PRODUCTIVITY ENHANCEMENT IN FEEDING & AIRLOCKING USING RFS TECHNOLOGY

- A STUDY BY UNIVERSITY OF WESTERN AUSTRALIA (UWA) ON HOW ANVAL'S RFS TECHNOLOGY COMBATS LEAK & WEAR!

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ABSTRACT

The Cement Companies are facing tough time with Rotary Airlocks & Feeders when handling highly abrasive materials - which causes environmental issues due to Flushing, Jamming, Frequent Line Stoppage & lower productivity and Frequent Replacement of equipment due to high wear. The conventional Rotary Airlocks often destroy itself within few months of operation and become the biggest bottleneck for the plant operations. The correlation between the wear in conjunction with pressure often underestimated, that triggers the need for an alternative solution, which forced Anval engineers to develop a new technology.

A study has been conducted over a period of months by University of Western Australia on Anval's RFS technology towards increasing the life; lower the running costs, minimizing the Wear & Tear, with enhanced performance of Rotary Valves at various applications including handling Alumina, Clinker, Lime Stone, Coal, Sinter Dust and other abrasive minerals.

This paper highlights our experience, interesting trial results and their outcomes.

1.0 Rotary Valve's Working Principle

Rotary valves can function both as volumetric feeders and as airlocks; preventing airflow between the inlet and discharge sides. The consistent feeding of product at a desired rate is achieved through the constant driving of the rotor within the valve. During operation of a rotary valve, the vanes turn or rotate, as they turn, the pockets, which are formed between the vanes, become rotating pockets. The material being handled enters the pockets at the top, through the Inlet port, travels around in a rotating motion, and exits at the bottom, or through the Outlet port. As the vanes and pockets continue to turn, material continues to be moved from top to bottom, or from Inlet port to Outlet port, in a rotating motion is to act as a seal, or lock to the air, between the Inlet and Outlet ports, while moving material in a continuous rotating motion through its pockets (*refer fig*- 1).The small clearance between rotor blades and valve body restricts airflow from the outlet to the inlet and therefore allows media to be transported across a pressure difference without significant air leakage.

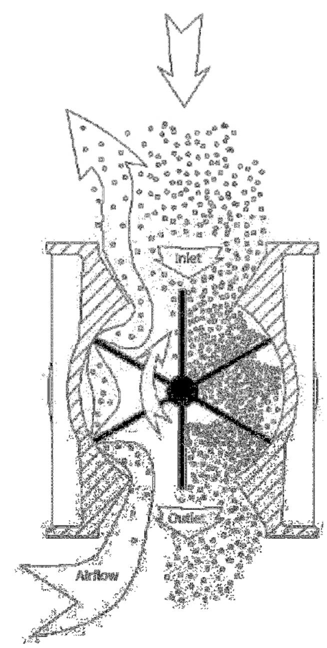


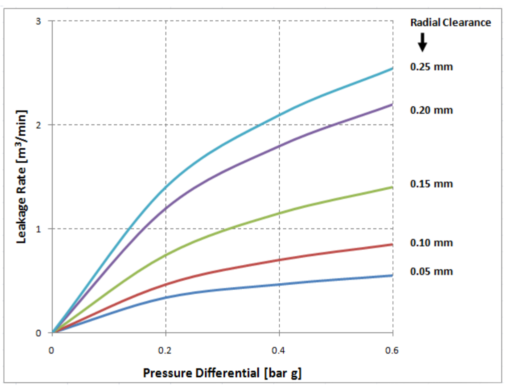
Fig – 1: Traditional rotary valve

2.0 Problems

When the Rotary Valves are used in the transport of Abrasive Solid media in conveying systems, due to high wear, resulting in a loss of performance in applications, damages itself & the other systems, Air leakage and Environmental Issues due to Flushing. In order to reduce the rate and effect of wear, there have been several design improvements, such as utilising harder, wear resistant materials, adjustable rotor tips that can be replaced as they wear and the use of various seals. However, these modifications increase the cost of the valve and the frequency of servicing. The major problems with the conventional Rotary Airlocks are as follows,

2.1 Air Leakages

Air leakage is defined as the loss of air through the valve from outlet conditions. The amount of air leakage increases with pressure difference, as seen in *graph- 1* and due to the increasing demand for rotary valves in high pressure applications, air leakage has become a significant problem. In pneumatic conveying systems, air leakage reduces the pressure and flow rate within the system, so additional energy is required to maintain the desired conditions within the system, increasing overall running costs. In situations where the transport media may contain toxic gases or if the transport gas is hazardous, the leakage of gas from the system to the surrounding environment can be a risk to health and safety of personnel.



