Detecting Output Pressure Change of Positive-Displacement Pump by Phase Trajectory Method

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The monitoring of hydraulic system condition change during its exploitation ran its complex problem. The main task is to identify early phase damage of hydraulic system elements (pumps, valves, ect.) in order to take decision which can avoid hydraulic system break down. This paper presents the possibility of phase trajectories use in detecting output pressure change of hydraulic system caused by positive-displacement pump wear.

Key words: *technical stability, phase trajectory, axial-piston pump, pump diagnosis*

Introduction

In hydraulic drive systems the positive-displacement pumps are one of the important elements. Proper work of these elements causes proper work of whole hydraulic system. The wear of pump elements causes pump's pressure lost and increase of volumetric losses, which lead to decreasing delivery of the pump and increasing in vibration and noise of its work. The run of vibroacustic diagnosis of pump is mainly guide to search: damage symptoms in vibration signals. In the case of high noise level and high level of mechanical complexity, the estimations of damage symptoms have big uncertainty. The diagnosis of process analysis shows only huge damage appearance which is critical in further exploitation. This methodology doesn't take into consideration development process so there are no possibilities to predict it (Batko, 2007). The searches for new method of pump diagnosis are mainly based on assumptions which eliminate disadvantages of now use methods.

Description of phase trajectory method

Detection of positive-displacement pump output pressure change should be independent from noises connected with operation of other hydraulic unit elements.

However it is impossible to distinguish from signal informative components which are connected with specific element of the pump. So we have situation when positive-displacement pump works in surroundings of others machines, devices or hydraulic elements. The influence of surroundings on testing element (independly from character of phenomena) could be described by functions so called: constantly operative disturbances. That's formulated problem has been described as Lapunov stability and technical stability (Bogusz, 1972). Let's assume that certain element of the pump is working on forces which come from other elements or object. Motion equation of testing element can be formulated as:

$$\ddot{x} = f(\dot{x}, x, t) \tag{1}$$

This equation has unique solution determinated by initial conditions. Taking into account environment reaction of testing element written as disturbance equation:

$$\ddot{x} = f(\dot{x}, x, t) + R(\dot{x}, x, t) \tag{2}$$

The solution of this equation is carry out by substitution and reduction of the order of equation which lids to:

$$\dot{x} = f(x, t) + R(x, t) \tag{3}$$

Taking into consideration that *R(x,t)* function consider permissible deviations from steady-state conditions, the change in initial conditions and predicted external and inner disturbance which operate on system in random character or periodic character, dynamic conditions of object thanks to technical stability conception can be determined (Bogusz, 1972).

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(Review and revised version 23. 2. 2010)

Proposed approach doesn't require full identification of system structure that is strict determination of function *f(x,t)* and we may concentrate only on equation (3) solutions. Effective tool for research solution of system of differential equations is trajectory analysis in phase space. From definition of technical stability system arise, that for initial condition included in ω area of phase space the solutions of system (3) remain in **Ω** area. So system is technically static.

Testing real object such as hydraulic axial piston pump we deal with many elements which interact each other. Stability of that system can be determined by motion parameter measured from particular element. Physically we may only base on elements which are connected with housing of pump. Vibration parameters of the housing are connected with motion of pump's components. After selecting proper place on housing of the pump which is geometrically connected with testing elements. The displacement and velocity of vibration measured in selected point related to phase space will characterize a class of solution of partial equation connected with particular elements of pump. The problem how to define **Ω** area can be solving in many way. In case of axial-piston pump it will be determination of **Ω** on the base of dynamics analysis of pump which define as good pump. Testing of phase trajectory for good pump with consideration of outer noise will allow trajectory determination. Observation of area change (which include trajectory) will create diagnostic symptom, so the diagnosis hypothesis will be state.

Theoretical consideration of this problem lids to conclusion that there is no knowledge how the area **Ω** (which is technically static) will change yourself as a result of degradation of testing element or his surroundings. Phase-space includes information about kinetics and potential energy. From machine model made as energy processor comes that in the case of total energy increase of testing element, the surface of area **Ω** will increase. This statement enables energy structure identification of testing object. Observation of elements which are connected with technological process (pumping) in case of energetic efficiency decreases it is possible to expect the area **Ω** decrease. For elements, where destructive coupling of dissipation energy occurred, the area **Ω** should increase.

