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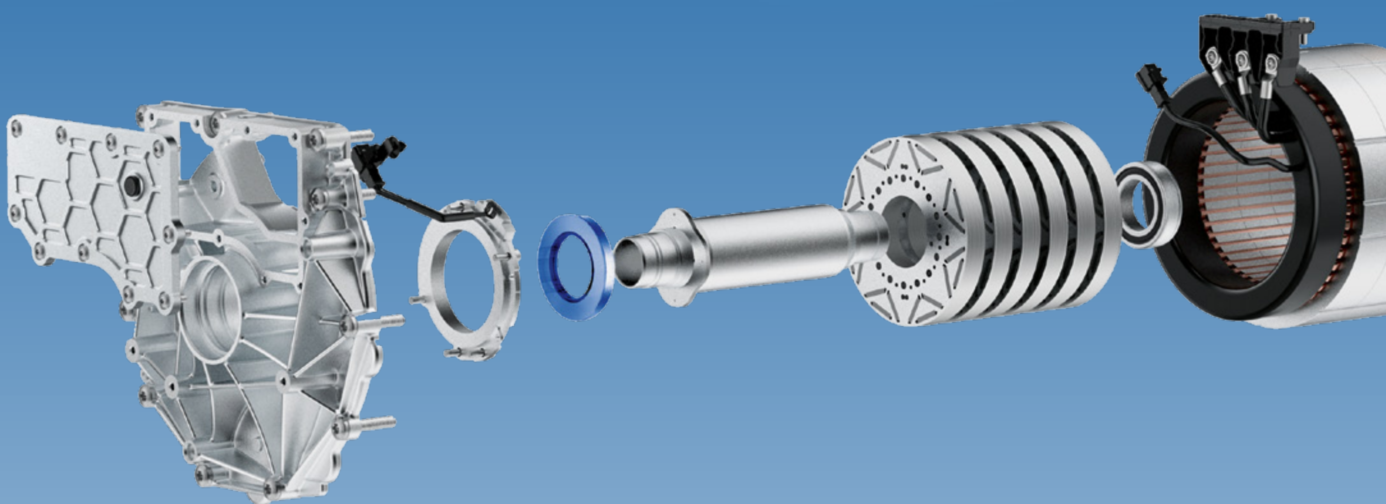

ElroSeal™ E Rotary Shaft Sealing Ring

Testing for Extreme Sealing Requirements

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Testing Rotary Shaft Seals for Extreme Sealing Requirements

AUTHORS

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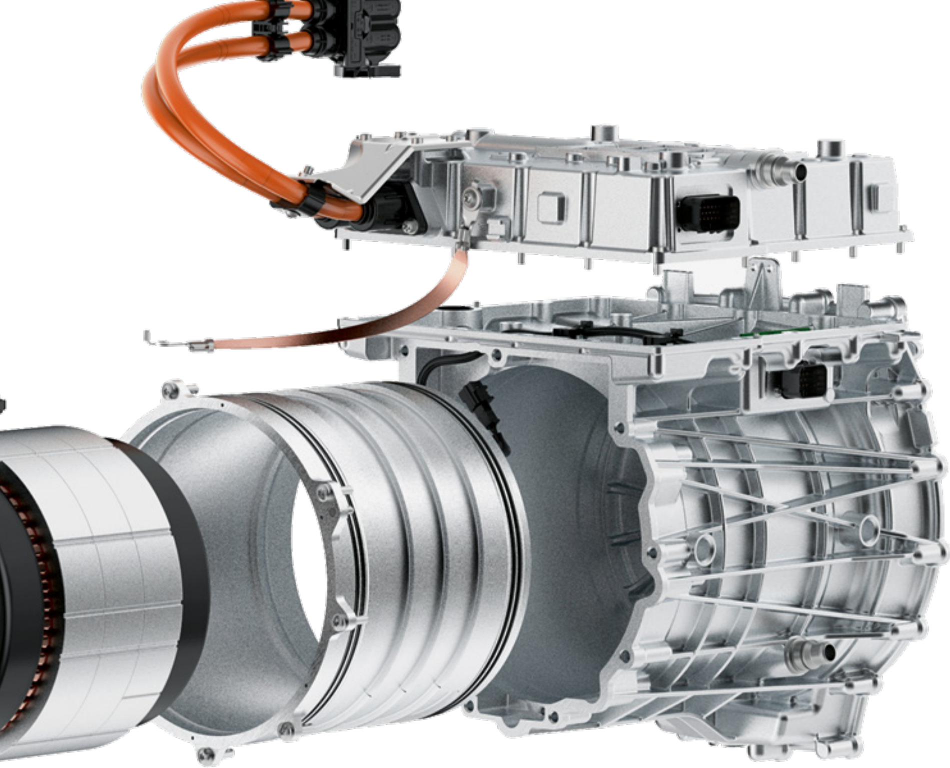
The significantly higher rotational speed of an electric motor at the transition to the gearbox, which is filled with lubricant, results in loads on the sealing system that require a unique sealing solution: the ElroSeal E shaft sealing ring. Test procedures of ElringKlinger Kunststofftechnik and their validity with respect to real-world vehicle service life are to be assessed by studying the ElroSeal E.