"One of the main problems with air leakage is that high leakage velocities accelerate the wear of components and increase clearances within the valve, which in-turn causes more air-leakage. This cycle can rapidly reduce the efficiency of the valve and the need to frequently replace or refurbish components can become uneconomical."

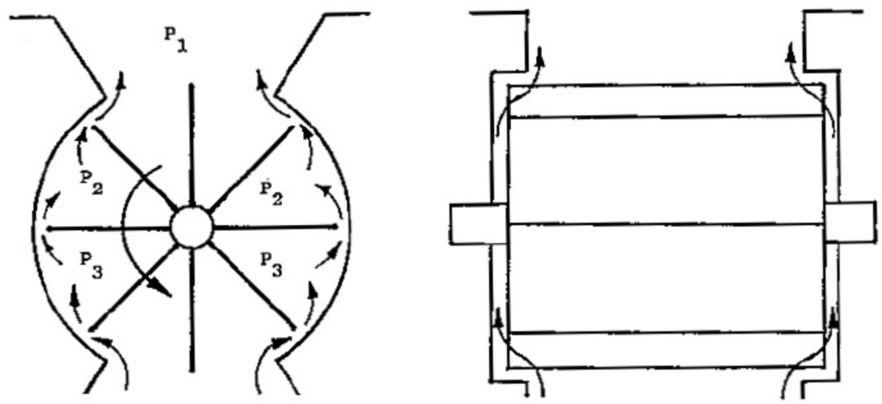
Graph- 1: Leakage Vs. Pressure Differential

Following are the three types of air leakages:

- 2.1.1 Clearance Leakage
- 2.1.2 End Leakage
- 2.1.3 Return Leakage

Clearance leakage occurs in situations where there is a difference in pressure between inlet and outlet conditions. The pressure difference causes air to flow around the sides of the valve, through the gap between the rotor tips and the valve body *(refer fig- 2(a))*.

End leakage is similar to clearance leakage, air leaking through the gap between the rotor and valve body. The difference is that the air flows around the ends of the rotor, rather than around the tips *(refer fig- 2(b))*.



(a) **(b)**

Fig- 2: Path of air leakage for (a) Clearance Leakage and (b) End leakage

Return leakage is generally less significant than the other forms of leakage but it can still have undesirable effects in some situations. When media leaves the rotor at the outlet side of the valve, compressed air fills the pockets and is transported to the inlet side of the valve where the gas expands. Depending on the pressure differential, the gas may expand rapidly, opposing the movement of the filling media and reducing filling efficiency.

2.2 Wear

Wear has become an important issue in rotary valve, the main wear mechanisms are abrasion and erosion. Abrasive wear occurs when particles slide in contact with a solid surface, causing the removal of material *(refer fig- 3)*. Erosion occurs with the removal of material from a solid surface by the impact of particles *(refer fig- 4)*.

