VDMA
Fluid Power Association

23rd ISC

International Sealing Conference

Stuttgart, Germany
Sept.30 - Oct.1, 2026

Sealing the future –
Facing the challenges of tomorrow

UNI STUTTGART

Fachverband Fluidtechnik im VDMA e. V. Lyoner Str. 18
50628 Frankfurt am Main
Germany

Phone +49 69 6603-1513
E-Mail maximilian.baxmann@vdma.eu

Internet www.vdma.eu/fluid

Selection of Sealing Ring Materials as a Key Factor for the Reliable Operation of Shaft Seals

Hendrik Gieraths

The reliability of sealing systems is a crucial factor for the operational safety and economic efficiency of technical plants and machinery. In this context, the selection of suitable sealing materials is essential to ensure long service life, low leakage rates, and minimal temperature generation at the sealing interface.

In applications such as fans, blowers, and equipment used in the chemical industry, non-lubricated sealing systems for technical gases, such as the SDW50, are commonly used. This sealing system consists of overlapped, mortised seal ring segments that are in direct contact with the shaft and are therefore subject to wear over operating time. The extent of wear is strongly influenced by the specific operating parameters of the overall system, including rotational speed, pressure, medium and temperature.

Furthermore, this type of sealing system can be used in applications involving potentially explosive atmospheres (ATEX). In such cases, the surface temperature of the seal is of critical importance. Depending on the sealed medium, even minor temperature increases caused by frictional contact between the rotating shaft and the sealing elements may lead to an exceedance of the permissible surface temperature. At the same time, there is a growing demand to operate these sealing systems under increasingly challenging conditions, such as higher pressures and rotational speeds.

To identify suitable sealing materials for demanding and/or explosive applications, an experimental test series was conducted on a newly developed test bed for shaft seals. Under constant high pressure and rotational speed, temperature, leakage, and pressure characteristics of carbon-based materials with different impregnations as well as PTFE-based materials with various fillers were investigated and compared under identical test conditions. Based on application-specific requirements, preferred materials could be identified regarding food compliance, cost efficiency, best technical performance, and minimal temperature generation.

1 Introduction

Shaft sealing systems are essential components in technical equipment, as they separate media at different pressure and temperature levels and prevent leakage to the environment. In applications such as fans, blowers, and process plants, sealing systems for technical gases must ensure reliable operation while minimizing leakage, wear, and thermal loads.

For contacting shaft seals, the selection of the sealing material plays a decisive role. Material properties directly influence friction, wear behaviour, leakage rates, and temperature generation at the sealing interface. The latter becomes particularly critical in applications involving potentially explosive atmospheres, where the maximum permissible surface temperature limits the operational range of the equipment. In addition, application-specific requirements, such as food compliance, impose further constraints on material selection.

Although carbon-based and PTFE-based materials are widely used in segmented sealing systems, their performance strongly depends on material modifications such as impregnation or fillers. Comparative investigations under identical operating conditions, especially for contacting non-lubricated seals, remain limited.

Therefore, this study investigates the behaviour of selected carbon and PTFE-based materials in a contacting shaft seal (type SDW50) using a dedicated test bench. The focus is on experimentally evaluating temperature development, wear, and leakage to assess material-dependent performance under controlled conditions.

2 State of the Art

2.1 Shaft sealing concepts

Shaft seals are used to separate media at different pressure and temperature conditions and are therefore essential for the safe and efficient operation of technical systems. Depending on the application and operating conditions, different sealing principles are employed, which significantly influence leakage, wear, and thermal behaviour [1].

In applications such as fans and blowers, segmental gas seals are commonly used and can be broadly classified into non-contacting and contacting designs. Non-contacting seals, such as floating ring or clearance seals, operate with a defined gap between the sealing element and the shaft. This gap reduces wear but typically results in higher leakage, particularly under varying thermal conditions due to differing thermal expansion of shaft and sealing material.

Contacting seals (see Figure 1), in contrast, rely on direct contact between the sealing element and the rotating shaft. In segmental designs with overlapped joints, the sealing rings are pressed against the shaft by process or buffer gas pressure, enabling reduced leakage compared to non-contacting systems. However, the permanent contact leads to friction-induced wear and heat generation. At the same time, the segmented design allows for self-adjustment, compensating for wear and shaft movements during operation.

