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THEORETICAL AND EXPERIMENTAL RESEARCH REGARDING MALFUNCTIONING DETECTION FROM HYDRAULIC SYSTEMS

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Abstract: *In this paper a method to detect the malfunctioning from hydraulic systems is presented. This method allowed the identification of faults, even apparatus with malfunctions, without the need to dismantle the hydraulic system. The detection method of the inappropriate function of the installation is based on establishing the temperatures from the whole system. A map of temperatures is created and the user or an automatic system analyzes it.*

Key words: *hydraulic systems, detection of malfunctioning, local heating.*

1. INTRODUCTION

Recently, the demands as regards the equipment's performance parameters have been continuing the competition between the driving systems, leading to a natural improvement and to the maximization of performances. The hydraulic and electro-hydraulic systems are used as adjustment systems in a big number of industrial applications: machine tools, maritime ships, hydraulic and thermal turbines [1]. In comparison to other driving systems, the hydraulic systems have a bigger power-weight ratio and a big response speed.

The advantages of those systems are: speeds and forces in large domain of values; slight reverse of the movement sense without big dynamic demands; relatively rigid mechanical feature. Among the disadvantages of those systems, we mention: losses of pressure and volume; difficulties of faults diagnosis; influence of temperature on the fluid compressibility [2].

Today a very important place is occupied by the diagnosis of the hydraulic systems. For that reason we are looking to determine all the malfunctioning of the hydraulic systems using a thermal method. This method was implemented using an infrared non-contact thermometer with which a map of temperatures was created. The diagnosis is made analyzing the map of temperatures.

However, from what we know, the current diagnosis methods do not make it possible to diagnose a hydraulic system so fast and easy.

In this context this work consist on the one hand in developing a good map of temperatures distribution able to be read by all personnel and on the other hand to create an automatic malfunctioning detection system to survey continuously the hydraulic system and to warn the human user about the faults or about the possible faults from the hydraulic system.

The problems of this work are the temperatures detection of the hydraulic system in order to create a good temperatures map easy to be analyzed. To implement an automatic surveying system it is, consequently, necessary to set up a model able to interpret all the temperature signs from the map.

For this purpose, a programming platform will be developed based on a picture analyzing algorithm. An advanced infrared thermometer system will be used to create on-line thermal pictures of the whole installation. The program will be able to detect and to warn the human user about all the faults detected in the installation.

The results of this study may be useful to diagnose almost all of the hydraulic systems from industrial installations.

In the next section some theoretical aspects about this problem will be presented. Then a briefly discussion about local heating in the hydraulic systems is presented.

Knowing that the problem is how to generate the map of temperatures the method and the experimental researches are detailed in the next paragraph. Finally some conclusions and future development of this method are presented.

2. THEORETICAL ASPECTS

If a liquid transits from pressure p_1 to pressure p_2 ($p_1 > p_2$) as shown in Fig. 1, its temperature will be changed [3].

Between these areas of different pressure the following equation it can be written [4] :

$$\rho \frac{(\Delta V)^2}{2} = \Delta p = p_1 - p_2, \tag{1}$$

$$m \frac{(\Delta V)^2}{2} = mc\Delta T_1 \tag{2}$$

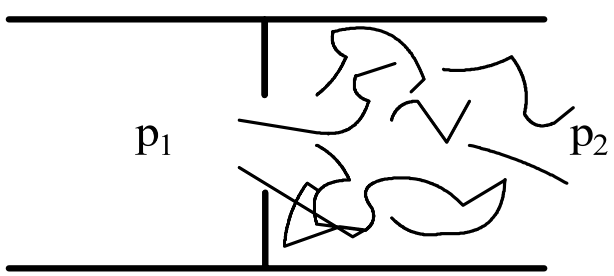


Fig. 1. Temperature change.

In relations (1) and (2) we notate: ρ – oil density; ΔV – flow speed variation; Δp – pressure variation; m – oil weight; ΔT_1 – temperature variation; c – oil specific heat.