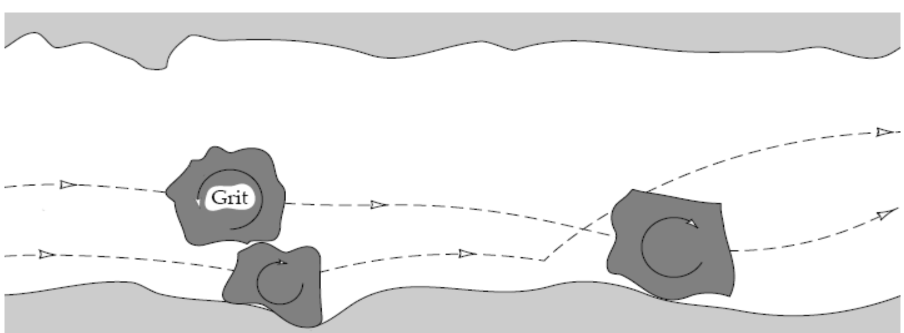


Fig - 3: Abrasive wear caused by sliding contact of abrasive particles

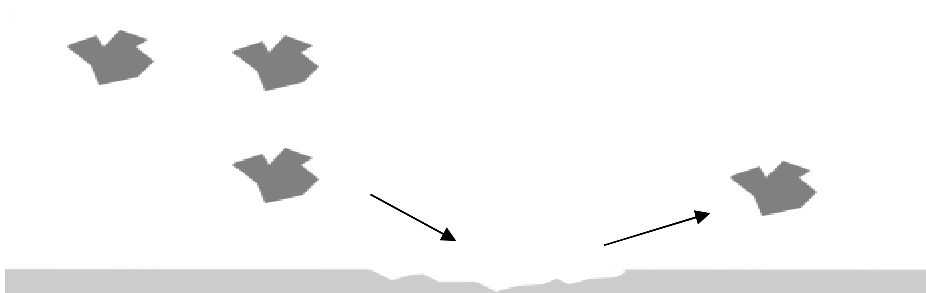


Fig - 4: Erosive wear caused by impact of particles

3.0 RFS Technology - The Rotary Floating Shoe Valve

In an effort to change the way that rotary valves wear and the effect that wear has on supplementary systems, a new type of valve has been developed by ANVAL, known as the Rotary Floating Shoe Valve (RFS valve) *(refer fig- 5)*. The RFS valve operates under the same theory as traditional rotary valves, with the pockets of the rotor filling and emptying under the force of gravity. However, the difference is in the way the inlet and outlet sides of the valve are sealed from each other. The RFS provides a physical seal, where the rotor is constantly sliding against a cast iron shoe so that there is essentially no air flow between the pockets of the rotor, therefore providing a better seal between the two sides of the valve.

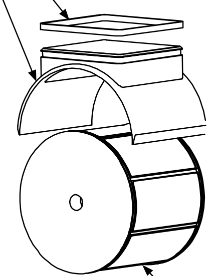


Fig - 5: Rotary Floating Shoe Arrangement

RFS uses a hardened cast iron shoe that slides in contact with a ceramic tipped rotor, creating a physical seal between the two surfaces. Ceramics are well known for being very hard and low wearing when paired with relatively soft materials, which is why ceramic alumina tiles are used as tips on the rotor blades. The shoe is Spheroidal Graphite Cast Iron (SG Iron) and has been heat treated to raise its hardness to approximately 500 HVN. The presence of graphite in the form of nodules or spheroids provides a unique wear mechanism, where the graphite is released from the nodules during sliding to form a thin, lubricating layer of graphite between the two wear surfaces *(refer fig- 6)*. This mechanism leads to a significantly lower wear rate in the body and, therefore, an increased level of consistency and performance throughout the extended life of the RFS valve.

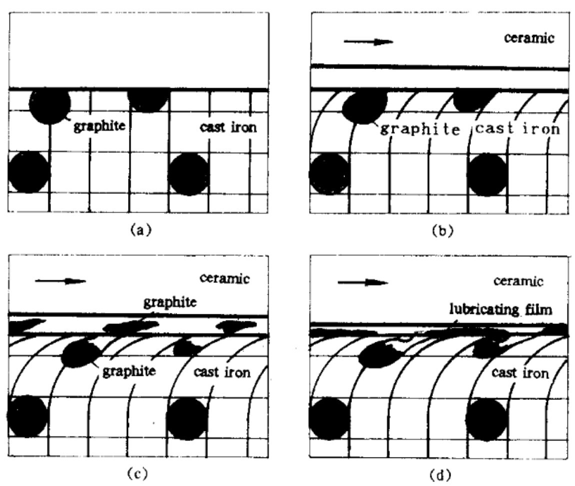


Fig -6: The formation of lubricating graphite layer during sliding contact between SG iron and ceramic.

The inside of the shoe has a cylindrical face that matches the profile of the rotor and the entire shoe is free to move in the vertical direction. External adjusting bolts force the shoe downwards and can be tightened to maintain a physical seal between the shoe and the rotor during operation. This reduces the effect of wear on air leakage throughout its lifetime, which usually increases in standard valves due to increasing clearances *(refer fig- 7)*.

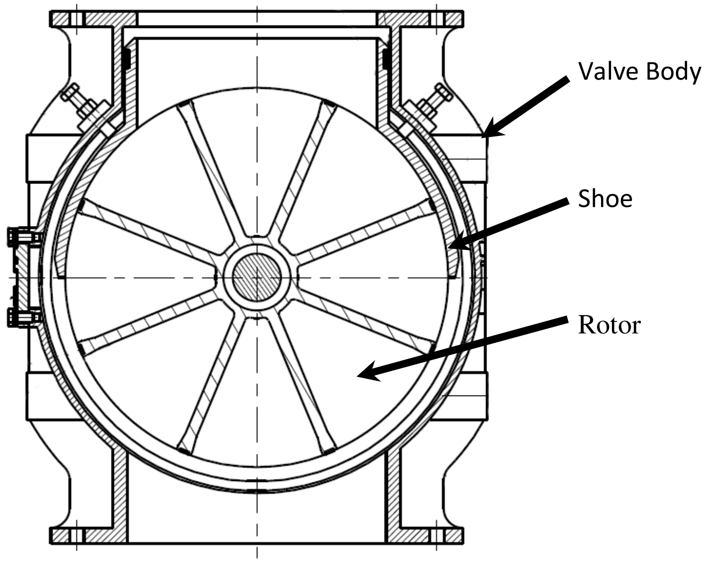


Fig - 7: Cross section of an RFS valve

This mechanism leads to a significantly lower wear rate in the body and, therefore, an increased level of consistency and performance throughout the extended life of the RFS valve.