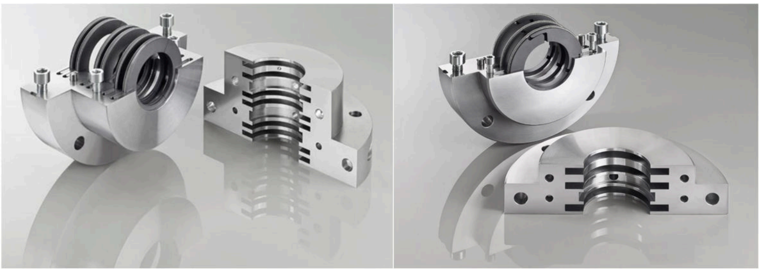

Figure 1: Floating ring seal SDW20 (left) and contacting ring seal (right)

As a result, the selection of the sealing concept represents a trade-off between leakage, wear behaviour, and thermal load.

2.2 Sealing materials

The performance of shaft seals is strongly influenced by the properties of the applied sealing materials. Carbon and graphite-based materials as well as PTFE-based compounds are commonly used in segmental sealing systems, each offering specific advantages and limitations.

Carbon-based materials are characterized by high temperature resistance, good chemical stability, and favourable tribological properties. Their performance can be tailored by material modifications such as impregnation, which reduce porosity and improve mechanical strength and wear resistance. However, such modifications may affect their suitability for specific applications [2].

PTFE-based materials exhibit low friction coefficients and excellent chemical resistance, making them suitable for dry-running conditions. Their mechanical limitations, particularly related to creep behaviour, can be mitigated by incorporating fillers such as fibers or solid lubricants, which enhance wear resistance and load-bearing capacity. Nevertheless, PTFE materials are generally limited in their maximum operating temperature [3].

Overall, the behaviour of both material classes depends strongly on their specific composition. Therefore, a general performance assessment based solely on material type is not sufficient, and material selection must consider application-specific requirements.

3 Application and Operating Conditions

Segmental shaft seals are widely used in applications involving technical gases, particularly in fans, blowers, and process equipment. In addition, they are applied in machinery such as centrifuges, mixers, dryers, and chemical processing units. Depending on the application, requirements may include chemical resistance, thermal stability, or compliance with regulatory standards such as food-grade suitability.

A relevant field of application is the use of these systems at explosive atmospheres. In such cases, the surface temperature of the sealing system is a critical parameter, as it determines compliance with temperature classes and thus the permissible operating range. Friction-induced heating at the sealing interface must therefore be carefully considered when selecting both, the sealing concept and the material.

The examined sealing systems are typically operated in low to moderate pressure ranges, generally up to approximately 3 bar(g). Rotational speeds vary depending on the application and can range from moderate values to high circumferential velocities. The resulting thermal and tribological loads are governed by the interaction of pressure, speed, temperature, and the sealed medium.

Under these conditions, the sealing material becomes a limiting factor for the operational performance of the system. Its influence on friction, wear, and temperature development directly defines the achievable operating window. Therefore, a detailed understanding of material behaviour under defined boundary conditions is essential for the reliable design of contacting shaft seals.

4 Design and Working Principle

The investigated sealing system is a contacting, segmental shaft seal with overlapped and interlocked ring segments (see Figure 2). The seal housing consists of two horizontally split halves, which are bolted together and mounted at the shaft passage of the machine.

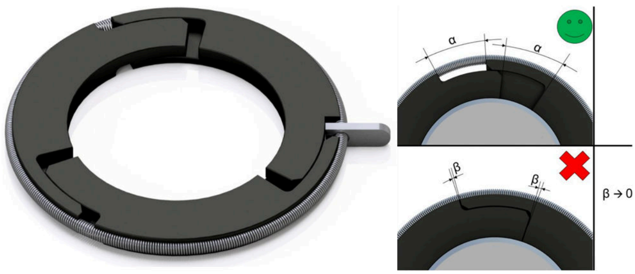

Figure 2: Contacting sealing rings with overlapped and interlocked ring segments

Inside the housing, circumferential grooves guide the multi-part sealing rings. The segmented design with overlapped joints reduces leakage at the segment interfaces while allowing for wear compensation during operation. A retainer plate prevents the sealing rings from rotating with the shaft. Due to the design, the sealing system provides directional sealing performance.