The decision by many countries to abandon combustion engine technologies has made alternative drives increasingly important in the automotive industry. Many of these use an Electric Drive Unit (EDU) with an electric motor and gearbox unit mounted directly on the axle. The lubricant must be prevented from entering the electric motor even at maximum speeds.

The basis of the ElroSeal E technology consists of an optimal combination of material, geometry, and functional properties, among others due to special twist structures. The key feature is the sealing lip, which is made of a special, extremely wear-resistant Polytetrafluorethylen (PTFE) compound. The patented surface structure of the sealing lip also produces a unique sealing and backflow function that is independent of direction of rotation, even at very high speeds. This sealing behavior has been verified on the test bench using special testing programs that are based on current sealing requirements. Further special functions of the seal, such as grounding behavior, can also be integrated and checked at any time.

A special surface structure on the sealing lip produces a uniform lubricating film between the sealing lip and the shaft when sealing against oil, which means that the wear on the sealing lip will be very low even in the case of insufficient lubrication. The structure of the sealing lip surface also produces a hydrodynamic transport (pumping) effect at high speeds, which further improves dynamic oil sealing behavior regardless of the direction of rotation. The advantage is that this is possible with very low radial sealing lip contact pressure and low frictional losses.

Under dry run conditions, surface structuring of the sealing lip is not necessary, as the dry run qualities of the sealing lip PTFE compound have been optimized for this use case.



EKT WLTP PLUS CYCLE

Establishing the suitability of seals involves [1] a clash of objectives. On the one hand, the actual vehicle service life should be simulated, while on the other hand, the time required to complete the test should be as short as possible in order to quickly assess performance and thereby validate optimizations within a reasonable time frame. But how can actual operation be simulated on a test bench, and can this approach yield useful information about the service life of the rotary shaft seals used? Unlike the transmission in a combustion engine vehicle, there is no history of vehicles with high mileage over many years. Furthermore, increasing the rotational speed and therefore the circumferential velocity places substantially greater loads on the sealing system in EDUs.

The WLTP driving cycle for a class 3 vehicle consists of the four components low, medium, high and extra high speed, from which near-real-world consumption data can also be determined for electric vehicles. The cycle is precisely defined in terms of driving speeds. In order to use it on the test bench for rotary shaft seals in a cycle based on rotational speeds, some assumptions must be made. When the test program was created, information currently available on transmission ratios and tires in existing electric vehicles was analyzed.

Based on this information, the overall ratio for converting to rotational speed was defined as 0.2, which incorporates the transmission ratio and tire size. This allows the speeds defined in the WLTP cycle to be converted to near-real-world rotational speeds.

