PAPER • OPEN ACCESS

The impact of viscosity and propagation velocity of the flow on the initiation of the cavitation in a gear pump

To cite this article: A S Lunev *et al* 2020 *J. Phys.: Conf. Ser.* **1515** 042039

The impact of viscosity and propagation velocity of the flow on the initiation of the cavitation in a gear pump

A S Lunev, A S Kaverzina, A A Nikitin, A V Novik and V A Kramarenko

Siberian Federal University, 79, Svobodny Avenu, Krasnoyarsk, 660041, Russia

E-mail: Allynev@mail.ru

Abstract. The article analyzes the cavitation behaviour of gear pumps. If the liquid is more viscous and the liquid volume is underpressure less time, the dissolved air escapes in a significantly less amount than under a given pressure according to Henry's law.

1. Introduction

As a result of maintenance of pumps under low atmospheric pressures, or when pumping high-temperature liquids, or when the suction height is higher than the permissible one, cavitation can occur in the pump, accompanied by specific vibration, cracking, hissing and other noises inside the pump resulted in the rapid wear of the pump working element.

The flow pressure may decrease to the saturated vapour pressure in some sections of the pipeline with the pumped liquid, thereby bleed multiple bubbles of vapors and gases evolve inside the continuous flow. The bubbles expand to large cavernous bubbles under the influence of underpressure. These caverns burst getting through the zone having higher pressure than the saturated vapor pressure. The bubbles collapse is very quick and comes with hydraulic shocks leading to cavitation erosion, mechanically destroying the surfaces of the working elements of pumping equipment and complicates its further operation [1, 4, 8].

The area filled with moving bubbles is the cavitation zone, which is habitually formed when the liquid pressure at the entrance to the impeller is less than the vapor pressure. The discharge head of the pressure fluid sometimes decreases to zero and causes the interruption of the feed, resulting in the sharp decrease of the pumping capacity (efficiency).

In order to exclude the possibility of cavitation for sure, cavitation characteristics are calculated for each pump.

The saturated vapor pressure varies over a wide range depending on the state and physical properties of the pumped liquid, therefore, the saturated vapour pressure is taken at a particular temperature to determine the cavitation characteristics.

Cavitation in the flow part of the pumping system can be prevented taking into account the causes of general and local pressure reduction. But a better method of release and complete exclusion of cavitation is the optimal geodetic calculation of the installation location of the pump and the corresponding choice of suction height and temperature of the pumped liquid. It is possible to create a certain margin guaranteeing reliable and continuous secure operation of the pump system without cavitation by reducing the suction height or increasing the head up compared to the calculated values.

Pump inlet pressure variation, the frequency diversity of the shaft, and viscosity fluctuation of the pumped liquid directly affects the change of the cavitation characteristics of the pump [2, 6, 7].

2. Analysis of change of characteristics of the gear pump when changing the viscosity of the fluid and the shaft speed

The cavitation characteristics of gear pumps, taken at a pump shaft speed of n = 220 - 235 rpm and a fluid viscosity of υ = 0.04 - 0.14 cm^2/sec are characterized by a low angle decrease as pressure decreases at the pump inlet. Similar characteristics were obtained when testing the NSh-10 pump and in some cases of testing the NSh-32 and NSh-46 pumps [7].

This difference can be explained by the fact that tests of all three sizes of pumps were carried out using a suction pipe of constant diameter and length. In this regard, having an equal rotation speed of pumps, the time of volume of liquid being underpressure of a smaller pump will be longer. Therefore, the conditions for the evolving of dissolved air in a liquid in this case are more favorable.

For the NSh-32 and NSh-46 pumps, in contrast to the NSh-10 pump, low angle cavitation characteristics were obtained when testing them on a less viscous liquid under other identical conditions [3, 5].

The impact of fluid viscosity on the type of cavitation characteristics at a constant speed is shown in figures 1 and 2. The characteristics were obtained when testing the NSh-10 pump with Ind-12 oil at rotational speed n = 220 - 235 rpm (the velocity of the liquid in the suction pipe with a length of 180 cm is approximately 0.06 m/sec).