The sealing effect is based on a pressure-induced contact between the sealing rings and the rotating shaft. Process or buffer gas pressure generates a radial force pressing the rings against the shaft, forming the dynamic sealing interface. Simultaneously, pressure gradients across each ring create an axial force, ensuring sealing against the housing. A leakage flow is established through the remaining clearance between ring and shaft.

During operation, continuous contact between the sealing rings and the shaft leads to friction, resulting in heat generation and progressive wear at the inner diameter of the rings. The segmented design allows for self-adjustment, partially compensating for material loss and maintaining sealing performance over time.

Depending on the application, the seal can be operated with or without buffer gas. When buffer gas is applied, it is maintained at a pressure level above the process gas pressure, preventing the escape of the sealed medium and establishing a defined leakage flow of the buffer gas.

5 Material Selection

A total of seven sealing materials were selected for the experimental investigation, including four carbon-based materials and three PTFE-based compounds (see Table 1). The selection aims to represent a broad range of material properties by considering both unmodified and specifically modified materials.

Table 1: Selection of materials for the test

Material designation	Type of material	FDA	Temperature limit
SK10C	Hard carbon without impregnation	Yes	350°C
SK10K	Electrographite impregnated with antimony	No	500°C
SK10X	Electrographite without impregnation	Yes	500°C
SK32K	Electrographite with salt impregnation	No	600°C
SK202	PTFE filled with glass fiber, carbon, and graphite	Yes	180°C
SK313	PTFE filled with bronze, carbon fiber, and MoS_2	No	180°C
SK49	PTFE filled with carbon and graphite	Yes	180°C

The carbon-based materials include non-impregnated variants as well as materials modified by impregnation, such as with antimony or salts. While non-impregnated materials may offer advantages in terms of cost and regulatory compliance, impregnated materials are typically designed to enhance mechanical strength, reduce porosity, and improve wear resistance. However, such modifications may limit their applicability in regulated environments.

The PTFE-based materials differ primarily in their filler composition. Additives such as fibers, carbon-based particles, or solid lubricants are used to improve wear resistance and mechanical stability, reducing the limitations associated with the viscoelastic behaviour of pure PTFE. Due to their comparatively lower temperature resistance, their application range is generally restricted to moderate thermal conditions.

Overall, the selected materials enable a systematic comparison of different material concepts under identical operating conditions. This provides a basis for evaluating the influence of material composition on temperature behaviour, wear, and leakage in contacting shaft seals.

6 Experimental Setup and Methodology

Experimental investigations were conducted using a contacting shaft seal of type SDW50 under controlled operating conditions. The aim was to enable a reproducible comparison of material-dependent temperature behaviour, wear, and leakage.

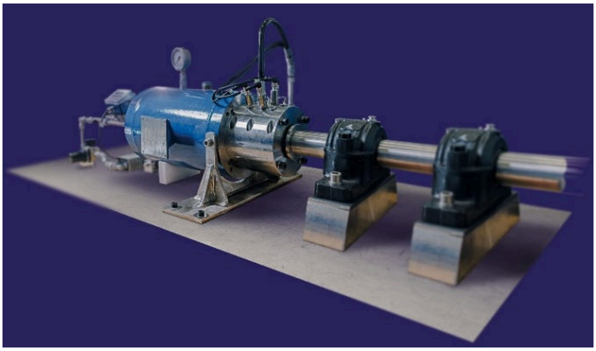

Figure 3: Shaft seal test bed for the experimental investigation

The tests were carried out on a dedicated test bed equipped with a modified seal housing made of stainless steel (1.4021). Three sealing rings were arranged in series. Temperature sensors (PT100) were integrated at each sealing ring, while pressure sensors were installed between the individual sealing stages to monitor the internal pressure distribution. Leakage was measured using a volumetric flow sensor downstream of the seal.

The shaft was supported by two bearing units, with one end extending into a pressurized chamber. The sealing system was mounted to this vessel, which was supplied with compressed air. The escaping gas flow through the seal was continuously recorded and used to quantify leakage.

All experiments were performed under constant operating conditions to ensure comparability (see Table 2). The rotational speed was set to 1800 rpm, representing the maximum capacity of the test bed, and the pressure was fixed at 1.5 bar(g) to promote measurable wear. Air was selected as the test medium to represent typical operating conditions in gas-handling equipment.

