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INFLUENCE OF AN ULTRASONIC DEGASSING SYSTEM ON THE OPERATION OF A HYDRAULIC PUMP

1 Introduction

One way to stabilize the fluid properties, in order to achieve reliable and durable hydraulic drive system, is to reduce the gas content in working fluid. It is obtained using an ultrasonic degassing method which introduces high power ultrasonic oscillations into the fluid. Due to the osculations, air bubbles are moving into the nodal regions of the pressure standing wave [1-4], then coalesce (stick together) and finally emerge onto the fluid surface. However, the efficiency of the diffusion based degassing process is practically negligible. On the other hand, if the intensity of an ultrasonic wave in the expansion phase is high enough to drop the fluid pressure below the saturation vapour pressure, the ultrasonic cavitation appears. For such condition, the cavitation bubbles are created from cavitation embryos of a radius no smaller than the critical radius [2, 3]. In the expansion phase, while increasing the size of the bubble and by the decrease in gas concentration inside that bubble, the gas dissolved in the fluid diffuses into the bubble. At the same time, the bubble size grows due to fluid evaporation from the bubble inner surface. This process leads to the cooling of the bubble's surface, as well as the vapour-gas mixture in its interior, which additionally supports the evaporation process. Similarly, during the compression phase, the bubble size decreases and the vapour-gas diffusion from the bubble to the fluid appears. Because the amount of the diffused gas is proportional to the bubble surface, which is greater during the expansion phase, the growth of the gas mass and the bubble size takes place. If the oscillation amplitude is high enough, the bubble size is slightly reduced instead of collapsing. Consequently, the cavitation bubble oscillates, accumulating energy and the amount of gas entrapped in its interior up to the drop point. At that moment, depending on its proximity to adjacent bubbles and to solid surfaces, spherical shock waves or energy-intensive cumulative jets may appear. This additionally increases the efficiency of the degassing process. In contrary to the above, if the cavitation bubble bursts during the compression phase, it becomes a cavitation embryo again.

The above analysis shows that the cavitation based degassing system is a highly effective and expedient method but it requires the use of a high-amplitude ultrasonic emitter featured well-developed radiation surface. Such a device guarantees the occurrence of cavitation bubbles oscillation and micro-flows which, as was mentioned above, intensify the degassing process.

2 Test stand

The influence of the ultrasonic degassing system on the operation of a hydraulic pump has been tested using the test stand diagram of which has been shown in Fig. 1a, and the actual view in Fig. 1b.

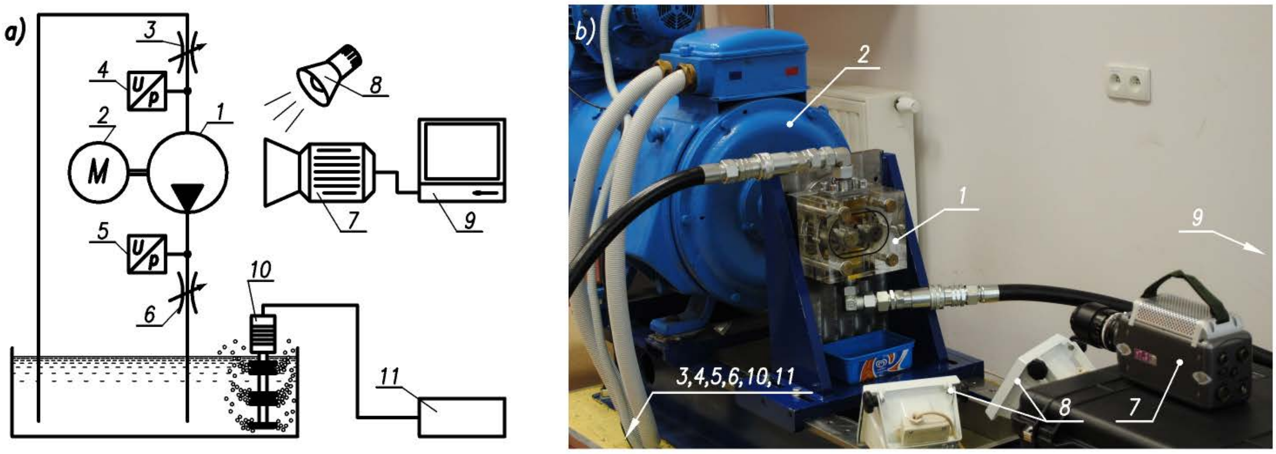

Fig. 1. Test stand : a) simplified diagram, b) view of the test stand

The test stand consists of 3 subsystems, namely: a hydraulic-mechanical system, a degassing system and a visualization system. The mechanical system consists of an experimental gear pump (1), partly made of a PMMA, and a 50kW DC electric motor (2) whose speed is adjusted by a controller with a built-in speed indicator. The pressure of the working fluid, a typical ISO VG 68 hydraulic oil, at the inlet of the pump is controlled by a throttle valve (3) and the WIKA A-10/-1...+15 bar pressure transducer (4). Similarly, the pump output pressure is set using a throttle valve (6) and the WIKA A-10/0...+100 bar pressure transducer (5).

