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D. Rags / O. Linins

Minimal wear research and selection of corresponding surface parameters in pneumatic elements

INTRODUCTION

In nowadays, more often are used pneumatic systems for various movements and manipulations. It's because pneumatic systems are easy to install in producing machines and because their energy source – compressed air is relatively easy to get. Due to growing demands on product quality, service life and possible breakdowns, it's important to develop precise condition monitoring methodology of pneumatic elements (pneumatic cylinders, grippers, valves etc), which will allow us to make a proper and forehand servicing without breakdowns.

To create such a condition monitoring of pneumatic elements, it's required to develop mathematical model of wear and to find out the influencing parameters. After creating this wear model and knowing the influencing parameters, we can calculate the possible service life, and if calculated service life doesn't satisfy us, then we can change the influencing factors already before machine has been developed, which is much cheaper, than or already existing machine.

Some of wear influencing factors, we can name the following ones, work load, physical parameters of contacting surfaces, work temperature, amount of working cycles and duration of loading. By making further analysis of pneumatic elements, we can point out the following wear types:

- Adhesion wear

- Abrasive wear
- Corrosion wear
- Surface fatigue

1. ADHESION WEAR

Adhesion wear appears between two solid surfaces, which are sliding against each other at low speed or without lubrication. Surface roughness asperities from both surfaces are under deformation and welds together due to high local pressure. If sliding continues, these welded joints are destroyed thus creating scratches on surfaces. Part of material remains between these two sliding surfaces, thus increasing further wears of surfaces.

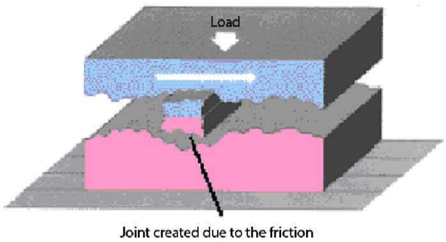

Fig. 1. Adhesion friction sample

As a good example we can show the internal combustion engines crankshaft sliding bearings, which after some time of downtime pushes out oil from both surfaces and afterwards crankshafts welds together with bearings (see fig. 1.).

Fig. 2. Damaged engine bearings due to adhesion

By starting up the engine, these joints are dismantled, but the engine started to worn out faster, because between bearings are free material particles, which are working now as an abrasive material.

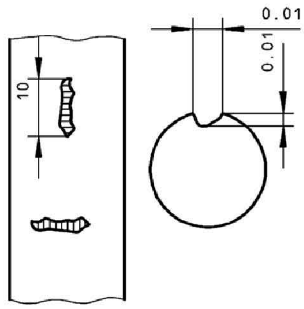

Fig. 3. Damaged piston rod due to the adhesion.

We can see in fig. 3. the damaged piston rod, where on surface are cracks. This kind of damages occurs in those cylinders, which are mounted on ventilation shutters, because they are actuated a few times per year. During this downtime, piston rod and it’s bearing bush, due to external forces are welded together. When actuating such a cylinder, there can occur above mentioned scratches, but if cylinder hasn’t been moved for longer time, it could happen so, that this welded joint didn’t breaks and the piston force draw out the bush from it’s seat.

2. ABRASIVE WEAR

When material has been destroyed by solid particles, then this process is called abrasive wear (see Fig.4.).

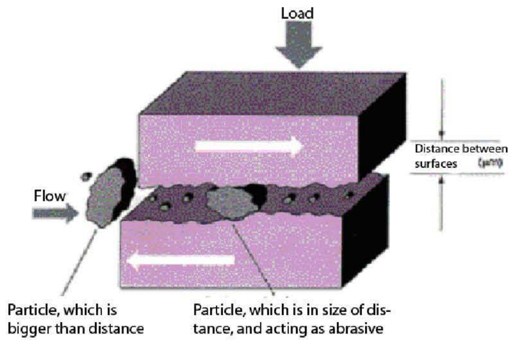

Fig. 4. Abrasive wear sample

This kind of friction isn’t so often seen in pneumatics, but it could occur. This friction is caused by dust from outside and dust that comes via tubing.

Most common friction in pneumatics systems is erosion friction, which is one type of abrasive friction.