Table 2: Test conditions

Speed	1800	rpm
Pressure	1,5	bar(g)
Medium	Air	
Shaft diameter	Ø60	mm
Ambient Temperature	~ 20	°C
Test duration	310	h

Wear was determined by measuring the radial height of the sealing rings before and after each test (see Figure 4). For each segmented ring, nine measurement points were recorded, allowing a statistical evaluation of wear. The difference between initial and final measurements was used to quantify material loss. This combination of in-situ measurements and pre/post-test analysis enables a comprehensive assessment of material performance under defined and reproducible conditions.

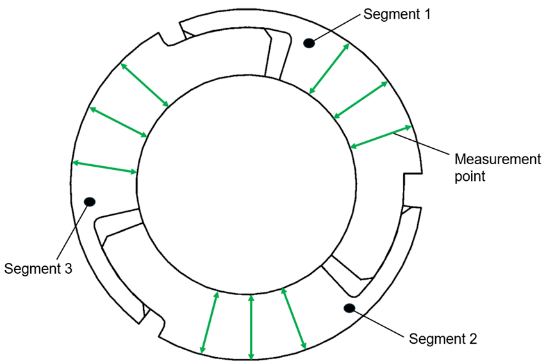

Figure 4: Measurement points for wear analysis

7 Results

7.1 Temperature behaviour

The temperature increase at each sealing ring was evaluated relative to the measured ambient temperature to minimize external influences. The maximum temperature rises are shown in Figure 5.

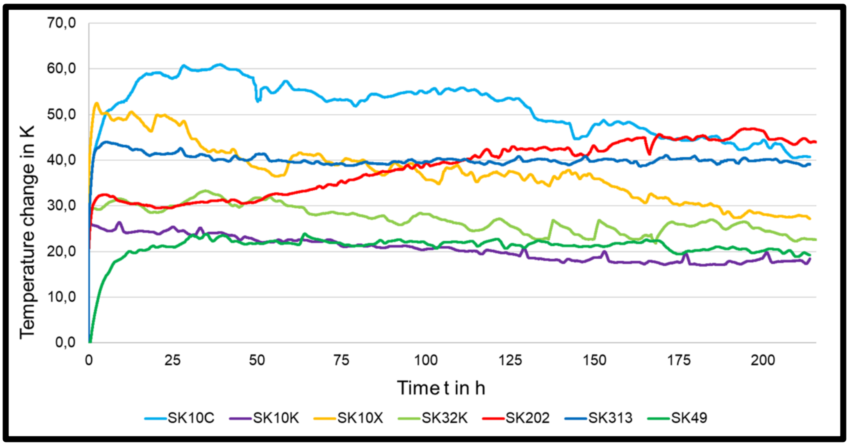

Figure 5: Temperature changes by friction of the sealing materials

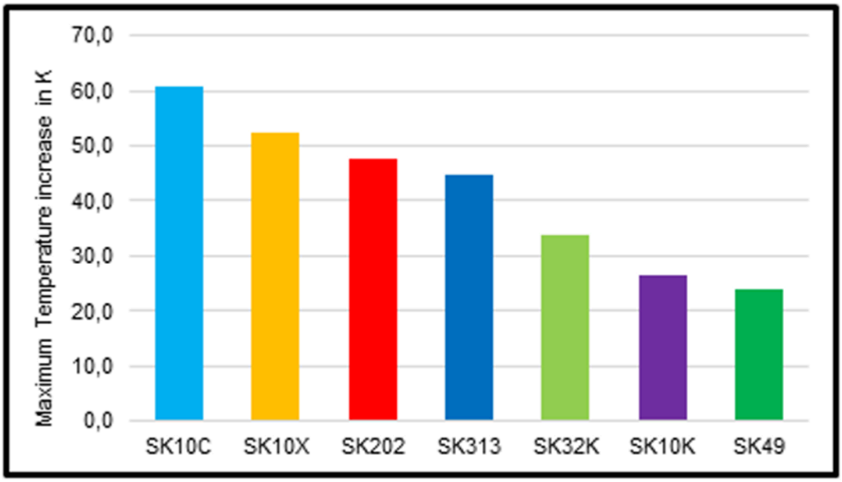

Figure 6: Maximum temperature development sorted from highest to lowest

The results reveal significant differences between the materials investigated (see Figure 6). The highest temperature increase was observed for SK10C (60.9 K), while SK49 exhibited the lowest value (23.9 K), resulting in a difference of more than a factor of two. The impregnated carbon material SK32K also showed comparatively low temperature increase (26.6 K). Overall, both carbon-based and PTFE-based materials exhibit a wide range of thermal behaviour. A general classification based on material group is therefore not possible.

