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Influence of Mechanical Wear on the Pumping Behaviour of Rotary Lobe Pumps

Double shaft rotary lobe pumps are often used for conveying slurries in liquid manure, biogas and sewage plants. Increasing mechanical wear enlarges the gaps and decreases the effective flow rate. The effects on the pumping behaviour of helical toothed lobe pumps were systematically analysed and the influential factors were evaluated.

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Keywords

Rotary lobe pumps, abrasive pump wear, gap leakage, pumping behaviour

Two shaft Rotary lobe Pumps are commonly used for pumping highly viscous liquids, slurries and sludge with high dry content in agricultural, municipal and industrial applications. These rotating positive displacement pumps have a large flow channel through the wet end and because of their compact design they are used instead of progressive cavity pumps for pumping large volumes. One shaft is driven direct; the second one is moved by timing gears located outside of the wet end. This design ensures that the lobes do not touch each other. The lobes are commonly covered by a layer of elastomer and are used to move a constant volume from suction to discharge and also seal between the two sides. The shape of the lobes is determined by the number of wings as well as their straight or helical orientation. Above all, the volumetric efficiency is limited by leakage through the pump, so called slip. Most of the time the sizing of the pump is based on clean water which leads to minimisation of the gaps between the lobes and housing as well as between the lobes. If these pumps are used for pumping high viscous products like municipal sludge or liquid manure, wear can quickly cause the capacity to drop significantly and the lifetime of the pump becomes unacceptable. To optimise the pump designing process and reach the maximum lifetime of the pump, it becomes necessary to adjust the gaps based on the properties of the pumped liquid. In order to achieve this, it becomes imperative to gain fundamental knowledge of the effects of wear on the behaviour of virtually liquid substances in rotary lobe pumps. These studies were conducted on the test bench at the ATB and are a basic requirement for an optimised designing process of rotary lobe pumps.

Method of survey

The slip losses in a rotary lobe pump depend on different variables, which have to be rated separately in their complexity:

- Shape of the gap (head-, centre -, side gap)
- Size of the gap (height, width, length)
- Flow behaviour of the pumped liquid (viscosity, structure of liquid substance)
- Pump speed
- Differential pressure (Shaft deflection of cantilevered shafts, difference in velocity)
- Shape of the lobe (straight, helically twisted, number of wings),
- Lobe material (PE, rubber coated core).

It is differentiated between the following gaps:

- Head gap between lobe tip and housing,
- Centre gap between the lobes,
- Side gap between the lobes and wearplates.

These gaps are enlarged by sliding wear while moving suspensions with abrasive content. The largest amount of material is removed at the tip of the lobe.

To conduct the survey of simulated pump wear, a test pump VX136-140Q with cantilevered shafts manufactured by Hugo Vogelsang Maschinenbau GmbH, Essen/Oldbg is used. Multiple housing segments of various thickness, lobes with different diameters and wearplates of different thickness can be interchanged. The head gap can be varied in steps between 0 and 2.5 mm, the centre gap between 0 and 5 mm and the side gap between the lobes and wear plates from 0 to 2.5 mm.

The test bench basically consists of two identical rotary lobe pumps in series which can operate in both directions and be speed adjusted with a variable frequency drive. Pressures, speed, torque, capacity and temperature can be measured at each pump. A throttle valve is located on the suction side. To adjust the discharge pressure after the working pump, the second pump is used to throttle the flow. The following measurements are conducted at the test bench:

- Indirect measurement of the wear status of the pump by pumping against a closed valve. The flow is $Q = 0$ and $Q_{th} = Q_S$, as it has to flow back through the gaps. The pressure that can be reached is an indicator for the real wear status of the pump.
- Direct measurement of the flow through the gaps on the blocked test pump $Q_S = f(p)$. Using the second rotary lobe pump the capacity Q_S is pumped through the gaps of