Description of the Laboratory station

In order to carry out tests the laboratory station had been set up (fig. 1). The main elements of station are: constant delivery axial-piston pump (1), safety valve (2), throttle valve (3), low pressure filter (4) and additional equipment.

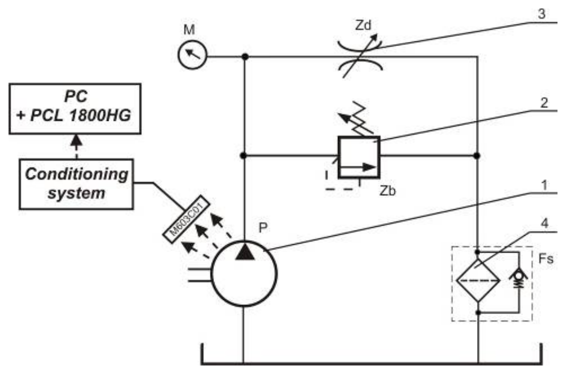

Fig. 1. Simplified diagram of the laboratory station.

The change of work pressure in hydraulic unit which was caused by wrong or wear element of axial-piston pump was simulated by throttle valve (3). Before the experiment started, the three work pressure of the pump had been set up. First it was assumed 10 MPa pressure level which is suitable for proper work of new pump (without damage). The next level of the pressure was set to 4 MPa. It simulated the work of the pump with damage or wear element. The 0 MPa was suited to work with completely damage pump. As diagnostic signal, which includes an information about the condition of hydraulic unit, the vibration signal of the body of the pump was assumed. The measurements of vibration was carried on characteristic places of pumps body: swash plate, valve plate, rotor and axis shaft. The view of mounted sensors on pumps body is shown on fig. 2.

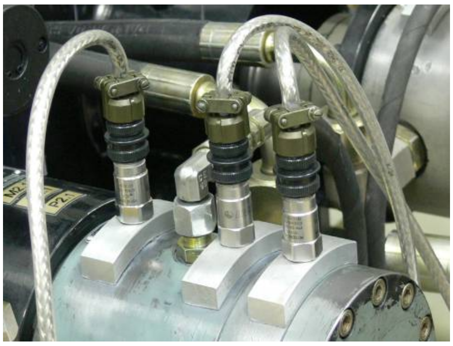

Fig. 2. The view of mounted sensors on pumps body.

Measurements of pumps body vibration were possible thanks to piezoelectric transducers type M603C01 [www.pcb.com]. In experiments 12 bits high speed data acquisition card type PCL 1800HG had been used [www.advantech.pl]. This card was controlled by DASYlab program [www.dasylab.com]. As conditioning system for measured signals three-channels unit PA-3000 [www.energocontrol.pl] was applied. Received signals were written down on PC hard disk.

Findings

The measured vibrations signals from pumps body (which were received for assumed pressures) had been put on numerical analysis. The next step was determination of phase trajectories. The methodology of phase trajectories estimation used so as to detect pressure output change of positive-displacement pump was based on integration of numerical acceleration's runs, measured in assumed points of pump's body. Obtained phase trajectories runs had been shown on figures 3÷6.

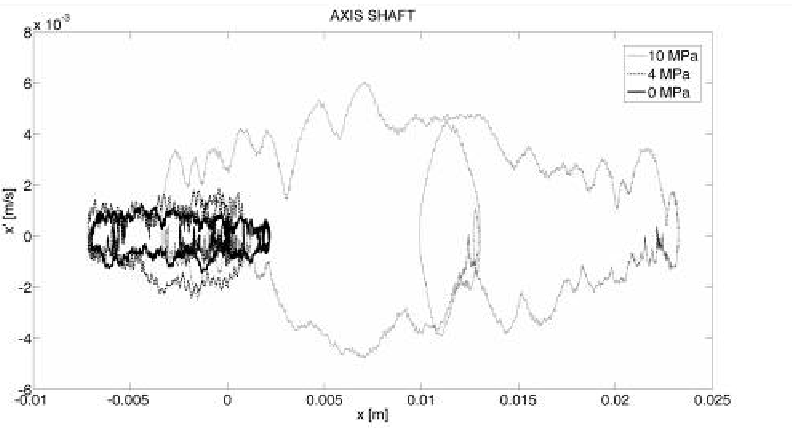

Fig. 3. Phase trajectories runs estimated from vibrations signal measured on axis shaft.