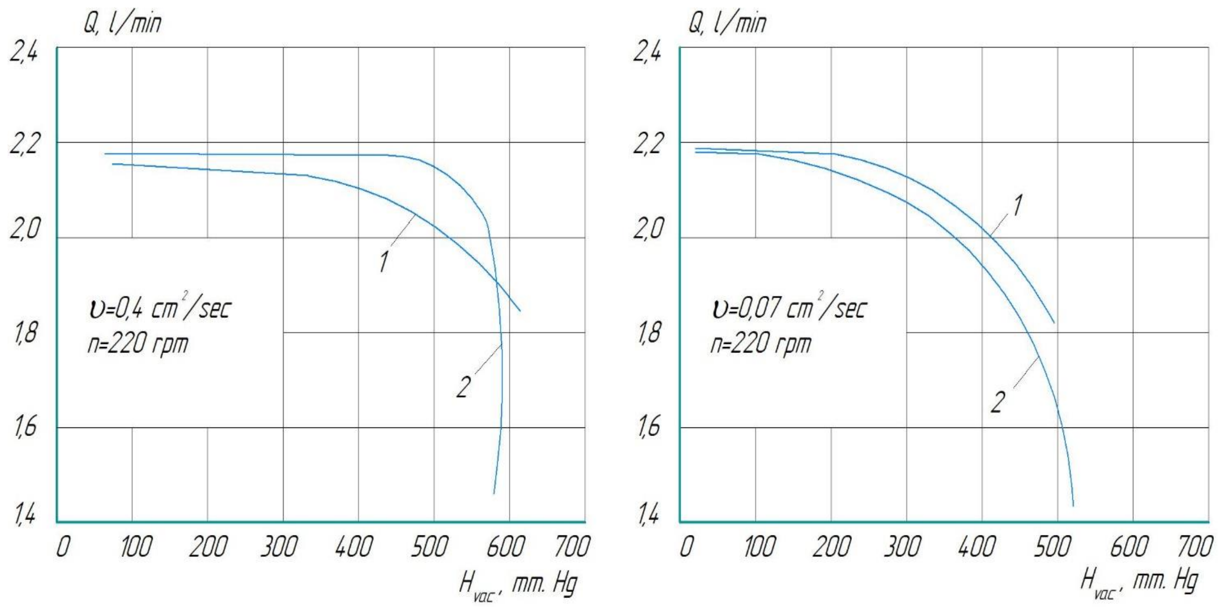

Figure 1. Cavitation characteristics of the NSh-10 pump, obtained at various viscosity values of Ind-12 oil with a rotation frequency of n = 220 rpm: 1 - design characteristic; 2 - experimental characteristic.

The same graphs show the Q - H_{vac} curves. The experimental cavitation characteristic, taken at a viscosity of υ = 0.4 cm^2/sec, has a rectilinear section passing close to the horizontal, on which the supply practically does not decrease with an increase in the vacuum height of the suction. This indicates that under these conditions, the air dissolved in the liquid does not have time to evolve the mixture in an amount that ensures the establishment of its equilibrium state in the liquid under a pressure at the inlet of the pump. It is necessary to change the conditions of the experiment in order to ensure air evolution in accordance with Henry's law for the current value of the pressure P_{inlet}: reduce the speed of rotation of the pump or reduce the viscosity of the pumped liquid. In these tests, the viscosity of the fluid has changed.

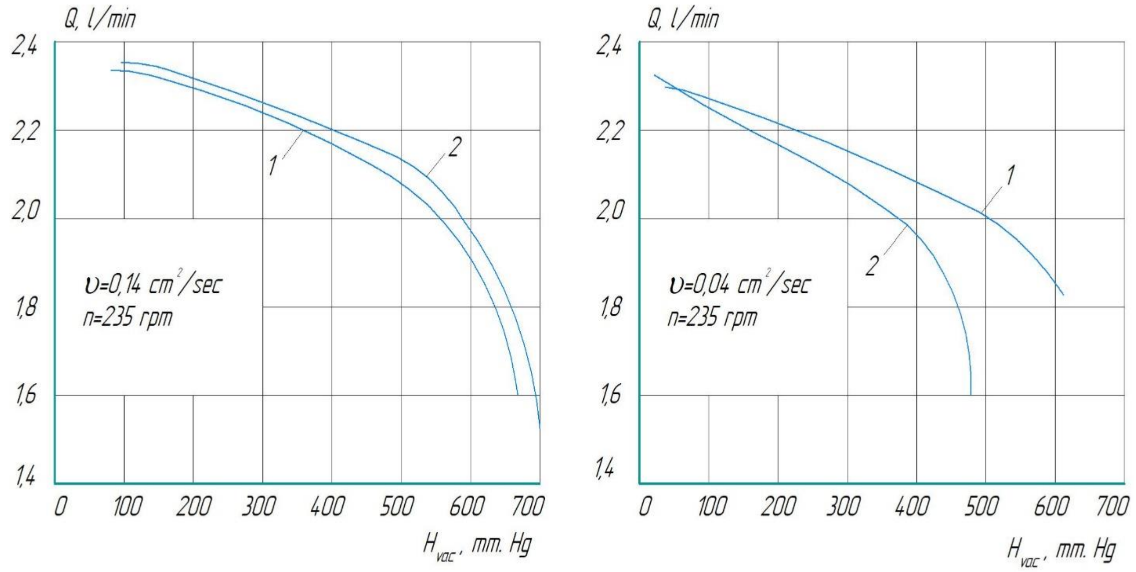

Figure 2. Cavitation characteristics of the NSh-10 pump, obtained at various viscosity values of Ind-12 oil with a rotation frequency of n = 235 rpm: 1 - design characteristic; 2 - experimental characteristic.