From previous relations we obtain:

$$\Delta T_1 = \frac{\Delta p}{\rho c}. \qquad (3)$$

Besides heating phenomenon caused by pressure variation, we must take in consideration the temperature diminution. The diminution value is:

$$\Delta T_2 = 1.21 \cdot 10^{-2} \Delta p. \qquad (4)$$

The final temperature variation is:

$$\Delta T = \Delta T_1 - \Delta T_2. \qquad (5)$$

For usual oils and materials it can be considered:

$$\Delta T = \frac{\Delta p}{16.8}. \qquad (6)$$

If Δp is constant, then ΔT is the same.

3. LOCAL HEATING IN HYDRAULIC SYSTEMS

Hydraulic apparatus usually used in machine-tool domain, is characterized by the fact that the oil crosses them through active edges generated by construction. We talk about the pressure valve, distributors, regulators etc. Liquid flows through these edges generating local heating. Local heating appears also in case of apparatus with drain circuit. The pumps are under the same heating effect because of the friction appeared while functioning. Distributor's electromagnets change their temperature during functioning. In case of normal functioning, after a period of time, the temperature is stabilizing. Starting from these presumptions, we may consider that for a system with normal functioning, we have "a map" of temperatures distribution. We may consider this distribution as a reference system. If a certain element from the hydraulic system has a malfunction, there will appear local changes of temperature. These changes can be detected by realizing a periodic distribution of temperatures. The blockage of a pressure valve or a distributor, the same as a pump wear, will be detected.

For temperature measuring different apparatus can be used from classical thermometer to complex infrared systems.

4. EXPERIMENTAL RESEARCH

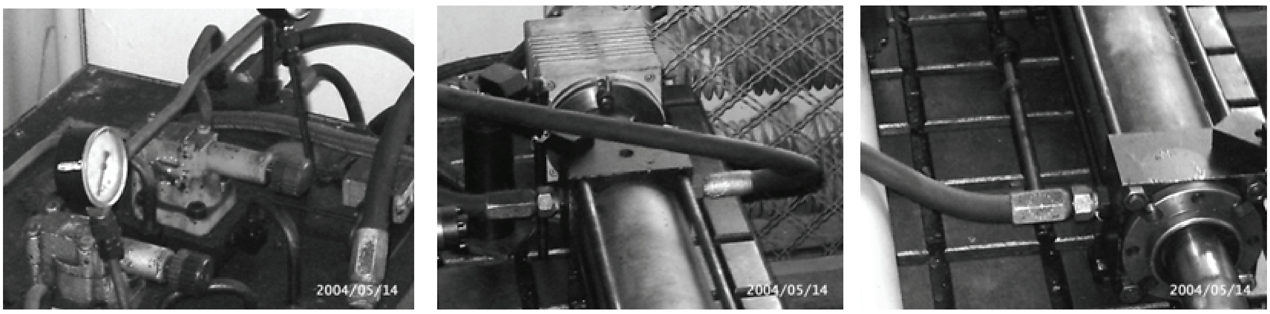
For experimental research we have used two hydraulic systems from our department's laboratory.

First system is used for "step by step hydraulic system" studying, and the second is represented by a robot's hydraulic drive system. For local temperature measurement we have used a classical infrared non-contact thermometer, presented in Fig. 2.

This apparatus can measure temperatures between: –30ºC – 900ºC, with errors of 1°C. For temperature's measurement we localize the measurement point with laser beam and read directly on display the associated value, like in Fig. 3.

Fig. 2. Infrared non-contact thermometer

Fig. 3. Temperature measurement



a. point A   b. point B   c. point C

Fig. 4. The measurement areas.

In this phase of research we intended to detect malfunctions from a hydraulic system using temperatures measurement. Two malfunctions were simulated on these systems from the test laboratory. For the industrial applications we plan to create an automatic malfunctioning detection system to survey continuously the hydraulic system and to warn the human user about the faults or about the possible faults from the hydraulic system.

