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Cavitation Behaviour of Rotary Lobe Pumps

The cavitation behaviour of rotary lobe pumps is of considerable importance in pump design. Cavitation leads to unstable pumping conditions and causes typical noises. It is always found at zones with maximum flow velocity. Important influential variables on cavitation behaviour, such as rotational speed, lobe wear, fluid viscosity and the discharge pressure are analysed and evaluated.

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Keywords

Cavitation, suction behaviour, rotary lobe pump, wear

Literature

Books are identified by •

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Two-Shaft Rotary Pumps can be used for a very broad spectrum by pump-media - from low viscous pure liquids up to high-viscous coarse-dispersive suspensions. Also a stable suction behaviour is important in this case. An essential cause for troubles at pumps is cavitation, which is in most cases a result of unfavourable flow and pressure conditions. In case of cavitation low pressure zones form themselves at the suction side or inside of the pump where the static pressure locally drops under the vapour pressure of the fluid, and vapour bubbles [1] arise. If the pressure increases again, these bubbles implode suddenly, and considerable noise emissions are created. In the long run, abrasion as well as material fatigue and a reduction and/or the complete breakdown of the flow are the result.

To avoid pump cavitation a specific suction-side pressure height is necessary. $NPSH_r$ (required Net-Positive-Suction-Head) is the term for this purpose. $NPSH_r$ describes the minimum absolute fluid pressure required on the suction side of the pump to avoid cavitation. So the $NPSH_r$-value is an essential parameter for a pumping plant [1].

The pump user has to observe certain safety limits, which are marked e.g. by a reduction of pressure or flow rate (3 or 5 %). Regarding lobe pumps with stabile suction characteristics, mainly flow rate reductions are found [1]. This procedure requires sophisticated measurement equipment because a permanent checking of the volume flow in real time is necessary.

During flow measurements at the pump test bed in the ATB two different cavitation states were defined by means of typical audible noises. That is a practical and simple method how the customer can determine cavitation effects without using sophisticated measurement equipment. The influences of most important parameters on the cavitation behaviour of helical geared rotary lobe pumps are examined by audible observations and are evaluated.

Test methods

Following influencing variables are examined:

- Pump speed in a range of 200 to 600 rpm with pumping of water at 20 °C
- Lobes wear by mounting differently worn-out lobes with tip gaps of 0.5 mm, 1.5 mm and 2.5 mm [2]
- Fluid viscosity by tests with water (η = 1 mPa s at 20 °C) and glycerine (η = 1,450 mPa s at 20 °C)
- Discharge pressure in a range of 2 to 6 bar

The pump test bed consists basically of two equal models of in series arranged rotary lobe pumps with helical toothed rubber lined lobes (model VX 136-140Q built by Hugo Vogelsang Maschinenbau GmbH, D-49632 Essen/Oldbg.) [2]. One pump is the test pump, the other one is serving as a brake pump for adjusting the discharge pressure of the test pump. The rotational speeds of both pumps are adjusted by frequency controlled electric motors. A throttle valve is arranged on the suction side of the test pump. Besides the absolute suction pressure and discharge pressure, the rotational speed, the torque, the volume flow and the temperature are measured continuously and saved in a measurement computer.

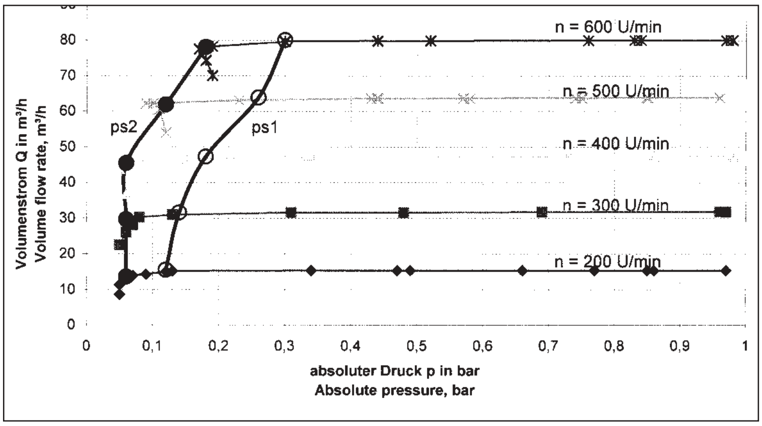

Fig. 1: Effect on rotational speed on tcavitation ; (water 20 °C, p_D = 2 bar, s_K = 0,5 mm); p_s1 - beginning of cavitation, p_s2 - full cavitation and stall of flow

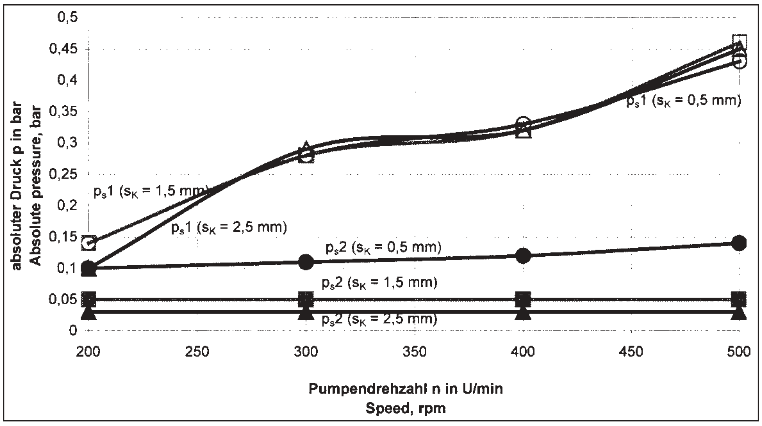

Fig. 2: Effect of lobe wear on cavitation; (η = 1,450 mPas, p_D = 2 bar), p_s1 - beginning of cavitation, p_s2 - full cavitation and stall of flow

The suction characteristics are checked until distinct cavitation and flow cut-off (Q = 0). The cavitation noises are characterised with the suction pressure at which they occur for the first time. Two cavitation points are distinguished.

