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The Importance Of Tribological Testing In Vacuum Valves

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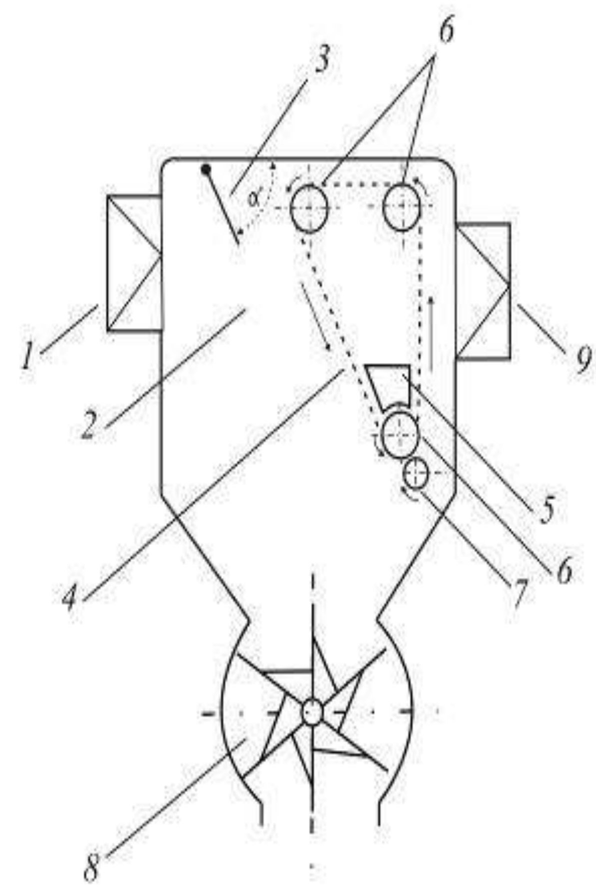
Abstract. Tribological testing plays a critical role in ensuring the reliability and performance of vacuum valves in a variety of applications, particularly in fields such as semiconductor manufacturing, aerospace, and vacuum-based research. The tribology of materials, which studies the interactions of surfaces in motion, is essential for understanding how vacuum valves will behave under real-world conditions, where high vacuum and mechanical stresses are common. Friction and wear are caused by complicated and multiplex sets of microscopic interactions between surfaces that are in mechanical contact and slide against each other. These interactions are the result of the materials, the geometrical and topographical characteristics of the surfaces, and the overall conditions under which the surfaces are made to slide against each other, e.g., loading, temperature, atmosphere, type of contact, etc. All mechanical, physical, chemical, and geometrical aspects of the surface contact and of the surrounding atmosphere affect the surface interactions and thereby also the tribological characteristics of the system. Therefore, friction and wear are not simply materials parameters available in handbooks; they are unique characteristics of the tribological system in which they are measured.

Key words: vacuum valve, temperature, microscopic interaction, wear, friction, lubrication, seal, seat

INTRODUCTION.

Vacuum environments pose unique challenges due to the absence of traditional lubricants and reduced atmospheric pressures. In these conditions, surfaces in contact, such as those within the valve seals or moving components, must interact without lubrication. Tribological testing in vacuum conditions helps identify the frictional forces between these surfaces and how they evolve over time, ensuring that the valve components maintain their functionality even under challenging conditions. It is known that the SS-15A type separator is widely used in the cotton ginning industry, and its operation is mainly based on the principle of air in an aerodynamic state. In the SS-15A separator, the cotton moves along with the air flow sucked through the mesh surface with the help of a fan, hits the mesh surface and is separated by scrapers and thrown into the vacuum valve. Long-term operation of the pneumatic transport due to the prevention of premature failure of the surface of the inner wall of the separator and the vacuum valve by eliminating the incoming air cotton hitting the right SS-15A separator wall and directing it to the vacuum valve, reducing its speed to 7-8 m/s The main goal is to create a separator that provides.



(Fig1.) Separator machine undergoing tribal testing

1-inlet pipe, 2-working camera, 3-guide, 4-mesh surface conveyor, 5-barrier, 6-shafts, 7-brush drum, 8-vacuum valve, 9-air suction pice

Research methods. For vacuum valve most surfaces in relative sliding or rolling contact, the area of real contactis much smaller than the noinal contact area. The applied load is carried by a number of small local asperities making up the area of real contact, and the friction and wear behavior results from the interactions between these local contact asperities. At the regions of these local contacts, the conditions are characterized by very high pressures and shear stresses, often well above the yield stress of the materials, high local (flash) temperatures of short duration, and maybe also very high degrees of deformation and high shear rates. Under such conditions, the local mechanical properties of the materials may be very different from what is found, for example, in normal tensile testing. The importance of oxide layers, small amounts of contaminants, local phase transformations, etc., is also much greater than in large-scale mechanical testing. Consequently, the properties of a material in the real contact areas may be far from those measured in normal mechanical testing procedures, and the coupling between wear and friction properties and traditional mechanical properties, such as elastic modulus and yield strength, is weak. See Zum Gahr (1987) and Hutchings (1992).

Key Concerns:

- High friction can lead to excessive wear or failure of sealing surfaces.
- The absence of lubrication or the effect of vacuum on conventional lubricants might lead to increased friction and wear.
- The ability to maintain smooth and controlled motion over extended cycles is critical for valve reliability.