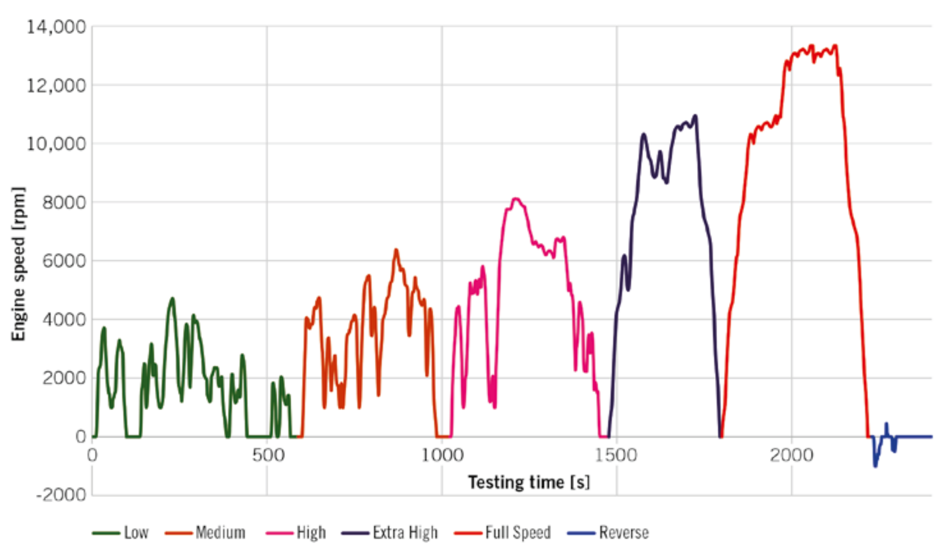
For wear behavior, in particular, full speed phases play a major role. While these are not as dominant internationally due to applicable speed limits, they are a significant factor of influence in Germany.

Another important factor for the assessment is driving in reverse, which is not included in the WLTP cycle, as it is insignificant for consumption results whether the vehicle is traveling forward or in reverse. This is not the case for sealing. Sealing systems with a single twist can definitely generate a pumping effect, which can cause leakage. For this reason, a patented surface structure was developed to cover reversing as well, with a sealing and return flow function that is independent of direction of rotation.

Both conditions – Full Speed (up to V_{max} = 160 km/h) and Reverse – were added to the existing test cycle as additional portions, so that a change in direction and high-speed loading of the seal can be tested. The result is a practical EKT WLTP Plus test cycle that was used for testing the ElroSeal E shaft seal.

The speed graph used for the EKT WLTP Plus test cycle is shown in **FIGURE 1**. In contrast to the WLTP consumption cycle, with a test duration of 30 min, the entire EKT WLTP Plus test cycle has a test duration of 2400 s or 40 min. For the wear tests, this cycle was run up to 1500 times, for a total test duration of 1000 h, which corresponds to a comparable distance of

FIGURE 1 Speed chart of the EKT WLTP Plus test cycle (© ElringKlinger Kunststofftechnik)