4.1. Step by step hydraulic system

On step by step hydraulic drive system we have presumed that the system works on low pressure, then on high pressure and at a certain moment the following piston is being blocked. Temperature was measured in three points: on pressure valve – [Point A], in area with malfunction – [Point B], and in system's detour area – [Point C], like in Fig. 4.

The system worked 25 minutes on low pressure, then 5 minutes on high pressure without malfunctions. The malfunction was simulated after 30 minutes. Measurement results are presented, for these three points, in Fig. 5.

At the start temperature the pressure valve increases very fast [Point A]. Caused by local resistance modification, at the time where malfunction appears, temperature became higher in [Point B] area.

The oil from return circuit, flowing on low resistance area, is almost not affected [Point C]. Heating appeared in this area is normal, caused by oil circulation.

4.2. Robot's hydraulic system

For the robot's hydraulic drive system we have presumed that the usual malfunction is a line blocking, followed by a blockage of the pressure valve. After 25 minute of normal activity we have simulated the blocking of the pressure valve.

The temperature was measured on the exterior surface of valve, [Point D], like in Fig. 6 and the measurement results are presented on Fig. 7.

It can be observed that the blocking valve is detected because of the fast heating. This fact is explained by a flow difference between the two zones.

On step by step hydraulic drive system the pump has 6.3 l/min flow. For the industrial robot a double pump is used with approx. 22 l/min flow.

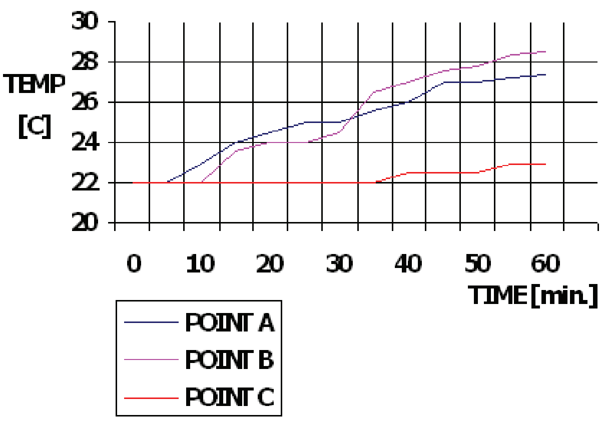


Fig. 5. Temperature change.

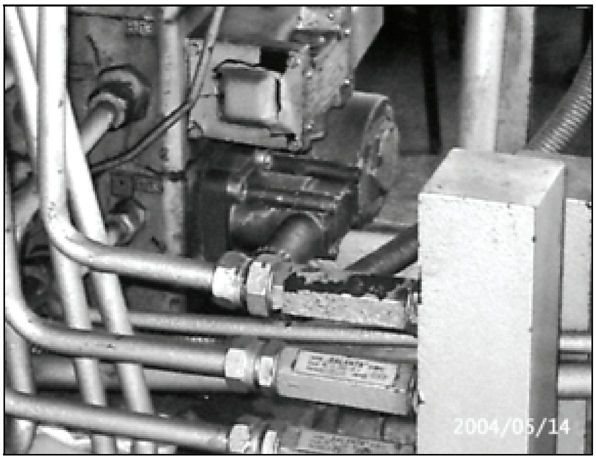


Fig. 6. Temperature change.

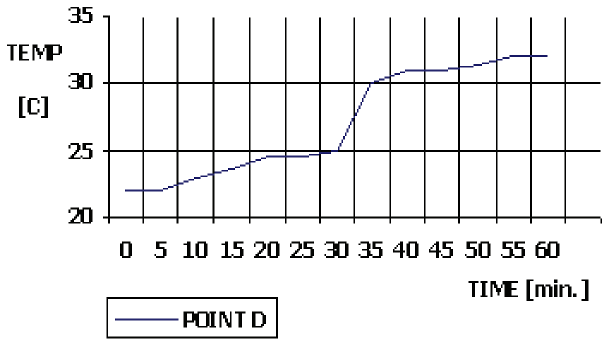


Fig. 7. Temperature change.