7.2 Pressure distribution

The measured pressure distribution within the seal is presented in Figure 7. Starting from an inlet pressure of approximately 1.5 bar(g), a stepwise pressure drop across the sealing stages is observed.

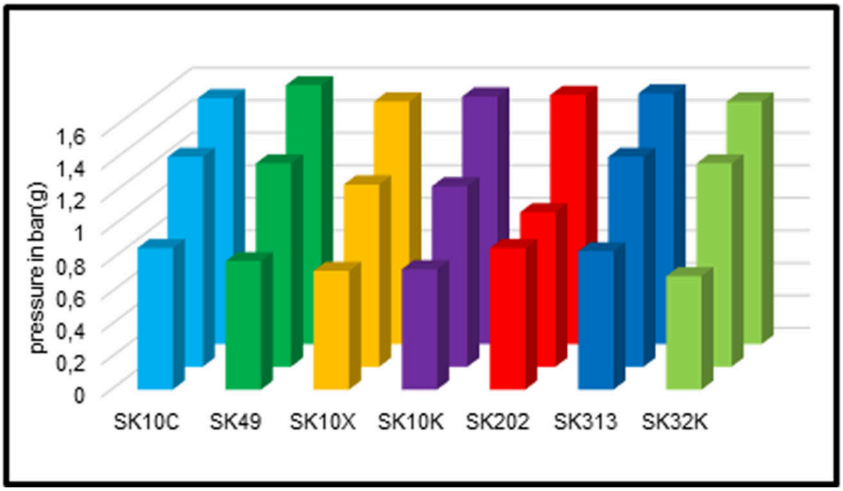

Figure 7: Average pressure profiles in the shaft seal housing

The first sealing ring reduces the pressure by about 0.3 bar(g), resulting in approximately 1.2 bar(g) between the first and second ring. The second ring causes a further drop of about 0.4 bar(g), leading to the highest pressure difference of approximately 0.8 bar(g) at the third sealing ring.

This indicates non-uniform loading of the sealing rings, with the last ring experiencing the highest mechanical and tribological stress. An exception was observed for SK202, where no significant pressure drop occurred between the second and third ring.

7.3 Wear characteristics

Wear was quantified by comparing the radial dimensions of the sealing rings before and after the tests. The results are summarized in Figure 8.

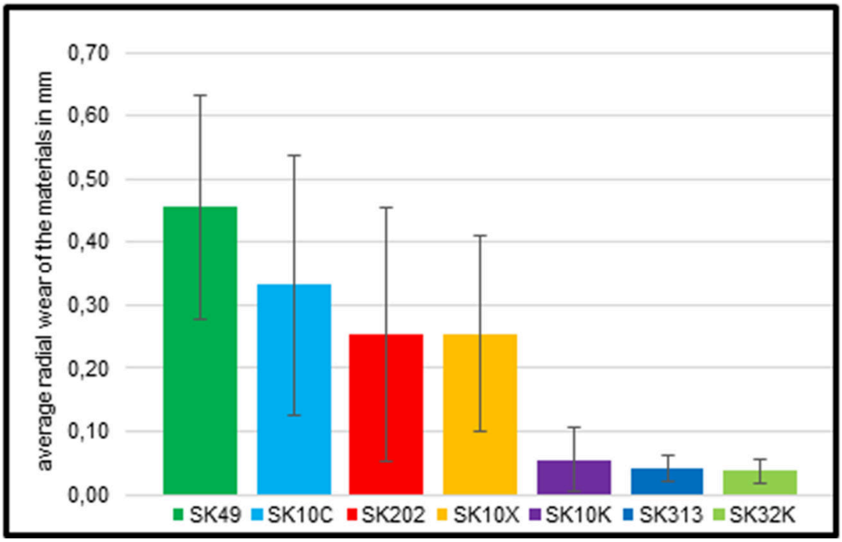

Figure 8: Average radial wear of all sealing rings

Significant differences in wear resistance were observed between the materials. Consistent with the pressure distribution, the highest wear occurred at the third sealing ring (results in Figure 9).