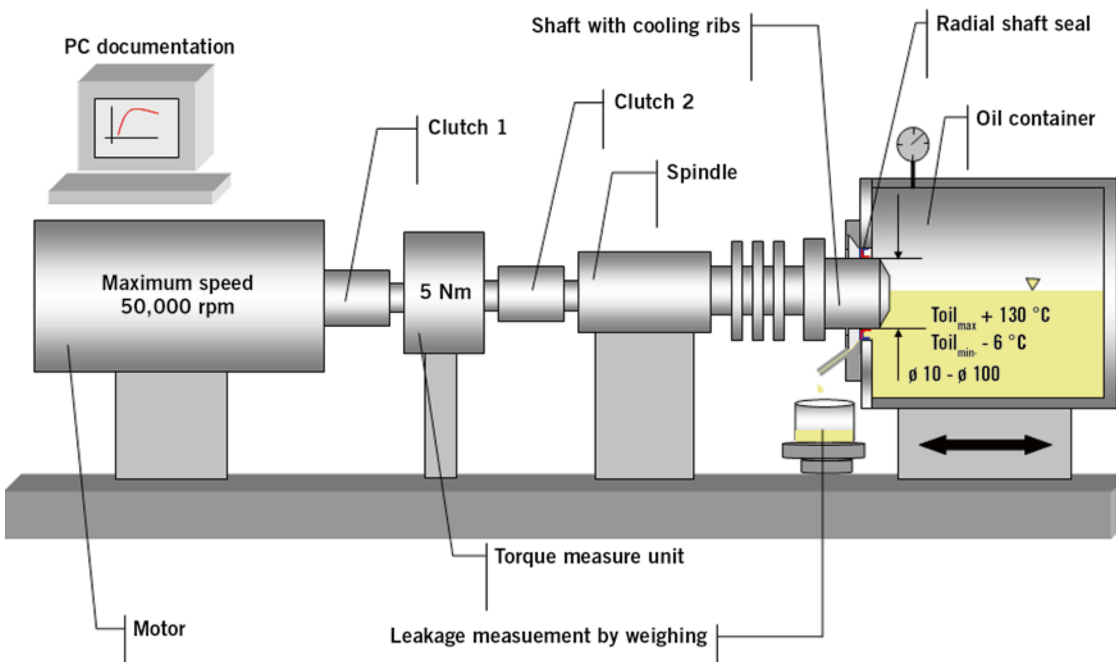


FIGURE 2 Schematic test bench structure for rotary shaft seals (© ElringKlinger Kunststofftechnik)

55,608 km under the given assumptions. In order to determine the wear as a function of the runtime, test runs were performed for 125, 250, and 500 h. To test the ElroSeal E shaft seal, specially built test benches designed for speeds up to 50,000 rpm were used, **FIGURE 2**. The test rig parameters are summarized in **TABLE 1**.

The results of the test runs are shown in **FIGURE 3**, WLTP Plus. Test runs with the maximum amount of wear are recorded here. The results clearly indicate that the highest wear rate occurs during the run-in phase, at about 13 % after 125 h, but then decreases significantly from that point forward. At 1000 h, the residual lip thickness was found to be 80 % (20 % wear).

From a number of different tests, it was ascertained that the function of the twist structure is not significantly impaired until the wear has reached over 50 %. Even this degree of wear does not necessarily lead to failure. Extrapolating the results by calculation indicates that mileage of over one million kilometers is possible under the conditions used for the test.

FIGURE 4 shows an excerpt from a test report for one such test bench run. It shows the EKT WLTP Plus speed stages and the very good leakage behavior of the ElroSeal E rotary shaft seal. The frictional loss determined for the seal is, as expected, dependent on the rotary speed. The frictional loss thus ranges from an average of 11 W in the low range up to an average of 125 W in the Full Speed range. The results closely match the information from field returns in series use.

EKT ISO 24 H CYCLE

Test methods such as the EKT WLTP Plus cycle described above are directly

Seal	ElroSeal E	Dimensions 42 × 60 × 8 mm
Shaft	Inner ring	Dimensions 35 × 42 × 36 mm
	Plunge ground without axial movement to ensure a lead-free shaft surface	
	Roughness (Rz)	≤ 2 µm
Test conditions	Medium	Oil (Castrol BOT 350 M3)
	Oil temperature	90 °C
	Oil level	3–5 mm above bottom edge of shaft (set oil level at 90 °C)
	Prelubricated alternating twist structure	
	Static eccentricity	≤ 0.1 mm
	Dynamic shaft runout	≤ 0.05 mm

TABLE 1 Test rig parameters for EKT WLTP Plus (© ElringKlinger Kunststofftechnik)