1. Cavitation pressure p_S1 corresponds to the suction pressure at which hissing and bubble noises occur in the pump. The cause of these hissing noises is the beginning of gap cavitation [1].
2. Cavitation pressure p_S2 corresponds to the suction pressure at which a vibrating and periodic knocks and continuous rattling-noises can be recognised. This is the region of full cavitation and the flow rate breaks suddenly down in this case (the stall of flow). This phenomenon it is caused by displacement chamber cavitation [1], which is caused by insufficient filling of pump chambers. In case of displacement chamber cavitation this kind of cavitation superimposes the gap cavitation.

Test results

A *rotation speed influence* on the cavitation could be found (*Fig. 1*). The cavitation pressure p_S1 (beginning of the gap cavitation) shows an almost linear characteristic curve with the volume flow and the speed. At higher rotational speed a higher relative flow velocity results in the tip gap. The $NPSH_r$ value can be set as cavitation point p_S1 and must be followed absolutely.

In the speed range n < 400 rpm the cavitation pressure p_S2 remains almost constant and is independent of the speed. Only at higher speeds (n > 400 rpm) p_S2 occurs at higher absolute suction pressures (> 0.1 bar), followed by strong strokes in the pump and the volume flow cuts off. Operating a pump under these unstable conditions, the pump is stressed enormously and the strong cavitation strokes can cause destruction.

The *wear influence* on the cavitation pressures p_S1 and p_S2 was examined with high-viscous glycerine and is shown in *Figure 2*. The cavitation pressure p_S1 is almost independent from wear and increases with increasing speed. The suction behaviour deteriorates. The cavitation pressure p_S2 decreases with increasing wear. That means that the cavitation behaviour is improved at high viscous media according to increasing wear and cavitation is found not until very low absolute pressures (< 0.05 bar). This effect is mainly caused by displacement chamber cavitation. The increasing wear causes a faster filling of the pump chamber since higher wear creates a raised back flow due to the bigger gap cross section. However, the cavitation behaviour improved by wear is combined with a smaller volumetric efficiency [2].

In water tests the cavitation pressure p_S1 is rising a little with increasing wear. The distinct cavitation condition at pressure p_S2 is almost independent of the wear. Only at higher speeds (n > 500 rpm) p_S2 decreases with increasing wear.

The *viscosity* has a strong influence on the flow rate, on the energetic efficiency [2] and on the suction behaviour. Compared to water the suction behaviour of glycerine is considerable poor. Pumping high viscous media a lobe pump appears almost sealed so that the back flow is minimised. If cavitation occurs it is pump chamber cavitation caused by lack of filling.

In further experiments the influence on cavitation of the *discharge pressure* was examined. The cavitation pressures p_S1 and p_S2 are strongly dependent on the discharge pressure. With increasing discharge pressure the cavitation pressures p_S1 and p_S2 increase considerably, that means with increasing discharge pressure the cavitation behaviour of the pumps deteriorates. The pressure influence on both p_S1 and p_S2 decrease at high speeds (n > 400 rpm). Probably this effect is based on the fact that - regarding increasing speed - the tip speed inducted cavitation is drowning out the pressure induced cavitation.

Probably the pressure influence on the cavitation is also increased by the shaft deflection of the one-side mounted pump bearings. The pressure forces press the shafts apart and create change of tip gaps. Pumps with both-side bearings show a much better suction behaviour [2].

The lobe shape too has a significant influence on the suction behaviour [3]. Multi-wing helical toothed lobes create significant less pressure pulses; they show quiet running and a better suction capability than two-wing oval lobes particularly if the speed exceeds 400 rpm.

Summary

Flow tests have shown that different actuating variables (pump speed, discharge pressure, fluid viscosity, lobe wear) as well as construction shape influence the cavitation behaviour of rotary pumps. With the aid of audible cavitation observations the suction behaviour was examined. Two cavitation states: p_S1 as the beginning and p_S2 as the distinct cavitation could be detected unambiguously. Probably, these two cavitation states result from two different cavitation forms (gap cavitation and displacement chamber cavitation) that show different reasons and overlay partly. Gap cavitation (p_S1) can be recognised by hissing noises in the pump, displacement chamber cavitation (p_S2) can be recognised by vehement strokes in the pump and flow cut-off (Q = 0). The cavitation point p_S2 must be avoided whenever designing a pump because the strong strokes can destroy the pump. The cavitation point p_S1 with typical hissing noises is a sufficiently precise limit to avoid cavitation in rotary lobe pumps. The pressure p_S1 is approximately equal to the $NPSH_r$ -value.

In practice the cavitation limit is often defined with the drop of the flow rate by e.g. 3 %. Regarding rotary pumps already vehement cavitation can occur under this criterion. Therefore continuous monitoring of suction behaviour is necessary in practice operation.

Formula symbols

Q	m^3/h	flow rate
n	min^{-1}	rotational pump speed
p	bar	absolute pressure
p_D	bar	absolute discharge pressure
p_S1	bar	absolute cavitation pressure (gap flow cavitation) at beginning
p_S2	bar	absolute cavitation pressure (displacement chamber cavitation) at stall of flow
s_K	mm	tip gap clearance
$NPSH_r$	m	required Net-Positive-Suction-Head, (minimum required inlet pressure to avoid cavitation)
η	mPas	viscosity of fluid