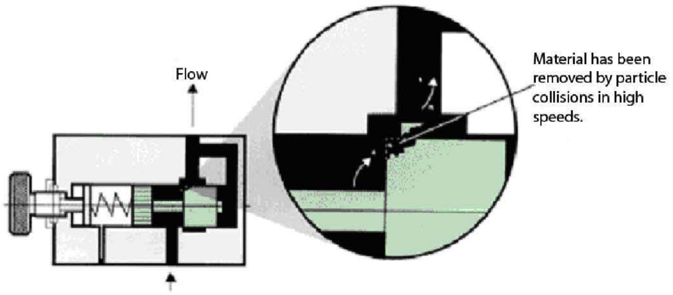

Fig. 5. Valve pistons wear, due to the erosion friction.

As typical example of erosion friction, we can name the pneumatically actuated diaphragm valve. If the actuating air wasn't filtered, in airflow existing dust causes the wear of diaphragm (see fig. 6.).

Fig. 6. Result of abrasive wear.

Wear occurs in those places, where airflow comes directly into contact with diaphragm. Airflow goes around this diaphragm, but dust and particles are making collisions against surface, thus creating the grooves (see fig. 6.). If amount of these grooves increases, the air leakage of valve occurs and due to these leakages, the valve must be replaced.

3. CORROSION WEAR

The corrosion wear is often caused in aggressive environments (for example in food and chemical industries). Because most of pneumatic systems are produced from light metal compounds, mostly from aluminium compounds, it's important to avoid these compounds without protection in places with high responsibility. For such places, you must use a proper corrosion resistant materials or protection. As good example we can show the pneumatic valve body, which during the 20 days of working has been corroded and loosed his robustness (see fig. 7.).

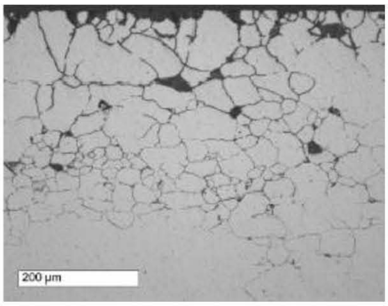

Fig. 7. Surface affected by corrosion (amplified)

The surface showed in fig. 7. which is photographed by using X-rays at high magnitude (x125 000), has many small cracks, which later leads to air leakage and surface destroying. Due to these cracks, pneumatics made from aluminium compounds cannot be used in places with high responsibility.

4. SURFACE FATIGUE

Surface fatigue is a process; during which surface of material is affected with cyclical loads, when friction pair contacts each other and if between these two surfaces are some other free material particles. Usually it can be observed in bearings, sliding bushes, guiding etc.

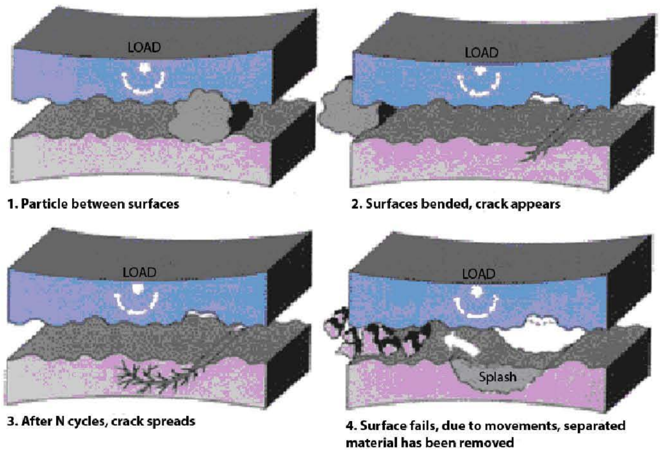

Fig. 8. Surface fatigue

The surface deformation starts with bending it other surface or solid particle, in bended place cracks started to appear. These cracks continue to growth by further cyclic loading, even if the surface hasn't affected with deformation. By reaching certain limit of loads, surface fails due to these cracks. Material from failed surface can be flush out by oil or grease and didn't cause any further damages, but if grease isn't enough, then these hard solids remains with these two surfaces, thus causing development of new cracks in surfaces.
In fig. 9. there has been shown valve seal, which is made from elastomer material and which has a dark ring in centre. This ring is a mark from seal seat, which came into direct contact during the working cycles. Due to the surface fatigue, after 200 million cycles, in seal surface has been created a groove in 0.5 mm depth, which is a copy of seal seat.