The reduction in the wear levels of the valve body means that when the shoe reaches its wear limit, it can be easily replaced, returning the valve to normal operation without having to replace the entire valve rotor and body.

4.0 Wear Testing

The wear rate of two surfaces in dry sliding contact can depend on a range of parameters such as temperature, humidity, chemical composition, microstructure, surface roughness and porosity. As wear rates are different for various conditions and material qualities, it is important to determine how specific materials wear when predicting the wear life of components. This is achieved using experimental wear tests that use simplified geometries to simulate realistic wearing conditions.

The test apparatus consists of a ceramic pin that slides against a cast iron disc, rotated by an electric motor running at a constant speed. The pin is loaded with a constant compressive force using a cantilever beam and weight system. The cast iron disc is weighed prior to wear and at regular intervals during the test to determine the amount of material lost due to wear for a given sliding distance. The Archard equation (Eq. 1), which relates wear volume to applied force and sliding distance, can be used to calculate the specific wear coefficient, ‘k’ (units [m3/Nm]).

$$V=kFL \quad (1)$$

This coefficient characterises the wear severity of two surfaces and is often referred to as the proportion of contacting asperities that result in the formation of wear particles. Since the majority of asperities slide over one another without causing wear, the values of ‘k’ are usually very small, with 10-2 being a typical value for high wearing materials and 10-4 for low wearing materials.

The wear test lasted a total of 38.8 hours, with the pin sliding 59000 metres relative to the disc and removing 1.4 g of iron from the disc. The known force applied to the pin was used to calculate the wear coefficient of 1.11e-4, for SG iron against alumina ceramic.

Microscopic examination of the two surfaces was performed to determine the main wear mechanisms for the two materials. The clean, pre-worn iron and alumina surfaces are shown in *fig- 8* and *fig- 10*. respectively, with each surface relatively free of existing wear or contaminants. The worn iron in *fig- 9* shows black, out-of-focus areas which are deformed pits, originally containing graphite. The grey plate-like areas are layers of graphite that form during the test. This is consistent with the previously outlined theory that suggests the nodules wear to form a lubricating film of graphite. However, it should be noted that the amount of iron covered by graphite in *fig- 9* would be less than that present during the test, since cleaning the surface prior to weighing (in order to obtain accurate readings), would remove a large amount of graphite and other debris.

The worn alumina surface in *fig- 11* has large amounts of iron (white areas) covering the ceramic (brown areas). This is evidence of the adhesive wear mechanism described previously and is the reason for the low wearing characteristic of alumina. There is some visible damage to the ceramic surface in the form of pits where grains of alumina have been pulled out during sliding. However, throughout the entire test, the thickness of the ceramic disc did not change on a measurable level, indicating that this damage is not significant.

Overall, the microscopic evidence and experimental data suggest that the theory of alumina wearing significantly slower than the SG iron is correct in practice. Additionally, the wear rate of the iron is still quite low, due to the formation of a lubricating graphite layer between the wear surfaces. This means that the iron shoe in the RFS valves will have a comparatively long wear life and the ceramic tipped rotor will wear less than the shoe, thus maintaining a positive contact throughout the life of the shoe.

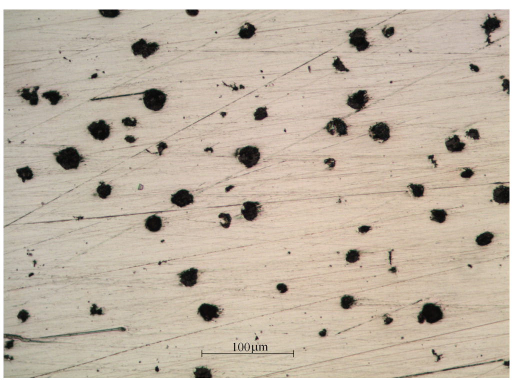


Fig- 8: SG iron surface prior to wear test.

