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CONTRIBUTION TO CAVITATION EROSION PREVENTION IN HYDROSTATIC PUMPS

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ABSTRACT
Cavitation erosion is a great problem in hydraulic systems. It can cause a loss of system efficiency, wear of elements and even their failure. This article analyses requirements of cavitation stability for an axial-piston bent axis pump. Equations and diagrams for non-cavitation work are given. Such approach can be very useful in phase of the projecting and in maintenance of the hydraulic systems.
Keywords: cavitation, axial-piston pump

1. INTRODUCTION
Cavitation is the process that occurs when pressure in hydraulic fluid is less than the vapor pressure of that fluid. The liquid locally vaporizes and causes appearance of the cavities. When the cavities in the fluid pass through the region of the higher pressure, they collapse. The collapsing causes vibration, noise and material damage.
Dissolved gases in the fluid cause a phenomenon very similar to cavitation. If the pressure acting on the liquid is lower than the saturation pressure, the gas will come out and form bubbles. These bubbles can be sucked into the pump. In the area of the law pressure bubbles’ volume will increase primarily and the bubbles will dissolve again in the region of higher pressure. It is very difficult to distinguish these two processes in the practice, so they are both considered as cavitation process. Physical effects are “water hammer”, “micro-diesel effect” and noise. Chemical effects are formation of reactive chemical intermediates and oxidative degradation of the hydraulic oil. All these effects lead to cavitation erosion of hydraulic pumps and other components in hydraulic systems.
Figure 1. shows damage of the pump suction elements when bubbles implode close to their surface.

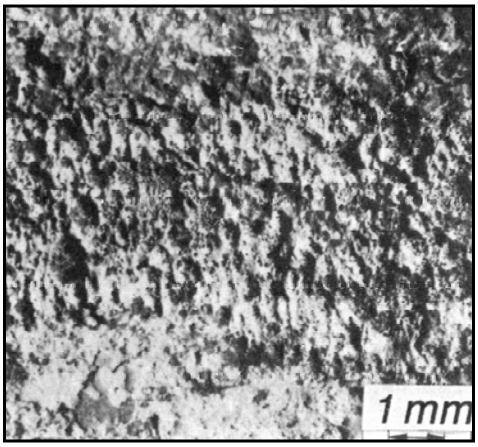

Figure 1. Cavitation erosion of the pump

2. CONDITION FOR NON-CAVITATION WORK OF THE PUMP

The main target in the phase of projecting a new hydraulic system is to insure conditions for non-cavitation work of the pump. That is the key to attain a good efficiency, long-lasting of the elements, especially of the pump and work without vibration and noise. As the reasons for cavitation appearing are known, it is important to pay attention on suction pressure i.e. follow in producer recommendations on suction line performance. If depart from the regular manner must be made, constructors and users must know basic facts on non-cavitation work. The following analysis in a quick and simple manner shows how to obtain that aim.

2.1 Suction pressure

The constructors and the mechanics of the hydraulic systems have a great responsibility when embedding the positive displacement pumps. It is important primarily to accept the recommendations of the way of the pump suction installation. Manufacturers of the hydraulic pumps specify the filling characteristics assisted by the minimum suction pressure, which must exist at the pump inlet. That is a prerequisite to induce sufficient flow at the pump suction port for filling the pumps chambers at maximum speed for specific fluid density and viscosity. Pumps have very different flow passages configuration, they firstly depend on the type of pump and secondarily that specific constructive detail depends on the pump manufacturer.

Making actual flow close to theoretic capacity i.e. high volumetric efficiency is the main assignment in pump manufacturing process and very important request for pump users.

For a given pump, fluid, temperature, and speed, the system must maintain a specific inlet pressure to have cavitation stability. Briefly, in order to avoid pump cavitation, the inlet pressure of the pump should be higher then the pressure required accelerating fluid to the flow rate of the pump in order equal or exceeding the speed of the pump working element.

On example of one axial-piston pump cavitation number and its meaning will be explain. Fluid inertia force occurs when fluid is accelerated in suction port of the pump. Therefore is:

$$(p_1 - p_2)A = \rho Q (v_2 - v_1) \qquad \ldots(1)$$

where:

p_1 and p_2 are pressures in suction port and on the piston in cylinder

A is cross section of the cylinder

ρ is fluid density

Q actual flow rate, theoretical reduced for cavitation losses ($Q_T - Q_k$)

v_1 and v_2 are velocities of the fluid in cylinder and in suction port

Theoretical flow rate is:

$$Q_T = A\, v_p \qquad \ldots(2)$$

where v_p is piston velocity. When we introduce cavitation number [1]:

$$k = \frac{v_2 - v_1}{v_p} \qquad \ldots(3)$$

and suppose that $p_2 \approx p_v$ and $p_1 \approx p_s$, where p_v is fluid vapor pressure and p_s static suction pressure of pump inlet, the available suction pressure at pump inlet is then:

$$p_i = p_s - p_v = \left(1 - \frac{Q_k}{Q_T}\right) k\, \rho\, v_p^2 . \qquad \ldots(4)$$

It is obvious that if $(1 - Q_k / Q_T) = 1$ the pump is working without cavitation.

