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SPECIFIC ASPECTS REGARDING THE CONSTRUCTION AND MAINTENANCE OF SEALING ELEMENTS IN HYDRAULIC SYSTEMS

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Abstract: *In this paper, specific aspects regarding the manufacturing process of casting and CNC machining of the different types of seal elements used in hydraulic systems from various industries. Fluid loss monitoring options are also described, especially the vibration analysis of hydraulic cylinders.*
Key words: *hydraulic systems, maintenance, sealing elements.*

1. INTRODUCTION

Hydraulic seals are key components, used in all sorts of hydraulic systems from various industries such as automotive, aerospace, tool machining, etc. for transferring and utilizing mechanical power by the means of a working fluid [10].

As a main element of a hydraulic system, the seals prevent fluid leakage (for example from hydraulic cylinders, pumps, etc.), and they help prevent the ingress of contaminants that can cause component damage and reduce their performance. Hydraulic seals are available in a large variety of shapes and sizes depending on the application [9]. Some of the more common types of seals are rod seals, piston seals, scavenger systems seals, and guide rings. Each of these types is designed to suit a specific application and withstand the conditions in which it will be used. In addition to their importance in preventing fluid leaks and contamination, hydraulic seals play an essential role in the overall performance of the entire hydraulic system.

Properly designed and installed seals can help improve the system's efficiency, reduce component wear, and extend the life of the system [4].

Maintenance, especially the predictive one, is an extremely important aspect of the correct hydraulic systems functioning. Now, there are different variants of analyzing the specific behavior of these systems, such as the material of the sealing elements [8], the analysis of the remaining fluid film [2], the acoustic monitoring [3, 6, 7], or the analysis of the vibrations [1, 5].

Nowadays, the hydraulic seal industry plays a vital role in many different industries, and the development of new and innovative sealing technologies is critical to improving the performance and reliability of hydraulic systems. As the demand for hydraulic systems continues to grow, the importance of hydraulic seals is likely to grow even more, making this an exciting area of research and development.

As already pointed out, the main element of the hydraulic system is the seal - made from various materials and designed in different shapes and types. They must ensure the efficient and effective operation of hydraulic systems. There are two main types of hydraulic seals:

A. Static seals. They are fixed during the operation process of the hydraulic system. They are used to seal the joint between two stationary surfaces. Common types of static seals include O-ring seals (fig.1) and flanged seals.

B. Dynamic seals. They are used to seal the joint between two surfaces that are in relative motion such as cylinders and pumps. Some of the common types of dynamic seals include:

B.1 Rod seals (fig.2) which are designed to provide a seal between the piston rod and the cylinder bore.

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B.2 Piston seals (fig.3) should provide a seal between the piston and the cylinder bore. Also, they should ensure a smooth movement of the piston.

B.3 Wiper (wiper) seals (fig.4) or **scraper rings**. Those types of components are used to prevent contamination of the hydraulic system. They are also utilized to remove dirt, dust, and other contaminants from the piston rod before it enters the cylinder. They also help prevent hydraulic fluid from leaking out of the cylinder.

Understanding the different types of hydraulic seals is important to selecting the right seal for a specific application. Each type of seal has unique characteristics and capabilities that make it suitable for a particular hydraulic system.

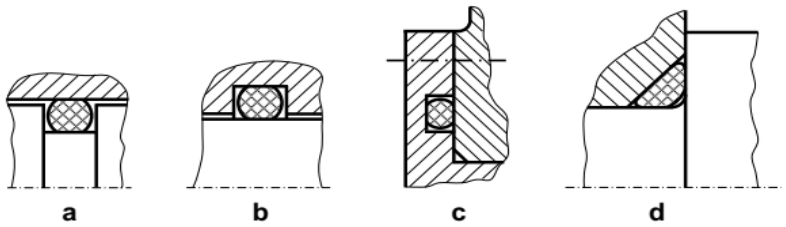

Fig.1 O-Ring seals [4]

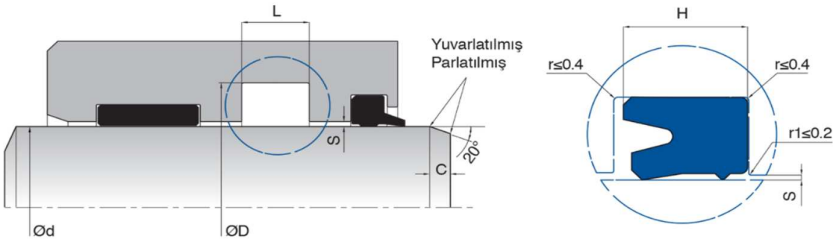

Fig.2 K33 rod seal KASTAS type [9]