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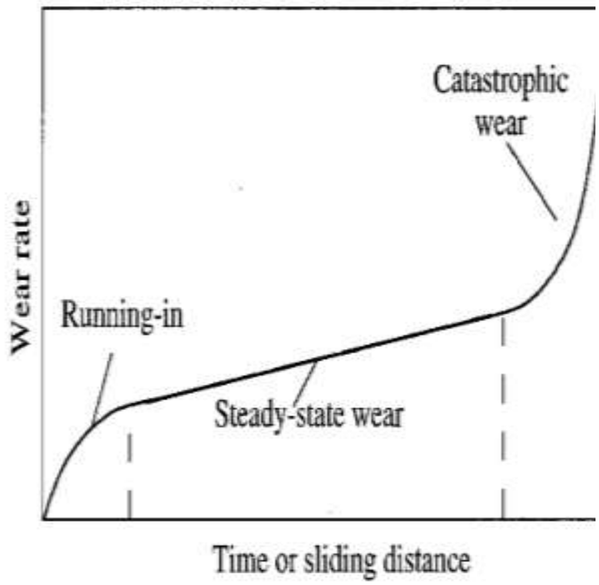

(Fig2.) Typical wear stages appearing over longer service times in sliding contactsin vacuum valve

Results. Vacuum valves often rely on seals, seats, and other moving parts that come into constant contact. The wear resistance of the materials used in these components is crucial for their longevity and performance. Tribological tests help engineers identify the best materials that can withstand the stresses and thermal variations in a vacuum environment without degrading quickly.

Materials Tested:

- Metals (stainless steel, titanium, etc.)
- Ceramics
- Polymers (e.g., PTFE, VITON)

These materials undergo testing to simulate wear, ensuring that they can maintain a seal and smooth operation under extended use, even in the harsh environment of a vacuum.

Sealing Integrity

The sealing performance of vacuum valves is one of their most important features. Leaky valves can compromise the vacuum system, leading to contamination, inefficiency, or failure of the process. Tribological testing helps evaluate the interaction between seals and their mating surfaces to ensure that the sealing integrity remains intact even under vacuum conditions. Understanding how materials interact under mechanical stress helps prevent leakage or degradation of the sealing elements.

Sealing Tests Considered:

- Compression and deformation of seals.
- The effect of wear on the sealing surface over time.
- The performance of materials under cyclic loading.

Impact of Environmental Factors

In a vacuum, environmental factors like temperature fluctuations, radiation, and outgassing can influence the performance of valve components. Tribological testing in vacuum environments allows for simulation of various environmental conditions, helping engineers understand how these factors will affect the valve's operation. This type of testing ensures that vacuum valves can continue to function optimally across a range of temperatures, from cryogenic to high-temperature conditions, without compromising the performance of their moving parts or seals.

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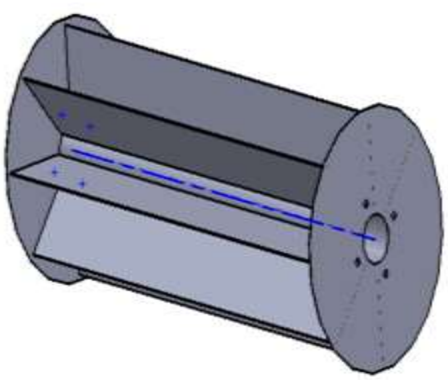
Predicting Lifetime and Reliability

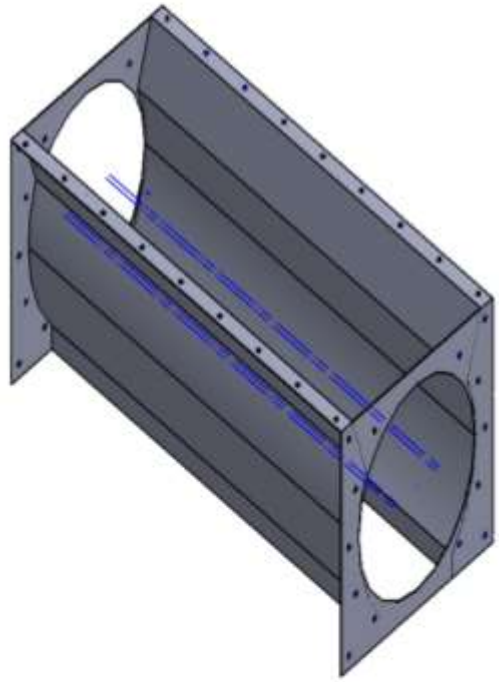
Tribological testing can be used to estimate the operational lifetime of vacuum valves. By simulating repeated cycles of opening and closing, as well as the wear and friction that occurs during these cycles, engineers can predict how long a vacuum valve will maintain its performance. This is essential for determining the maintenance schedules and predicting the replacement intervals, ensuring that vacuum systems remain functional without unplanned downtime.

Testing Methods:

- Wear rate measurement.
- Frictional force analysis.
- Cyclic fatigue testing to simulate long-term use.



(Fig3.) Vacuum valve



(Fig3.) vacuum valve outer part

Tribological testing informs better vacuum valve designs. By evaluating the friction and wear behaviors of different materials and configurations, engineers can optimize the geometry of valve parts (seals, seats, and moving components) to reduce wear and improve valve longevity. This testing can lead to improvements in the design of valve actuation mechanisms and sealing surfaces, ensuring that the valves perform efficiently and reliably over time.

Design Improvements Include:

- Optimizing seal material choices and geometries.
- Implementing coatings or treatments to reduce wear.
- Refining actuation mechanisms to minimize friction.

Conclusion

Tribological testing in vacuum environments is an essential part of the development and maintenance of vacuum valves. It allows engineers to understand the friction, wear, and sealing performance of materials and components under vacuum conditions. By identifying the ideal materials, improving valve design, and predicting the lifetime of components, tribological testing ensures that vacuum valves operate reliably and efficiently in demanding environments, making them indispensable in critical applications such as semiconductor manufacturing, space exploration, and high-precision scientific research.

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