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Original Research Article

Visualization study of the flow processes and phenomena in the external gear pump

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ABSTRACT

External gear pumps make some of the most frequently used hydraulic energy generators. In spite of the fact that those well known machines feature good operational parameters, the research and development work on the pumps is still going on. There is a number of various research methods applied. One of them, an experimental method, is a visualization study, on which this paper is focused.

In this article, the visualization research method has been presented, which has been used for the study of the flow processes and phenomena in the external gear pump. Findings of the research enabled a detailed description of the flow process, namely of the transporting of the working fluid through the pump, in each of the typical zones of the pump. It turns out that a characteristic feature of the process is the occurrence of various cavitation phenomena. All characteristic cavitation forms, as well as the degrees of their intensity, observed during the research, have been catalogued and specifically described. The research also made it possible to identify the critical areas of the pump, which, consequently, allowed the development of specific design, construction and operational recommendations. A result of applying those recommendations was a considerable reduction of the intensity of the cavitation phenomena, evidence of which is the experimental study presented in this paper.

1. Introduction

Gear pumps, and the external gear pumps in particular, make a group of the most commonly used hydraulic power generators in fluid power. Their popularity is due to their relatively simple construction and, what is a consequence of it, their low price. Those units feature high working pressures, and a large number of commercially available types and models allows for the selection of the optimum unit for practically every application. However, despite years of their presence on the market, the pumps can be and, actually, are continually improved. Numerous publications prove that there is still a lot to be done in this matter, and the researchers worldwide, using various methods and tools, are working on the improvement of the already existing as well as new solutions.

Analysis of the literature shows that the research work on gear pumps, including the external gear pumps, are conducted in four different directions.

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Nomenclature

B	bubble
B_I	input bridge
B_O	output bridge
CL_I	input channel
CL_O	output channel
CR_I	input chamber
CR_O	output chamber
F	foam
G_A	axial clearance
G_B	bearing clearance
G_I	intertooth (backlash) clearance
G_R	radial clearance
J	jet
n	rotation speed of a pump [rev/min]
n_{nom}	nominal rotational speed of a pump [rev/min]
p_I	input pressure [bar]
p_O	output pressure [bar]
P	plume
T	displacement chamber, temperature [°C]
V_e	veil
V_x	vortex

The first one is the research in which FEM (Finite Elements Method) is applied. An example of such work is the research on a new type of pump, namely a miniature gear pump, carried out by a group of scientists from Samara State Aerospace University. In paper [1], the authors do the FEM simulation research aimed at verification of the possibility of building a miniature gear pump in which bearing seats would be made directly in the body of the pump, eliminating the necessity of using special slide bearings. The research has proved such a concept correct, and the pump of such a design works properly.

Another example of this type of research is work [2], in which the authors look into the possibility of using an asymmetric body in a miniature gear pump. The research results presented in the paper prove that this possibility exists, and the use of such a body results in a considerable reduction of internal stress.

The FEM has also been extensively used in the work of researchers making the FRPG (Fluid Power Research Group) from Wroclaw University of Science and Technology. In papers [3–7] the authors use the FEM method to determine the stress, pressure and deformation values observed in one type of gear pumps, namely in the gerotor pump.

In paper [3], the authors study a mechanism of induction of stresses and deformations in plastic cycloidal gears used in gerotor pumps. They determined that in such conditions radial and axial intertooth clearances are formed, which result in internal leakages in the pump, as well as in lower working pressure and efficiency of the machine.

The continuation of this work is presented in the paper [4], where a question of a more efficient application of plastics in building the gears is discussed. For this purpose the Author carried out a two-stage optimization process which allowed him to determine the most suitable tooth profile for the hydraulic machine featuring the cycloidal gears.

In the paper [5] the same author introduces and discuses plastic cycloidal gears with steel internal cores. This approach is proposed to increase working pressure of gerotor pumps with plastic gears. As the author claims, the results show that such a solution significantly strengthened the gears allowing them to work at higher working pressures.

Another example of this type of research is the article [6], in which the authors present the process of designing the gerotor pump body made of plastic. Starting from a simple cuboid, through a multi-stage optimization process conducted by means of strength analysis, the authors achieve more optimal body which can operate with higher operating pressures.

A similar approach, but with reference to gerotor gears system, is presented in the paper [7]. The aim of the article is to present strength analysis of a POM gear system used in the gerotor pump, as well as to determine the design rules in terms of strength. As a result of the analysis, the principles of designing the gerotor pump gear system have been specified.

As mentioned above, in their research, the authors point out that in the construction of pumps of this type, both the gears [3–5,7] as well as the bodies [6] can be made of plastic. What is more, they show that the optimization of the shape of the gears and the pump bodies allows the improvement of the characteristics and operating parameters of those machines.

The second direction of the research present in the literature is a variety of simulations of the pumps' work, conducted by means of specialized software, often developed originally by the authors of the simulation studies. Typically, the software is based on more or less complex mathematical models of phenomena and processes which take place inside the studied pumps. Such software is usually closely related to the type and geometric characteristics of the units in question, which allows the optimization of computational algorithms and significant acceleration of the calculations. It should be noted, however, that such specialization makes such software unlikely to be universal.

One example of this type of research is work [8], where the authors use HYGESim software to simulate a pump operation determined by conditions in which the cavitation phenomenon may occur. The research findings, showing very good convergence with the experimental research results, show that this approach is appropriate and that such specialized software can be used to predict the theoretical performance of the pumps.

Another instance of this trend are works [9–11], in which the authors, using a mathematical model and original software based on it, try to determine the characteristics of pressure change in the displacement chamber of the gerotor pump.

In the paper [9] the authors discusses the process of creating a mathematical model of flow processes in a gerotor pump. A good qualitative convergence of the simulation and the experimental research results, proving the theoretical model correct, enables to optimize the geometry of the internal channels system.

An improved simulation model, presented by the same authors in [10], is used to study an influence of some geometrical and operational parameters on pressure change