The experimental and calculated curves almost coincide when viscosity decreases to υ = 0.14 cm^2/sec. The amount of air evolving the mixture under these experimental conditions, as shown by graphs, corresponds to Henry's law.

The calculated curve is higher than the experimental one if the viscosity decreases further to υ = 0.04 and 0.07 cm^2/sec and the shaft rotation frequency changes. This is due to the fact that a decrease in the pump flow occurs not only due to the evolving of air dissolved in liquid, but also as a result of evaporation of light oil fractions, because the vapor saturation pressure increases if the temperature of the liquid rises [9, 10].

In broader terms, the impact of fluid viscosity on the type of cavitation characteristic is shown in figure 3, where Q_{exp} shows the dependences of the Q_d / Q_{exp} relationship on the viscosity of the liquid, where Q_d and Q_{exp} are the design and experimental values of the pump flow, based on the ratio ΔQ / Q = 0.03.

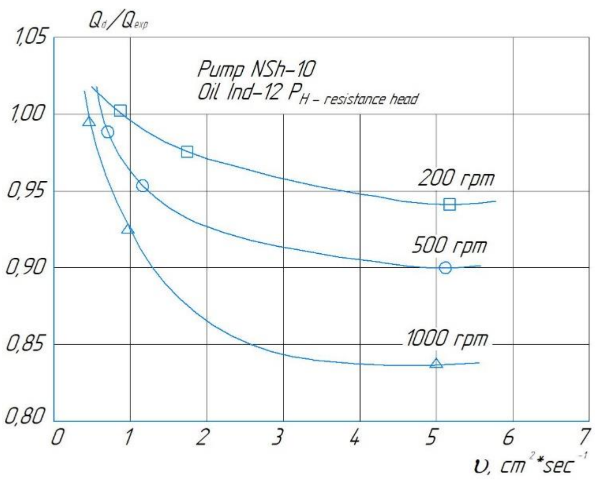

Figure 3. Dependence of the relation Q_d / Q_{exp} on the viscosity of the liquid and the rotation speed of the pump shaft NSh-10.

As can be seen from the graph, only at a certain viscosity of the liquid and the speed of rotation of the pump, the calculated and experimental cavitation characteristics approach each other.

Thus, it has been experimentally shown that, at relatively low values of the pump rotation speed and the viscosity of the pumped liquid, conditions when the dissolved air evolves the liquid in an amount corresponding to Henry's law are made.

Increasing the rotational speed of the pump, the cavitation characteristic is no longer low angle: a horizontal or near-horizontal section appears. A similar phenomenon is observed increasing the viscosity.

3. Conclusion

The results of our experiments are not in the line with the main point of the method of calculating the supply of a gear pump subject to the dissolved air impact, proposed by Schweitzer and Constance, who believe that the volume of air evolved the liquid is proportional to the pressure at the inlet of the pump, i.e. according to Henry's law. This conclusion is given without experimental data confirming its correctness and is not associated with the operating conditions of the gear pump.

References

[1] Kaverzina A S and Mineev A V 2015 The effect of the flow rate of a viscous fluid during operation of hydraulic drives with modifications *Equipment and Technologies for Oil and Gas Complex* **3** 36-8

[2] Mineev A V, Kaverzina A S and Timko A A 2015 Some issues of the impact on the operation of hydraulic drives of engineering machinery of various directions, manufacturing and methods of operation *Construction of Oil and Gas Wells on Land and at Sea* **10** 36-7

[3] Yudin E M 1964 *Gear Pumps. The Main Parameters and their Calculation* Ed 2 (Moscow: Mechanical engineering)

[4] Frolov E S, Avtonomova I V and Vasiliev V I 1989 *Mechanical Vacuum Pumps* (Moscow: Mechanical engineering)

[5] Schipakin A A and Arbuzova N A 2018 Cavitation in pumps and methods for its reduction *Sputnik* 334-6

[6] Mineev A V, Kaverzina A S and Timko A A 2016 Justification for considering the suction process of the main modifications of gear pumps. Stages of experimental research and their characteristics *Equipment and Technologies for the Oil and Gas Complex* **1** 15-8

[7] Zenke T, Turk M and Verhulsdonk B 2005 Das kavitationsverhalten von drenkolbenpumpen. Experimental studies of the effect of the rotation speed of a rotary pump, fluid viscosity and working pressure on cavitation intensity *Landtekhnik* **59(1)** 22-3

[8] Yakhno O M, Kostyuk D V, Strychek Y and Antonyak P 2012 The effect of cavitation on the value of pulsations of the gear pump supply *Equipment and Technologies for the Oil and Gas Complex* **64** 132-5

[9] Vasiliev A A and Igoshin D N 2016 Reducing the effect of cavitation on the export of pump parts *Equipment and Technologies for the Oil and Gas Complex* 28-9

[10] Efremova K D and Pilgunov V N 2016 Cavitation properties of liquids *Hydrostatic Cavitation* **3** 12-36