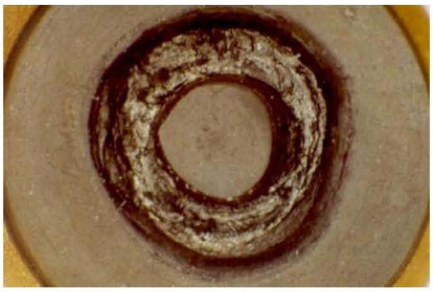

Fig. 9. Seal damage due to the surface fatigue.

If we look closer on this case, then we can make a conclusion that this wear has been caused by wear inside of material. This wear occurs mainly in cases of elastic deformations and in those wearing pairs, where one of contacting materials has been produced from elastomeric materials. As a classical example we can name the process valve-sealing diaphragm. These valves are quite popular due to fact, that they are easy and quickly exchangeable. But there is one minor disadvantage, these valves as closing element uses and sealing diaphragm that is pushed against metal seal seat (see fig. 10). During the working cycles, in these elastomeric diaphragms occurs internal molecular friction, which caused by metal seal seat penetration into diaphragm material.

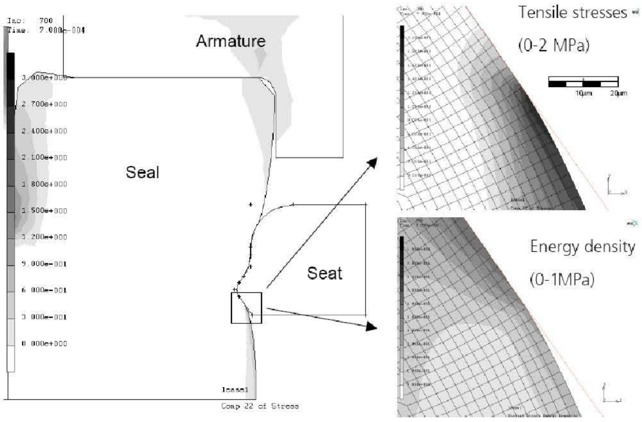

Fig. 10. Diaphragm valve seal deformation and internal friction

As other example of pneumatic elements surface fatigue case, we can name result of sliding friction. This wear type occurs between surfaces, which are in contact and movement against each other, for example wear of guiding due to the friction. Wear occurs during movements, and as one of influencing factors, we can name the length of friction way.

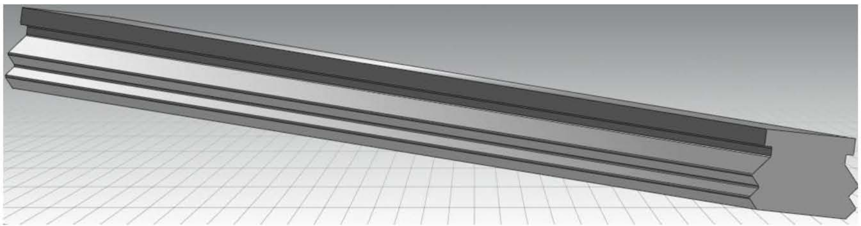
Fig. 11. Guiding of pneumatic drive

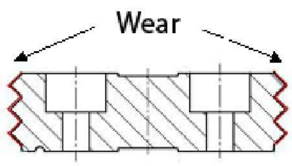

Fig. 12. Guiding surfaces, which are affected by wear

5. SURFACE PARAMETERS

By selecting corresponding surface parameters in pneumatic elements, we can decrease the working in time and prolong the overall service life of pneumatics. Decrease of working in time is possible due to fact, that surface roughness asperities will not be affected by plastic deformations, but only with elastic deformation. It's a known fact that too rough surfaces are wearing out quickly (it's caused by plastic deformations of surface roughness asperities), but we also must be aware from surfaces which are too smooth, because too smooth surface quite often leads us to adhesion.

Our task is to find out an optimal surface roughness parameters which will decrease the friction and wear, but in the same time, these parameters should be cost effective in production.

To find out these optimal surface roughness parameters, it's important to create a mathematical model of wear process in pneumatic elements, which can be later used by engineers for selecting the optimal surface parameters depending from possible working conditions (load, loading frequency, speeds, pressure, temperature etc.).

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