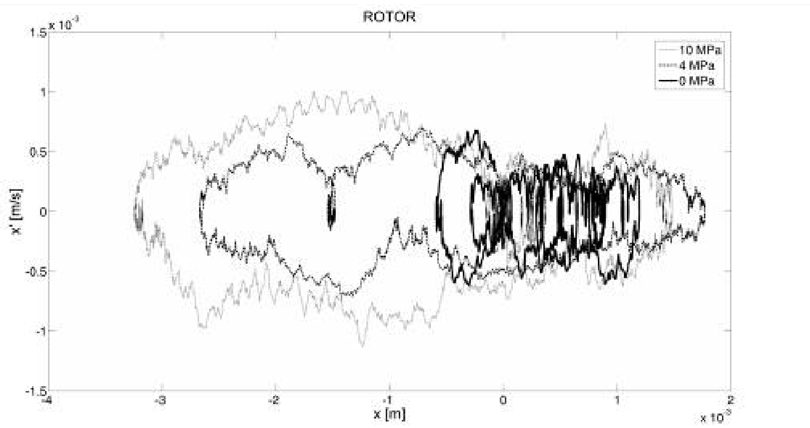

Fig. 4. Phase trajectories runs estimated from vibrations signal measured on rotor.

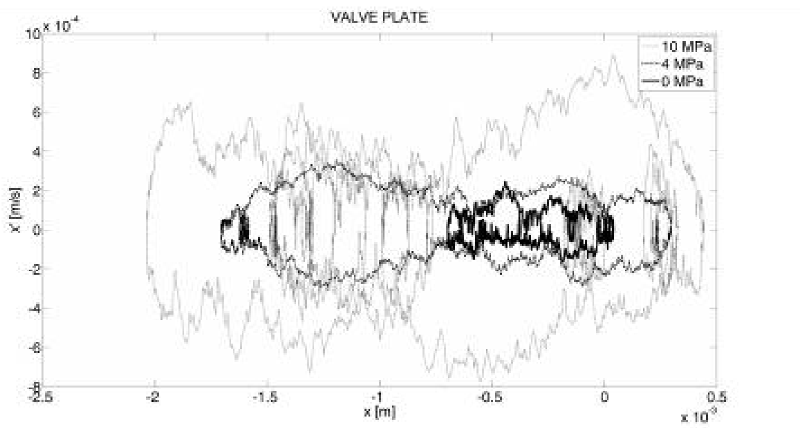

Fig. 5. Phase trajectories runs estimated from vibrations signal measured on valve plate.

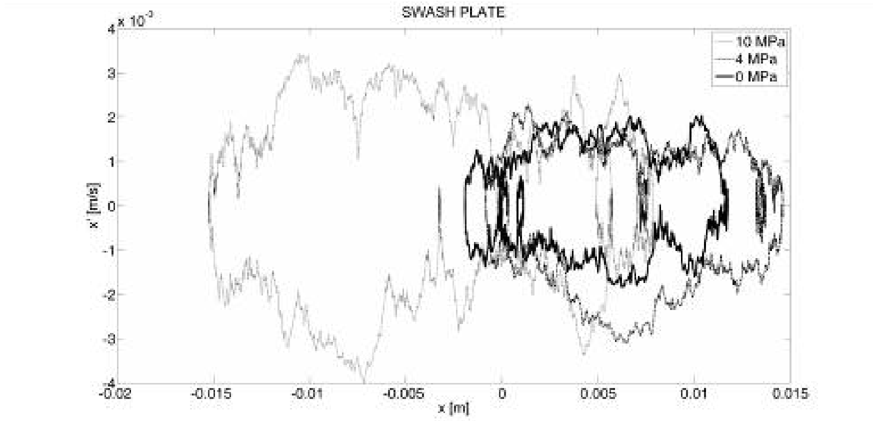

Fig. 6. Phase trajectories runs estimated from vibrations signal measured on swash plate

Summary

Analysis of phase trajectory runs lids to conclusions:

- the output pressure change of axial-piston pump has representation in phase trajectories runs,
- decrease in output pressure lids to decrease in field of trajectory run,
- selection of vibration transducer place on examined pumps body is important for obtaining trajectories runs,
- the main differences in phase trajectories runs which came from output pressure change were obtained for signals measured on valve plate and rotor of examined pump.

Summarize it was found that phase trajectories method could be a useful tool for axial-piston pump output pressure change detection caused by its damage.

Acknowledgement
Research carried out within the confidences
of KBN grant no. N501325135

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