In this second case, malfunction appears after 30 minutes and the temperature becomes higher in affected area. It can be observed that this temperature variation is much faster than normal heating.

5. CONCLUSIONS

In this paper a method able to detect the malfunctioning from hydraulic systems is presented. Two systems were analyzed: a step by step hydraulic system and a robot's hydraulic drive system.

In both cases, the simulated malfunction produced the heating of the affected area. Temperature variation is more obvious and it is faster than in the case of normal functioning. This variation is caused by pump's pressure and flow difference. By measuring temperature is possible to detect possible malfunctions that may appear in reality, and to localize them easy. In these conditions the repair time becomes shorter by eliminating the searching period used in maintaining activity. By constant observation, it is possible to predict a major malfunction that would require replacement of some system parts.

The suggested method was validated and the results obtained will be implemented into a programming platform.

The goal is to use this method to diagnose almost all of the hydraulic systems from industrial installations. For this purpose an advanced infrared thermometer system will be used to create on-line thermal pictures of the whole installation. The developed program will be able to detect and to warn the human user about all the faults detected in the installation.

Moreover, we can extend this study in order to detect malfunctioning from complex industrial installations with networks of infrared systems and computers. Using such a malfunctioning detection network only one human supervisor will be necessary for the whole factory.

REFERENCES

[1] Predincea, N., Bălan, E., Ghionea, A., Străjescu, E., Ghinea, M., Pupăză, C., Drăghici, M., Gândilă, S., Moraru, G. (2002). *Procedee de prelucrare prin aşchiere*, Edit. Bren, Bucharest, ISBN 973-9493-39-4.

[2] Oprean, A., Dorin, Al., Olaru, A., Prodan, D., Chirițoiu, R. (1998). *Echipamente hidraulice de acționare*, Edit. Bren, Bucureşti, ISBN 973-98652-2-4.

[3] Prodan, D. (2003). *Maşini-unelte. Elemente şi sisteme de ungere*, Edit. Printech, Bucharest, ISBN 973-652-842-1.

[4] Prodan, D. (2002). *Acționări hidraulice. Elemente, subsisteme, sisteme*, Edit. Printech, Bucharest, ISBN 973-000-000.

[5] Prodan, D., Ghionea, A., Iacob, R., Dobrescu, T. (2004). *Remanufacturing of hydraulic installations from specialized machine tools*, Machine-Building and Technosphere XI, Donetsk, Ukraine.

[6] Prodan, D., Iacob, R., Dobrescu, T. (2005). *Experimental and theoretical research regarding the achievement of geometrical corrections on heavy machine-tools by means of hydrostatic systems*, Machine-Building and Technosphere XII, Donetsk, Ukraine.

[7] Prodan, D., Iacob, R., Savancea, M. (2004). *The cross-rail counterbalance for heavy machine-tools*, Buletinul Ştiințific al Universității “Politehnica”, Bucharest, vol. 66, nos. 2–4.

[8] Dogariu, C., Cristescu, C. (2002). *Dynamic behavior research of the 4 MN hydraulic press in the pressing phase*, International Conference on Manufacturing Systems, Bucharest, 7–8 October, Romania.

[9] Marin, D., Predincea, N. (2004). *Circular contour errors and distortions in high speed machining*, International Conference on Manufacturing Systems, Bucharest, 7–8 October, Romania.

[10] Prodan, D., Bălan, E., Gândilă, S. (2004). *The calculation method of the point of functioning of the hydraulic system*, International Conference on Manufacturing Systems, Bucharest, 7–8 October, Romania.

[11] Guibert, Ph. (1991). *Hydraulique industrielle appliquee*, Universite de Metz U.F.R., Metz, France.

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