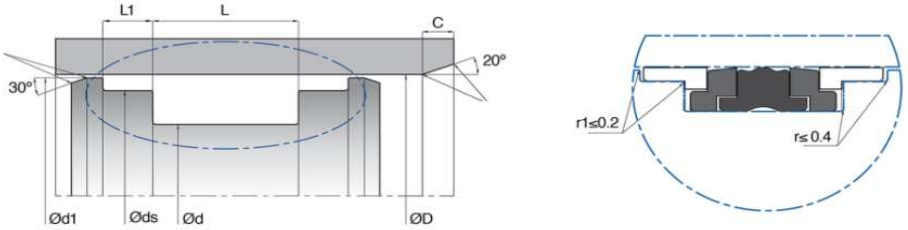

Fig.3 K17 seal KASTAS type [9]

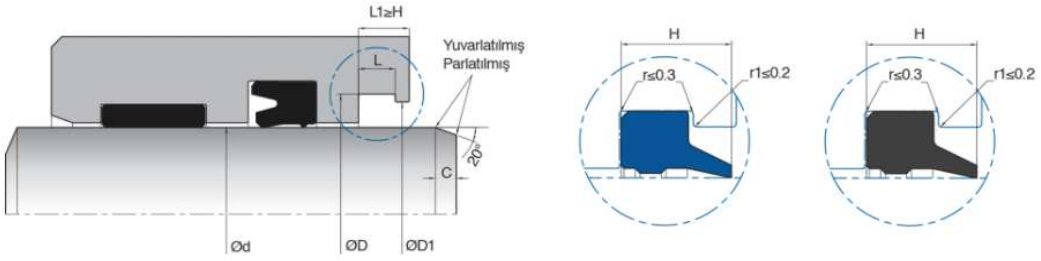

Fig.4 K06 scraper ring KASTAS type [9]

2. MANUFACTURING OF SEALING ELEMENTS. MATERIALS

There are two main types of seal manufacturing techniques used in industry:

A. Cast seals. Those types are produced using a casting process where the liquid material is poured into a mold and allowed to cool and solidify. This process is ideal for manufacturing complex shapes and is suited for large-scale production processes.

B. Machined seals. They are manufactured by cutting and shaping the gasket from a solid block of material on a CNC lathe. This process allows for tight tolerances and precise dimensions, making machined seals suitable for high-precision applications.

The selection of the manufacturing technique depends on various factors such as: where the gasket will be used, required tolerances, production volume, and cost. In recent years, advances in Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) have enabled manufacturers to create complex shapes and patterns using both manufacturing techniques. The use of CAD/CAM technology has also reduced production time and improved the accuracy and consistency of the designed gaskets.

The performance of the hydraulic seal is strongly influenced by the materials from which is made. Several types of materials are commonly used for manufacturing hydraulic seals: elastomers, thermoplastics, and composite materials.

A. Elastomers are the most used materials in hydraulic seals. They are characterized by their ability to elastically deform and return to their initial shape, making them ideal for dynamic sealing applications. Elastomers are available in a large variety having unique properties. For example, nitrile rubber is commonly used in hydraulic seals due to its excellent resistance to oil and other hydraulic fluids. Viton is another elastomer that is commonly used for hydraulic systems that operate at high temperatures.

B. Thermoplastics are another class of materials that are commonly used in hydraulic seals. These materials have several advantages over elastomers, including improved temperature resistance and chemical compatibility. Some of the thermoplastics commonly used in hydraulic seals include polyurethane (known for its excellent abrasion resistance and high load capacity) and PTFE (Teflon - a high-performance plastic that is known for its excellent chemical resistance and low coefficient of friction - a solid lubricant).

C. Composite materials are a relatively new class of materials that are used in hydraulic seals. They are often utilized in high-performance hydraulic seals due to their improved wear resistance, strength, and thermal stability.