The degassing system consists of an ultrasonic emitter (10) mounted inside of a 60 litre hydraulic tank. The emitter is powered by a custom designed, high power electronic driver (11). The actual power used by the ultrasonic emitter is adjusted by a knob built in the driver.

The visualization system is responsible for recording the phenomena and flow processes occurring in the pump. The system consists of a high-speed camera (7) (Phantom v 7.3 by Visual Research), and a computer (9) with dedicated software. The software, Phantom Camera Control Software, also by Vision Research, has been used for the analysing and processing of the recorded images. The system is completed with a light source (8) consisting of two 500 watt general purpose halogen lamps.

The test stand, as a whole, enables conducting research on the influence of the degassing system on the flow phenomena and processes in a hydraulic gear pump. A similar system had been used many times for visualization research by a team of researchers from Wrocław University of Science and Technology [5-10], and it proved to be sufficient.

2.1 Ultrasonic emitter

Fig. 2a shows the main component of the ultrasonic degassing system which is the ultrasonic emitter. The emitter is designed by a team of researchers from National Technical University of Ukraine.

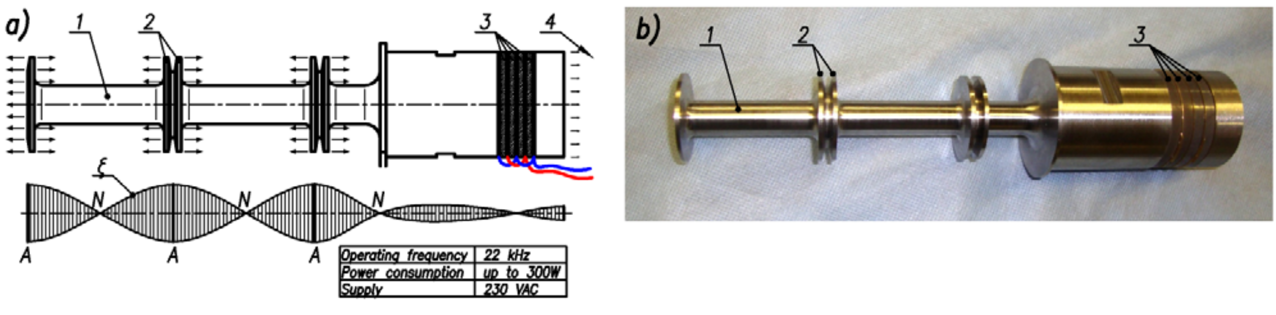

Fig. 2. Ultrasonic resonant drive-emitter with a developed radiation surface: a) design diagram, b) actual view

The ultrasonic emitter consist of a custom shaped ultrasonic emitter (1) featured radiating disks (2), placed in the anti-nodes (A) of a standing ultrasonic wave (ξ), and a piezoelectric transducer (3) which is the causative agent of vibration oscillations. The ultrasonic emitter, mounted vertically in a hydraulic tank and immersed in a working fluid, is excited by a driver which is a custom designed, electronic oscillator (4).

The actual view of the ultrasonic emitter is shown in Fig. 2b.

3 Research

Experimental research was carried out for the following parameter values:

- rotational speed of the pump 500±10 rev/min,
- inlet pressure of the pump 0±0.05 bar,
- outlet pressure of the pump 10±0.1 bar,
- temperature of the working fluid 21±2°C,
- ultrasonic emitter power 300 W.

The research was carried out in 3 stages. At the first stage, the visualization research was carried out for hydraulic oil which was not subject to a degassing process. Then, the degassing system was started for 30 minutes at full power, after which the visualization research was carried out again. This cycle was repeated twice, which allowed to determine the effect of the degassing system working for a total of 90 minutes.

The nomenclature used in the article on the forms and intensity of cavitation phenomena is described in detail in [10].

The research results, for two most characteristic gear set positions, are shown in Fig. 3.