2.2 Non-cavitation working analysis

The analysis has been made on an axial-piston bent axis pump as to how actual suction pressure depends on fluid characteristics and rotational speed of pump shaft. Towards equation (4), actual suction pressure, when pump works without cavitation, is:

$$p_i = k\,\rho\, v_p^2 \,. \qquad \ldots(5)$$

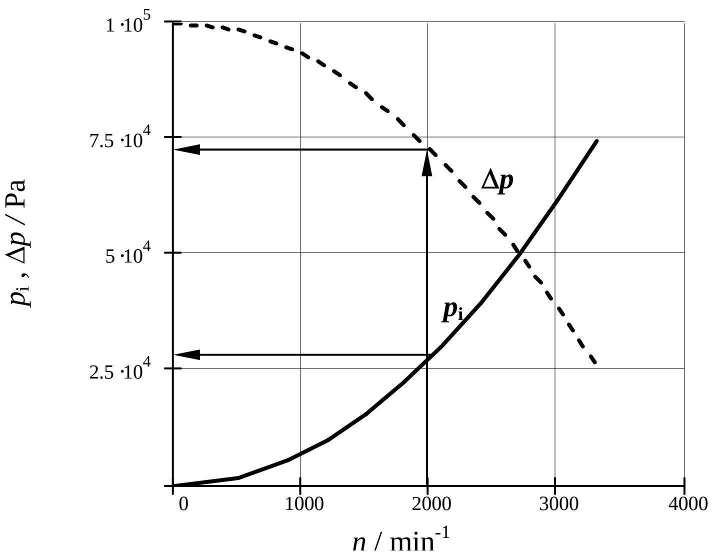

Figure 2. Suction pressure and pressure drop depending on rotational speed

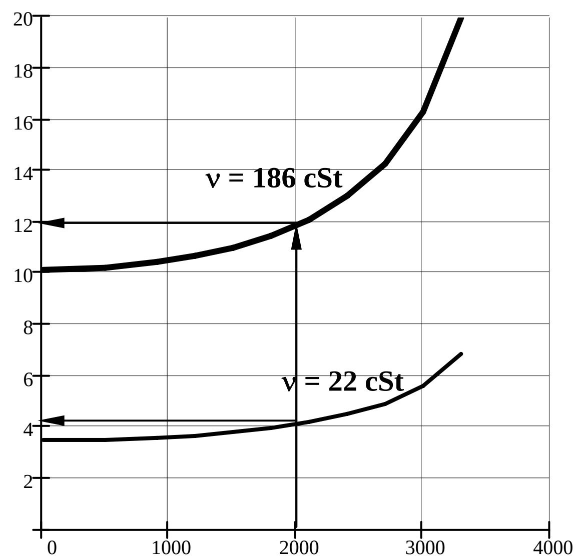

Figure 3. Suction pipe inside diameter

Cavitation number for piston pumps is from 0,7 to 0,8 [1]. Hydraulic oil HLP 46 is used [2], and accessibility of the air is not taken into consideration. The maximum piston velocity is:

$$v_p = \frac{D}{2}\varpi \sin\alpha \qquad \ldots(6)$$

where

D is graduated circle diameter

ϖ is angular velocity
α the slope angle of the cylinder block.

For non-cavitation work permissible pressure drop through suction pipe, armature and flow passages in the pump can be easily calculated if rotational speeds, dencity of the fluid and actual suction pressure (shown in Figure 2.) are known. When given pump is working in an open circuit, and fluid tank is subjected to atmosferic pressure, permissible pressure drop is shown on Figure 2., too.
Because of change viscosity, temperature of the working fluid has influence to pressure drop in the suction line and incorporated components (filter and fittings). Therefore, for mentioned oil, kimenatic viscosity at 20^{o}C is 186 cSt, and at working condition (60^{o}C) is 22 cSt. Toward equation for inside diameter of the suction pipe:

$$d = \sqrt{\frac{37{,}5\ \nu\, \rho\, v_s}{\Delta p}} \qquad ...(7)$$

where
$v_s = 1{,}5$ m/s is permisible fluid velocity
Δp is pressure drop per every meter of the suction pipe.

On Figure 2. and Figure 3. we can see that permissible pressure drop for non-cavitation work is about 75 kPa for axial-piston bent axis pump which rotational speed is 2000 min^{-1}, and for more adverse conditions (start conditions) inside pipe diameter must be minimum 12 mm.
Such analysis is possible for every type of pump, for knowing characteristics of fluid and suction conditions (characteristics of filter, number and type of fitting, pipe length and fluid tank location).

3. CONCLUSION

It is a very known fact that phenomenon of the pump cavitation means a great problem in hydraulic systems working. Despite pumps manufacturers' recommendation, in some cases their users must depart in fluid choice or embed manner of the pump. The possible quick solution to these problems is the equations and diagrams provided by this article. It must be taken in consideration that fluid tank must have proper capacity and be made in a correctly manner, that fittings are well fasted, so that air cannot admit in the suction line.

4. REFERENCES

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