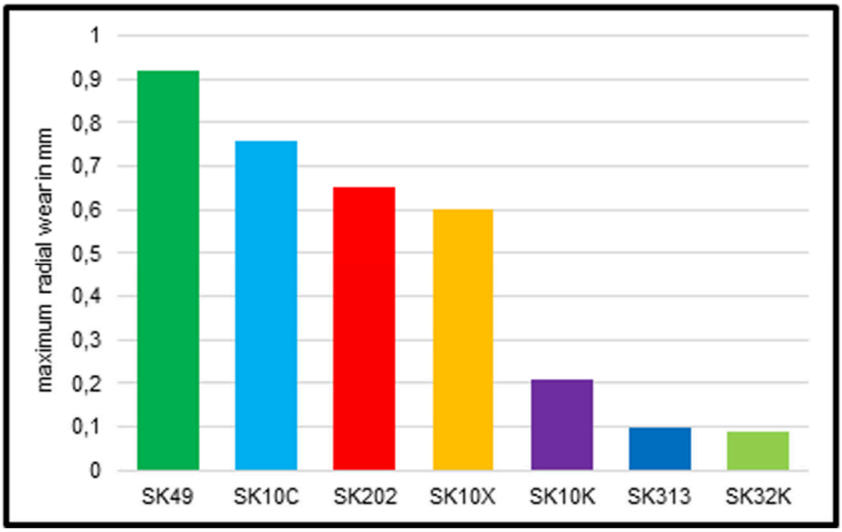

Figure 9: Maximum radial wear of the third sealing ring

SK49 exhibited the highest maximum wear of 0,92 mm, whereas SK32K showed the lowest value of 0,09 mm. The PTFE-based material SK313 also demonstrated low wear with approximately 0,1 mm. The non-impregnated SK10C carbon ranked second-worst. Averaged values confirm the same trends.

Within both material classes, considerable variations are present, indicating that wear behaviour is strongly material-specific.

7.4 Leakage rates

The leakage behaviour over time and the averaged leakage rates are shown in Figure 10. The maximum average leakage values are shown in Figure 11.

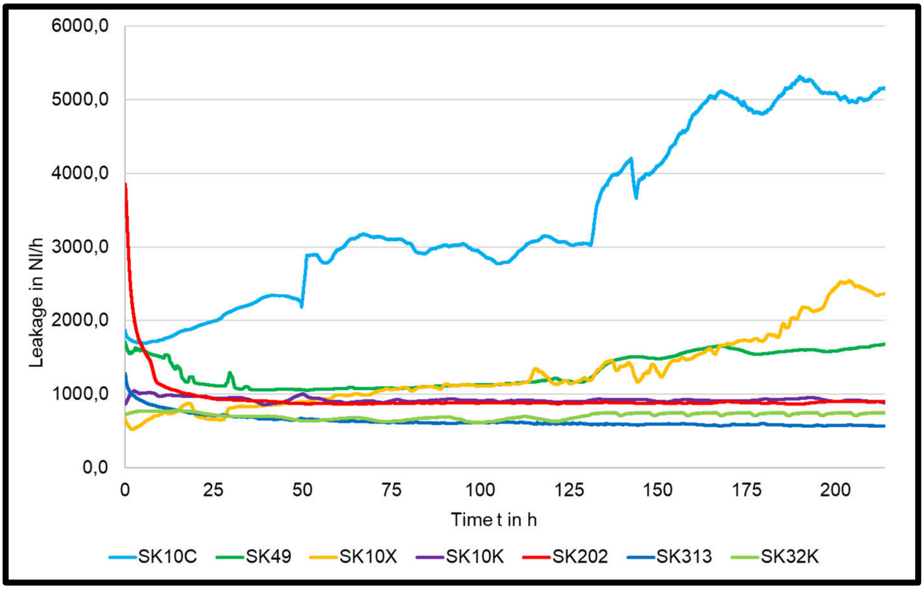

Figure 10: Leakage rates based on the sealing materials during the tests

Clear differences in both leakage magnitude and progression were observed. SK10C and SK10X exhibited increasing leakage over time, with SK10C showing an almost twofold increase by the end of the test. In contrast, SK313 and SK32K maintained comparatively low and stable leakage levels.