The selection of materials for hydraulic seals depends on a variety of factors, including the operating conditions of the hydraulic system, the type of fluid used, and the sealing requirements of the application. For example, if the hydraulic system operates at high temperatures or is exposed to harsh chemicals, a material with high temperature and chemical resistance such as Viton or PTFE would be suitable. Similarly, if the hydraulic system operates at high pressure or experiences frequent pressure peaks, a material with high abrasion resistance such as polyurethane would be suitable.

3. MONITORING OF FLUID LOSSES: MONITORING TECHNIQUES

Now, there are currently no visual features that can be used to monitor the initial stages of fluid losses in linear hydraulic motors until the fluid losses are visible or the system performance is affected. Planned internal fluid leaks in hydraulic systems are achieved when fluid is allowed to flow from the high-pressure area to the low-pressure area to lubricate, clean, and cool certain components or specific areas of the hydraulic system.

A key point for fluid leakage in hydraulic linear motors is where the motor rod exits the cylinder. Piston rod deflection, damage to seals, or the inability of the hydraulic cylinder to support external loads can result in significant fluid leakage. Knowing that the leaks from hydraulic cylinders affect both the dynamic and static performance of the equipment, it is necessary to monitor the condition of the hydraulic cylinders.

In recent years signal-based techniques are more and more used for monitoring hydraulic system leaks. In figure 5 are shown the main techniques which are based on the signal analysis.

Different signal processing techniques have been used to analyze sensor signal data, such as time-domain features, frequency-domain analysis, or time-frequency techniques. Those techniques are based on various sensors:

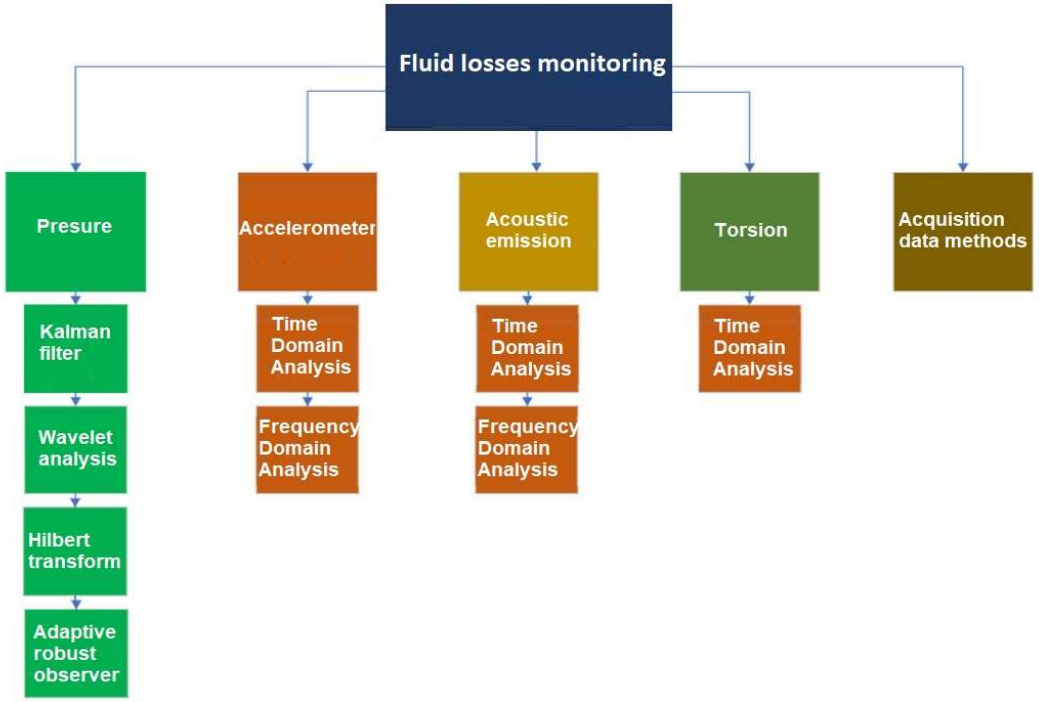

Fig.5 Scheme of monitoring for fluid losses

A. Pressure sensors. They measure the hydraulic fluid pressure inside the cylinder or system. They can help identify leaks or other problems in the system, as well as ensure that the hydraulic seals are operating optimally at the proper pressure.

B. Acceleration sensors measure the acceleration and vibration of the hydraulic system or other components, including hydraulic seals.