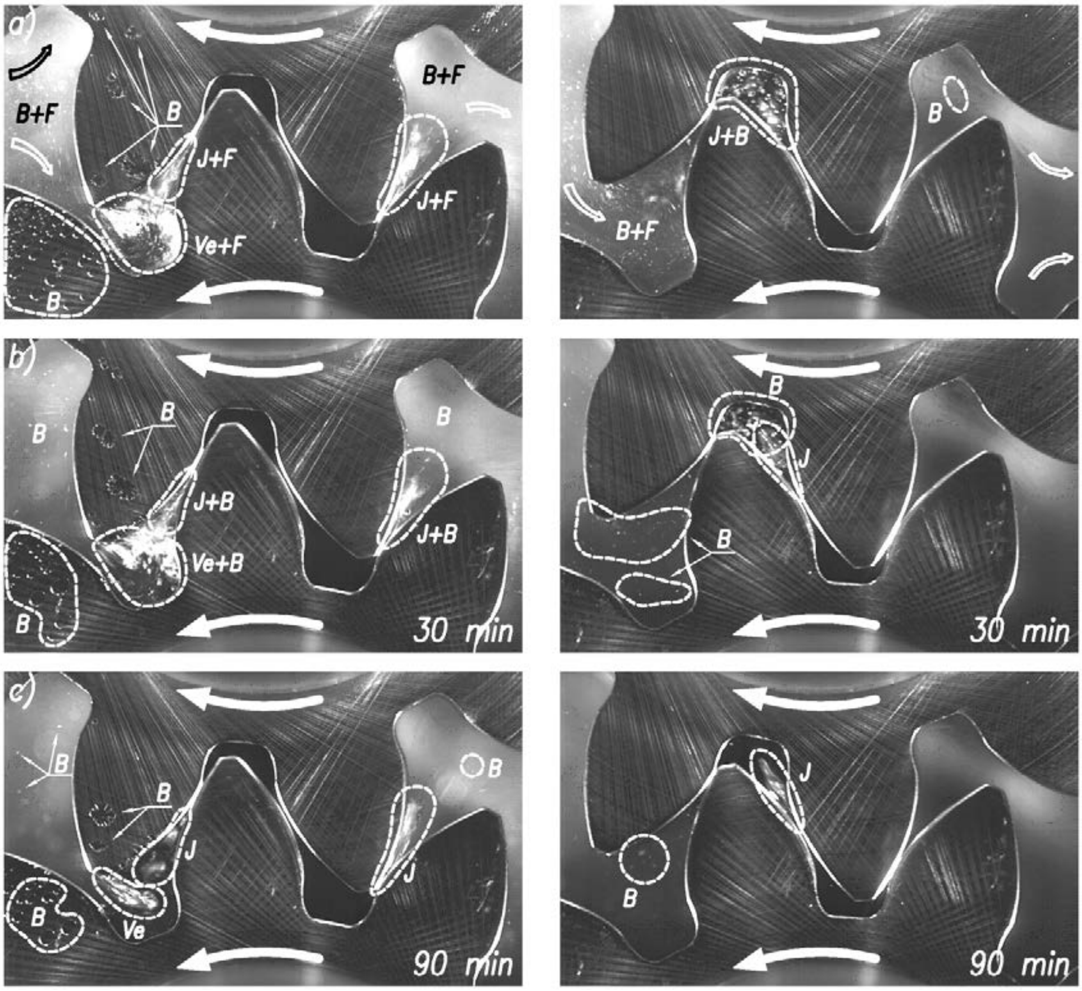

Fig. 3. The real flows in the outlet bridge zone for different degassing times

As one can see, it is perfectly evident that in the case of the non-degassed oil (Fig. 3a), there is a number of areas in the pump, where cavitation phenomena are clearly visible. What is more, the intensity of those phenomena is high, as evidenced by the occurrence of cavitation foam (F), cavitation bubble (B) or both (B+F). These phenomena are so intense that cavitation bubbles occur even in the axial gap between the surface of the body and the surface of the gear. In addition to bubbles (B) and cavitation foam (F), one can also notice two other forms of cavitation phenomena, namely veil (Ve), occurring near the tooth's head, and jet (J) appearing in the inter-tooth gap. However, also in that case, those phenomena are accompanied by a cavitation foam (J+F, Ve+F) or cavitation bubbles (J+B).

Tests performed after 30 minutes of the degassing system operation (Fig. 3b) showed that the intensity of the cavitation phenomena decreased. Evidence of that was the disappearance of cavitation foam (F) and the limitation of the cavitation bubbles (B) occurrence area.

Finally, after 90 minutes of the degassing system operation (Fig. 3c), it was concluded that virtually all cavitation bubbles (B) had been eliminated, and inside the pump only other forms of cavitation phenomena were visible, namely veil (Ve) and jet (J).

3 Conclusions

The presented research has proved that the ultrasonic degassing system works as expected and has a significant influence on the gas content in a hydraulic oil as well as on a hydraulic gear pump operation. Besides, the study has clearly shown that the reduction in the amount of gas dissolved in the medium causes a radical decrease of the cavitation embryos and, due to that, reduction of the cavitation phenomenon practically in all characteristic areas of the pump. Finally, that results in the noticeable reduction of noise and improvement of the hydraulic characteristics as well as overall performance of the pump.

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