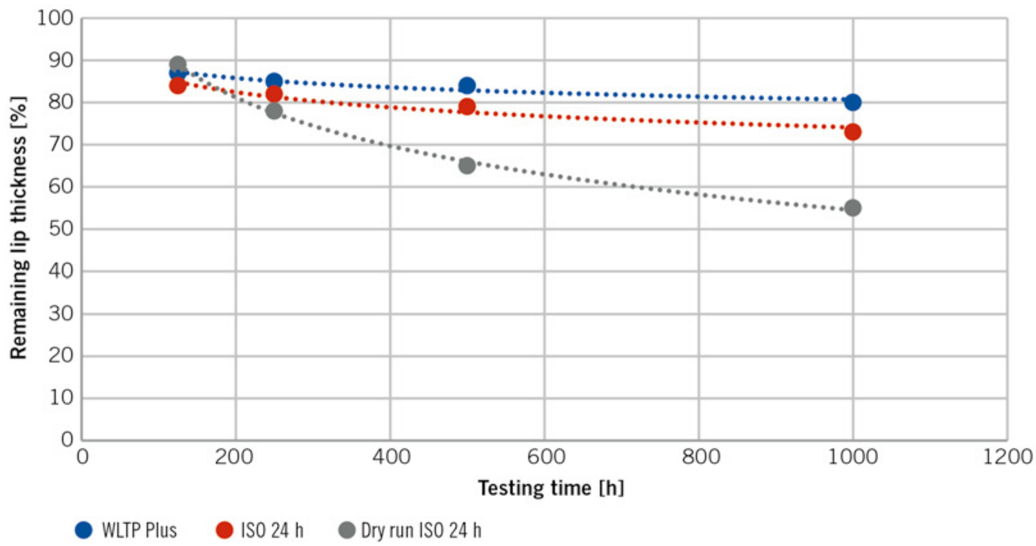


FIGURE 3 Wear curve of ElroSeal E shaft sealing rings and various test cycles (© ElringKlinger Kunststofftechnik)

related to near-real-world conditions. For development work and statistically repeatable tests, the testing times must be significantly reduced and the procedure must be simplified. ISO 16589-4 is used for this purpose. Based on these requirements, a test was created that represents extreme loading of the dynamic seal, **FIGURE 5**.

This test cycle, unlike the near-real-world EKT WLTP Plus cycle, does not involve continuous acceleration and deceleration. Instead, it is characterized by long, constant, very high speeds in both forward and reverse directions. Similar to the EKT WLTP Plus test, this test is also run several times in order to obtain comparable results. As a standard, the test is run for ten cycles – corresponding to a period of 240 h. To obtain comparable values, however, 1000-h tests (42 cycles) were also carried out. The objective is to obtain results indicative of lifetime behavior for various seal designs within a relatively short time.

WEAR BEHAVIOR IN THE ISO 24 H CYCLE

In addition to the test programs indicated above, special test conditions are applied for durability testing. The most important test criteria are summarized in **TABLE 2**.

The results are shown in **FIGURE 3**. It is evident that the curve lies well below the EKT WLTP Plus curve, which means, that higher wear is observed for the same runtime. This indicates that the load on the sealing system is significantly higher in the ISO 24 h test. The level of wear for the WLTP Plus cycle after 1,000 h has already been reached after about 240 h in the ISO 24 h cycle. This test is therefore suitable for statistically sound load testing on EKT multi-spindle test benches.

It is interesting to note that the wear after 240 h for shafts with Rz ≤ 2 µm is nearly identical to that for shafts at Rz = 2 to 3 µm in comparable tests. The optimized material appears to be able to smooth out the surface of the shaft at the contact surface without wearing excessively. This is an important result, particularly for applications that have higher shaft roughness values.

The above results apply to the state with oil lubrication. A test under dry

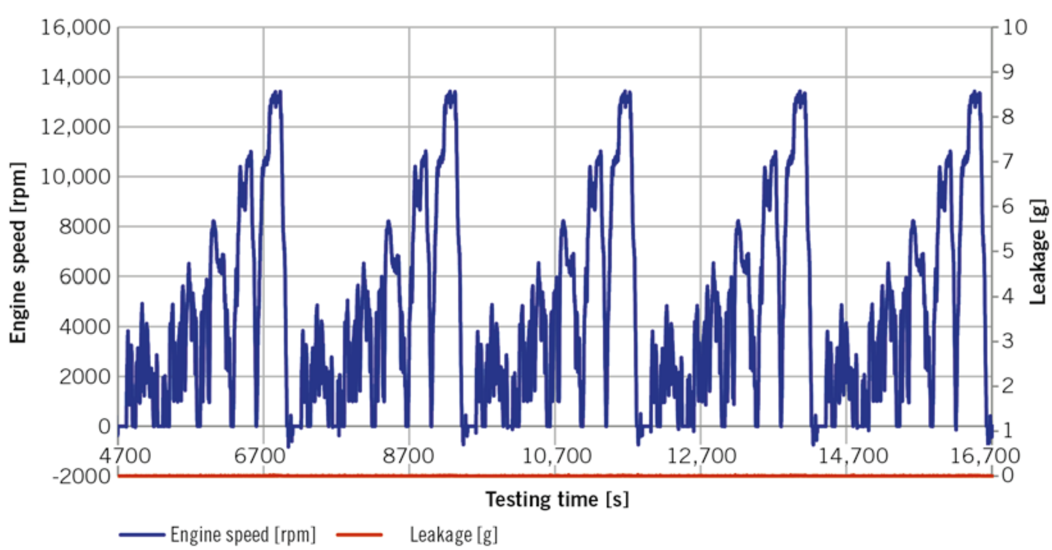


FIGURE 4 Excerpt from a test report for ElroSeal E shaft sealing rings in the EKT WLTP Plus cycle (© ElringKlinger Kunststofftechnik)

