be ensured in both directions of rotation.

### THE MATERIAL

The use of the right sealing lip material also plays a critical role. ElroSeal seals are produced with sealing lips made of PTFE compounds. The fillers incorporated in the PTFE base material have been adapted specifically to this application by in-house material development.

Soft shafts can be sealed successfully with the use of special filler materials. Electrically conductive fillers can also be incorporated in the sealing lip material to prevent static charge buildup. The best results with respect to wear under dry running conditions were shown by the material polytetrafluoroethylene (PTFE) 22157, which produced the results listed below.

### TEST CYCLE

To evaluate the sealing properties and promote targeted further development, ElringKlinger runs specially developed rotary shaft seal test benches that can map speeds of up to 150,000 rpm. The results below were obtained using test benches with a maximum speed of 50,000 rpm, designed especially for applications in electric mobility.

Various approaches exist to determine service life, leakage, or wear behavior. There are manufacturer-specific test cycles based on ISO 16509—FIGURES 1. The test cycle shown describes a typical driving situation with city traffic, country roads, and freeway portions. The freely programmable speed is 16,000 rpm at maximum, the medium temperature is 135 °C, the pressure corresponds to the ambient pressure. This cycle is repeated until the required test duration has been reached. FIGURE 2 shows the result of the wear test.

### FRICTIONAL LOSS AND WEAR

The wear curve shows a typical pattern for rotary shaft seals, with greater wear during the run-in phase and asymptotic behavior toward the end. Rotary shaft seals lubricated with oil were investigated. Wear behavior with insufficient lubrication, and partial dry running, is shown in the limit curve.

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**TABLE 1**: Representations of the ElroSeal family of seals (ElringKlinger)

<table>
<thead>
<tr>
<th>Description</th>
<th>Design example</th>
<th>Recommended circumferential speed</th>
<th>Special feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>ElroSeal e</td>
<td></td>
<td>20 to 40 m/s</td>
<td>Reduced friction seal design</td>
</tr>
<tr>
<td>ElroSeal e Spoolflex</td>
<td></td>
<td>40 to 60 m/s</td>
<td>Single-spring design</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60 to 100 m/s</td>
<td>Double-spring design with optional pressure relief system for turbochargers and other applications</td>
</tr>
</tbody>
</table>

**FIGURE 1**: Temperature and speed cycle per ISO 16509—(ElringKlinger)
The frictional loss of a rotary shaft seal is critical to its functional behavior. Too much frictional loss can cause high temperatures, leading to rapid failure of the sealing system. The frictional losses of EtroSeal seals at various speeds are shown in Figure 3. Regardless of the direction of rotation, the frictional loss increases as speed increases at a constant temperature. At an increased temperature of 135°C, the seal shows permissible levels of frictional loss. This means that the seal functions without leaking, even under deteriorating lubrication conditions.

EtroSeal rotary shaft seals demonstrate only a slight decrease in radial sealing lip contact pressure with very low frictional loss after running with oil or dry, Figure 4. The comparison with an elastic sealing lip material shows significantly higher residual force here. EtroSeal PTFE rotary shaft seals demonstrate a significantly lower drop in radial force, both in lubricated and dry conditions, in comparison with the measured elastomer rotary shaft seal.

**Static Leak Tightness**

In addition to the dynamic properties, static leak tightness is another significant property when considering the system. Static sealing behavior of the shaft seal is determined in part by pressing the seal into the installation space. This property is checked with a static air leak test on the test bench or as an end-of-line test during assembly. Static leak tightness is tested according to an internal standard at a temperature of 23 °C and test air overpressure of 0.2 bar after 5 s. The maximum permissible pressure drop is 0.05 bar.

In application, the shaft seals are typically pressed into aluminum installation spaces. The EtroSeal design has been customized for this application in terms of press-in force and static sealing behavior. This means that EtroSeal seals can be used in aluminum installation spaces, even with suboptimal surface roughness in the installation space and without additional elastic coatings on the outer diameter of the housing.

This has the advantage that critical conditions can be avoided after temperature effects, aging, or chemical exposure in comparison with elastomer-coated outer housings, by reducing press-in force. In the example above, the press-out force after the test cycle (100 h, 135 °C, leaching oil) was determined as only 25 % of the press-in force. EtroSeal PTFE rotary shaft seals demonstrated very good residual force, at 67 % press-out force to press-in force.

Much discussed is the influence of the surface conditions of the installation space on static leak tightness. Tests show no problems when installing EtroSeal-e in aluminum installation spaces with high roughness. An elastomer layer on the outer diameter is not necessary.

To test this, EtroSeal seals with stainless steel housings were pressed into an aluminum installation space with a uniform Htr borehole. The outer surface roughness of the shaft seal was produced as a standard surface roughness of ± 0.8 µm. The inner aluminum surface is produced in a turning process with a surface roughness of ± 0.1 µm. To evaluate the press-in conditions, an average press fit was set up between the outer diameter of the seal housing and the diameter of the installation space. After pressing in the seal with about 4000 N, the surface of the aluminum installation space was measured again in the region of the press-in surface.

With a surface roughness of Rz 6.9 µm, significant smoothing of the aluminum installation space would be evident. The special outer geometry produced compression of the aluminum installation space without forming chips. When the seal is pressed out afterward, running counter to the press-in direction, only a slightly lower press-out force was measured in comparison with the press-in force, Figures 5.

The percentage contact area increases in the example shown from 22.2 % to 84.8 %. Static leak tests demonstrate that EtroSeal rotary shaft seals fulfill the requirements for static leak tightness without any additional elastic housing coating.

**SUMMARY**

EtroSeal rotary shaft seals demonstrate excellent leakage behavior, even under the conditions required for electric mobility. After long periods of dry running, the shaft seal still holds up without leaking in a subsequent oil run. By smoothing the aluminum installation spaces, the EtroSeal-rotary shaft seal places no special requirements on the surface there. The sealing concept is also ideal for very high-speed applications due to low cost and very good wear resistance over the required service life.

For these reasons, EtroSeal rotary shaft seals are already in use in many electric mobility applications.

**REFERENCES**