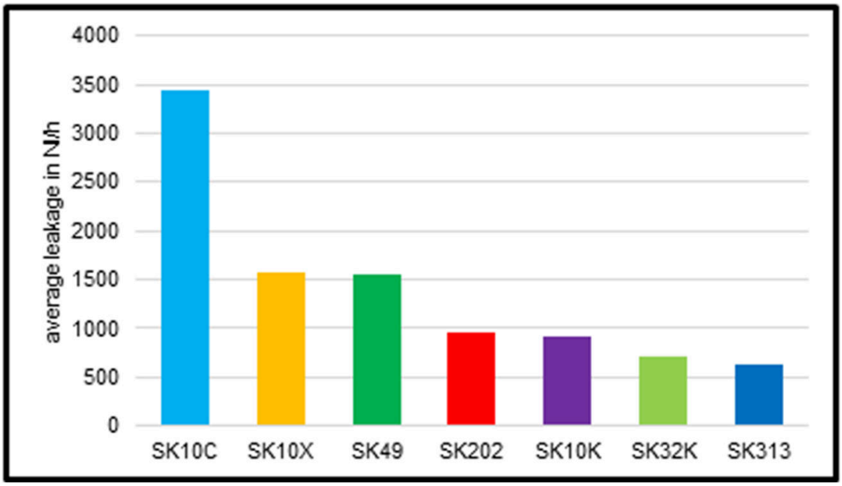

Figure 11: Average leakage caused by different sealing materials

The remaining materials showed largely constant leakage behaviour. Overall, SK10C and SK10X resulted in the highest leakage rates, while SK313 and SK32K demonstrated superior sealing performance.

8 Discussion and Conclusion

The results demonstrate that the sealing material has a decisive influence on the operating behaviour of contacting shaft seals. Despite identical seal geometry and constant test conditions, clear differences were observed in temperature development, wear, and leakage. This confirms that material selection must be regarded as a key design parameter for the design and application of such sealing systems.

Substantial differences were identified in thermal behaviour. Neither carbon-based nor PTFE-based materials can be generally classified as thermally favorable, since the temperature increase strongly depends on the specific material composition, including impregnation and filler content. This aspect is particularly important for applications in potentially explosive atmospheres, where friction-induced heating may restrict the permissible operating range.

The wear results are consistent with the measured pressure distribution inside the seal. The highest wear occurred at the third sealing ring, which was exposed to the largest pressure difference and thus to the highest tribological load. At the same time, pronounced material-dependent differences in wear resistance were observed. In particular, impregnated carbon materials and selected PTFE compounds showed improved wear behaviour, indicating that targeted material modification can significantly enhance seal durability.

A similar relationship was found for leakage. Materials with unfavorable wear behaviour tended to show increasing leakage over time, whereas more wear-resistant materials maintained more stable leakage levels. However, low temperature increase did not necessarily coincide with low wear or low leakage. The results therefore reveal a trade-off between the investigated performance criteria, which means that material selection cannot be based on a single property alone.

From an application perspective, the choice of sealing material must depend on the specific operating requirements. In ATEX-related applications, thermal behaviour is especially critical, whereas in long-term industrial operation wear resistance and leakage stability may be more important. Additional constraints may arise from regulatory requirements such as food-grade compliance.

Overall, the present study shows that no universally optimal sealing material exists. Instead, material suitability depends on the balance between thermal, tribological, regulatory, and operational requirements. Under the investigated conditions, the comparative experiments provide a reliable basis for evaluating material-dependent performance in contacting shaft seals. Further studies under varying media, pressures, and rotational speeds are required to extend the applicability of the findings.

9 References

[1] H. W. B.-R. H. K. S. Gustav Niemann, Maschinenelemente 1 - Konstruktion und Berechnung von Verbindungen, Lagern, Wellen, Garching: Springer Verlag, 2019.

[2] W. Bergmann, Werkstofftechnik 1 - Struktureller Aufbau von Werkstoffen - Metallische Werkstoffe - Polymerwerkstoffe - Nichtmetallisch-anorganische Werkstoffe, Berlin: Carl Hanser Verlag München, 2008.

[3] A. Daubner, Analyse, Modellierung und Simulation von Verschleiß auf mehreren Skalen zur Betriebsdauervorhersage von Wellendichtringen aus PTFE-Compound, Stuttgart, 2014.

10 Authors

STASSKOL GmbH

Address:

M. Sc. Ing. Hendrik Gieraths, hendrik.gieraths@stasskol.de

https://doi.org/10.61319/1ZDC941O