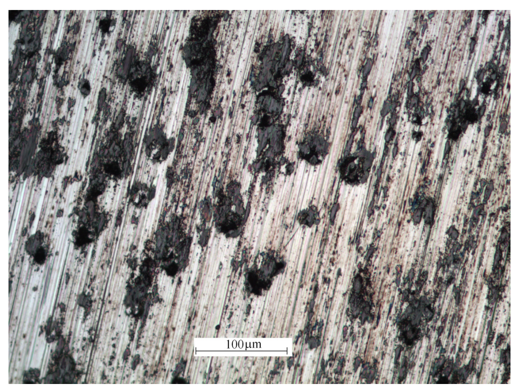


Fig- 9: SG iron surface after wear test.

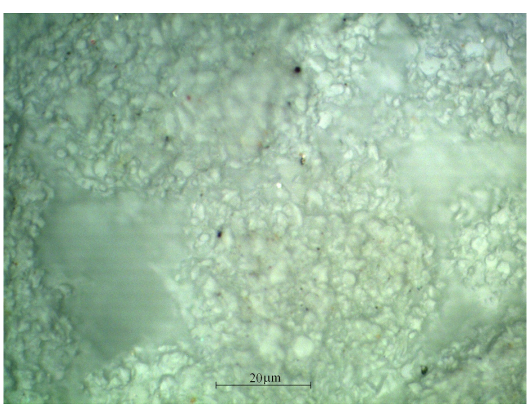


Fig - 10: Alumina ceramic surface prior to wear test

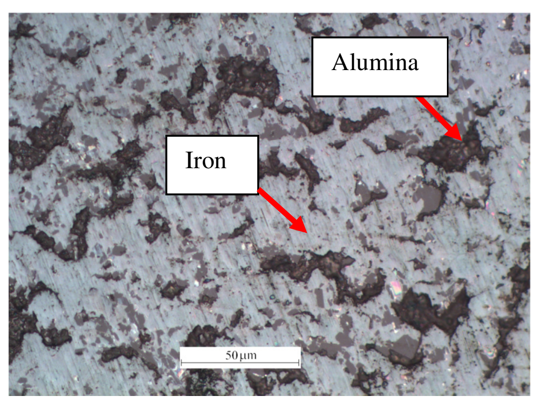
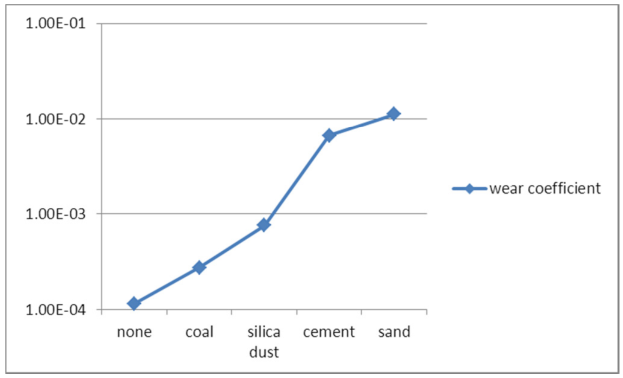


Fig - 11: Alumina ceramic surface after wear test

5.0 Effect of Media

To determine the effect that different media types have on the wear rate of the SG iron shoe, wear tests similar to those previously described were performed with the addition of several types of media from common rotary valve applications. The four types tested were sand, cement, coal and silica dust, with the results shown in *graph- 2*.



Graph- 2: Wear coefficients of different types of media

The lowest wear coefficient is for the case where no media is present, showing that the addition of media will increase wear rate. The tests show that the harder media types with large particles, such as sand and cement cause greater wear and result in higher wear coefficients, whereas softer materials like coal give comparatively low wear coefficients. This is a result of the harder materials removing the lubricating graphite layer between the ceramic and iron surfaces as well as removing the protective adhesive layer from the ceramic. As a result, the main wear mechanism is abrasion, rather than the adhesion process described previously.

These tests offer a relative comparison, showing the effect media type has on wear rates under the same conditions. The overall wear rate may vary with the different conditions found in real life applications, such as high pressure differentials, different speeds and the presence of contaminants or lubricants.

6.0 Conclusion

The testing conducted by UWA has proven that the ceramic tipped rotor in contact with the hardened cast iron shoe, allows RFS valve to efficiently traverse all manner of materials with a minimum of wear. Therefore, the RFS can be used to transport even the most aggressive product and still have a significantly prolonged lifecycle when compared to conventional rotary valves. With an extended life, lower running costs and minimised maintenance requirements, the RFS really has proven its ability to outperform efficiently.