C. Acoustic emission sensors measure the sound waves generated by the hydraulic system, including any noise generated by the seals. These sensors can detect small leaks or changes in the system, helping to prevent more serious issues in the future.

D. Torsion sensors are used to measure the torque or torsional force generated by the hydraulic system. By monitoring the torque, it is possible to detect changes or fluctuations that may indicate wear or damage to the seals.

Using a combination of these monitoring techniques, it is possible to achieve information regarding the operating condition and performance of hydraulic seals and take proactive measures to prevent incoming issues which will eventually become serious problems.

4. USING VIBRATION ANALYSIS TO EVALUATE THE PERFORMANCE OF HYDRAULIC SEALS

Using the vibration analysis method to is essential for understanding how seals behave in real applications. Vibration analysis is a non-invasive method that permits close monitoring of the hydraulic seal performance, which can help identify potential problems before they lead to costly equipment damage or even manufacturing process interruption.

Vibration analysis involves the measurement and analysis of vibrations in hydraulic systems. The purpose is to detect changes in vibration levels that may indicate the presence of problems such as seal wear, misalignment, or imbalance. Different types of vibration analysis techniques can be used, including here frequency analysis and time-frequency analysis.

A. Frequency analysis involves breaking down the vibration signal into its frequency components. This can help identify the specific frequency associated with a particular problem. For example, if a seal wears, it can produce a vibration of a specific frequency that can be detected and analyzed.

B. Time-frequency analysis, on the other hand, involves knowing how the frequency content of the vibration signal changes over time. This can help identify the presence of transient events or other changes in the vibration signal that may not be identified by using the frequency analysis.

Fig.6 Accelerometers

To perform vibration analysis on hydraulic seals, accelerometers are commonly used to measure the hydraulic system vibrations. Accelerometers (fig.6 [11]) are devices that measure acceleration and can be attached to different parts of the system to measure vibrations at different locations. They can also be used to measure the frequency and amplitude of vibrations. Vibration monitoring is a powerful tool for evaluating the performance of hydraulic seals. By analyzing the vibration signals generated by a hydraulic system, we can diagnose problems and compare the performance of different types of seals i.e. cast seals and CNC machined. Vibration monitoring for comparing the performances of the cast and CNC machined seals could be used in the following ways:

A. Collecting vibration from each seal type. To compare the performance of the two types of seals there will be used accelerometers or speed sensors.

B. Frequency Spectrum Analysis. The frequency spectrum shows us the frequencies of the vibration signals and their amplitudes. By comparing the frequency spectra of the two seals, we can identify any differences in their vibration characteristics. For example, if one seal generates more vibration at a certain frequency than the other, this could indicate a design or manufacturing problem with the seal.

C. Time-Frequency Analysis. In addition to frequency analysis, we can also perform time-frequency analysis to analyze vibration signals in both the time and frequency domains. This can help us identify any type of transient or intermittent vibrations that might be missed by frequency analysis alone. Time-frequency analysis can also help us identify the root cause of any vibration problems, such as cavitation, fluid-induced vibration, or mechanical resonance.

D. Comparison of Vibration Levels. One of the easiest ways to compare the performance of two seals is to compare the vibration levels. By comparing the maximum vibration levels generated by the two seals, we can identify any significant differences in their performance. However, it is important to note that vibration levels can be influenced by many other factors, such as the operating conditions of the hydraulic system, sensor installation, and location. Therefore, we must take these factors into account when interpreting vibration levels.

E. Seal Wear Evaluation. By monitoring the vibration signals over time, we can detect any changes in the seal wear rate and identify any issues that could be contributing to the wear.

5. CONCLUSIONS

Vibration monitoring is an important tool that can be used to compare the performance of machined and cast hydraulic seals. By analyzing the vibration signals generated by the seals, we can identify any differences in their vibration characteristics, assess their wear and diagnose any problems that might affect their performance. With this information, we can make informed decisions about the best gasket design and manufacturing technique for a specific application.

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Aspecte specifice privind construcția și mentenanța elementelor de etanșare în sistemele hidraulice

Rezumat: În cadrul acestei lucrări sunt prezentate aspecte specifice privind fabricarea, prin turnare sau prelucrare, a diferitelor elemente de etanșare care se regăsesc în cadrul sistemelor hidraulice. Sunt, de asemenea, studiate variantele de monitorizare a pierderilor de fluid, cu precădere analiza vibrațiilor cilindrilor hidraulici.

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