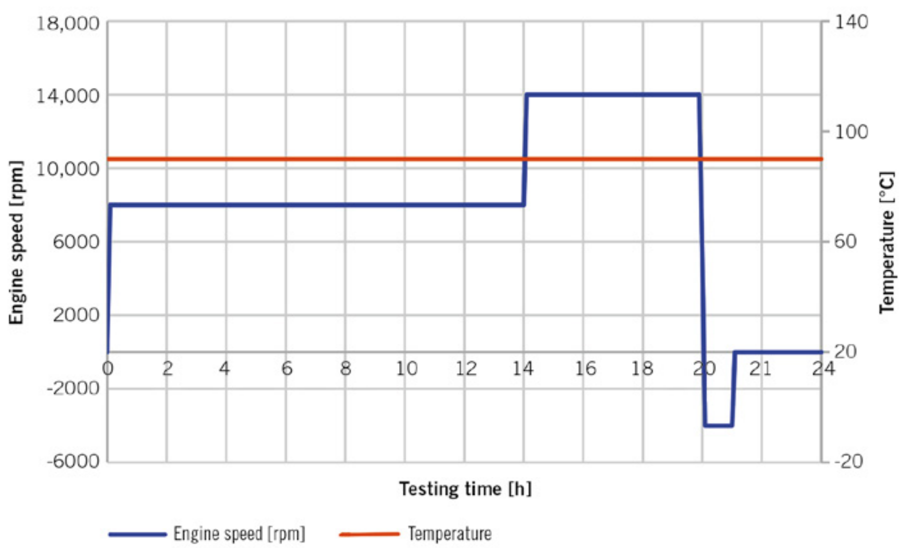


FIGURE 5 EKT ISO 24 h cycle (© ElringKlinger Kunststofftechnik)

run conditions is also shown in **FIGURE 3**. The seal was initially greased for this test. The wear behavior or the PTFE sealing lip is initially higher than in also flattens out and indicates a lower level of wear here. As previously described, hydrodynamic backflow is not absolutely necessary for seals running 80 % wear. Based on extrapolation, mileage values of over 1 million km are possible. In reality, absolutely dry running conditions are the exception. It can therefore be assumed that any oil that sprays would have a positive effect on reducing wear of the sealing lip.

Seal	ElroSeal E	Dimensions 42 × 60 × 8 mm
Shaft	Diameter	42 mm
	Hardened, ground with cut-in, no twist	
	Roughness (Rz)	≤ 2 µm
Test conditions	Medium	Oil (Castrol BOT 350 M3)
	Oil temperature	90 °C
	Oil level	Maximum shaft center
Test Bench Alignment	Static eccentricity	≤ 0.1 mm
	Dynamic shaft runout	≤ 0.05 mm

TABLE 2 Test rig parameters for EKT ISO 24 h (© ElringKlinger Kunststofftechnik)

SUMMARY

The tests demonstrate very low wear rates for the ElroSeal E rotary shaft seal in the near-real-world EKT WLTP Plus cycle. Comparisons also indicate that the 1000-h EKT WLTP Plus cycle correlates to the 240-h ISO 24 h cycle.

Extrapolating the captured data, mileage of over 1 million km can be expected under the given conditions. Together with the low level of friction and the very low leakage rate, along with dry running capability, the ElroSeal E rotary shaft seal is optimally suited for highly loaded applications in electric drivetrains. The tests also indicate that a lean 240-h test can provide comparable conclusions in a shorter time. This helps with statistical validation and produces faster results for modified problem cases, such as higher rotary speeds, greater diameter, or high circumferential speeds.

REFERENCE

[1] Koch, U.; Wallner, U: ElroSeal E – A New Standard for Electric Drives. In: MTZworldwide 10/2019, pp. 60-63

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