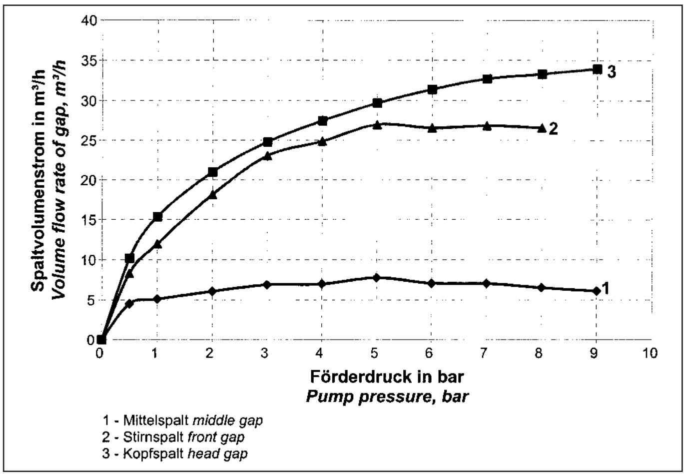

Fig. 1: Gap flow through head, front and middle gap (water) at the same gap heights of 1 mm

the non moving pump to determine the resistance p.
- Measurement of the pump performance curve by throttling down suction- or discharge side. Herein the measured capacity is $Q = Q_{th} - Q_S$. Knowing the theoretical capacity Qth, the slip losses can be determined.

With given gap geometries tests were conducted for water, glycerine 81%, glycerine 99.7% as well as for different liquid feed mixtures ($m_F : m_W = 1:2$ und 1:3) made from coarse meal and water.

The main purpose of the survey was to determine the impact of wear on the characteristic pump curve and the rating of the variables.

Test results and conclusion

The head- and side gaps have the largest impact (*fig. 1*), and are very similar to each other. The slip through the centre gap has significantly less impact and is much less dependant on the differential pressure. Even with increasing wear of the lobe tip the centre of the pump creates a reliable barrier against slip. Most of the time a complete sealing line is present.

The influence of the pump speed on slip losses is insignificant, so the measurements taken on a blocked pump can be transferred over to the rotating pump.

The viscosity of the pumped liquid has a very large impact on the slip losses (*fig. 2*). The flow through the gaps decreases with increasing viscosity, the effective capacity and the energetic efficiency grow. This fact shows the necessity to adjust the gaps to the viscosity of the pumped product. Pumping water the effective capacity drops significantly with increasing differential pressure, however pumping highly viscous products it nearly stays constant. Larger gaps can be chosen because the ideal height of a gap is directly dependant on the viscosity.

The influence of the shape of a lobe (straight or helically twisted) on the slip losses is insignificant. As a rule helically twisted lobes with more wings have better characteristics when they are under the influence of wear. The lobe material only has a small impact on the pumping behaviour when simulating wear.

Operating at higher differential pressures (p > 4 bar), the lobes in a pump with cantilevered shafts and relatively small gaps can collide with the housing because of shaft deflection. The wear increases locally and the gap area changes. In this case the pump has reached its operating limit. For high discharge pressures, high vacuum on the suction side and higher speeds a pump with bearings on both sides of the wet end is advantageous.

Summary

The impact of wear on the pumping behaviour of rotary lobe pumps with helically twisted lobes was investigated in close to practice tests by systematic alteration of the gaps. The largest impact is caused by the head- and side gaps resulting from wear and the viscosity of the pumped liquid. Pumping against higher differential pressures, the use of pumps with bearings on both sides of the wet end is recommended. For wear diagnosis pressure measurements while pumping against a closed valve or direct slip capacity measurements on a blocked pump can be useful to draw the characteristic curve of a pump.

The conducted surveys are essential for the calculation of characteristic pump curves.

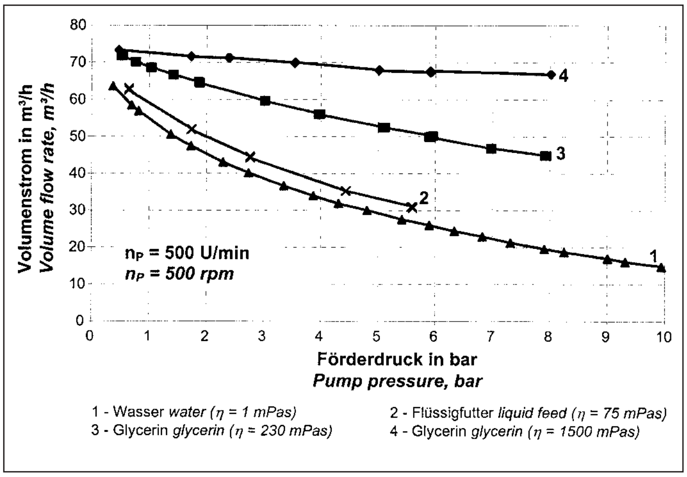

Fig. 2: Effect of viscosity on pump characteristics at the same gap heights