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Noise and vibration of self-adjust valve caused by hydrodynamic force

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ABSTRACT

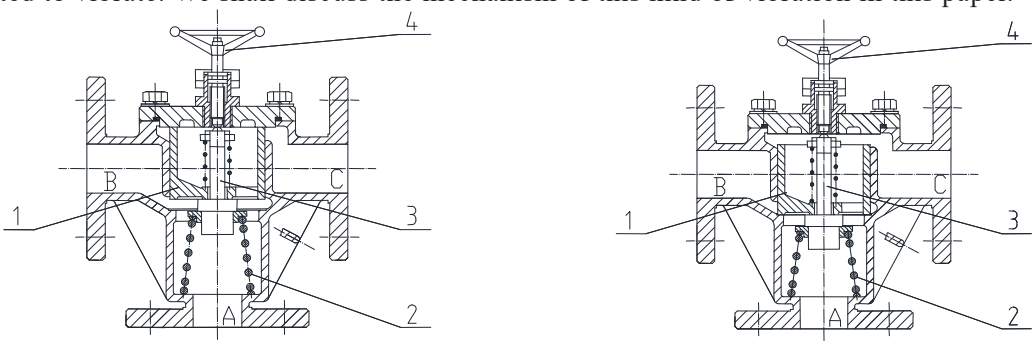
Liquid vibration is the source of duct noise and is main reason of pipe connector to be loosen and leaking out working medium from the connector also. Besides machine linked to the pipe line, valve in the pipe line is also one kind of vibration source to the pipe line because liquid passing through the valve can cause valve to vibrate and radiate noise. Thermostat control valve is a kind of self-adjust valve used in oil pipe line for protecting machines. To control the oil temperature in selected range the thermostat control valve can adjust the oil flows to the heating branch pipe and cooling branch pipe as the oil temperature is changed. But when it adjusts flow of oil, vibration and noise will be taken place in the valve. And this kind of liquid vibration may damage the thermal rod of the thermostat control valve. The mechanism of how this kind of valve liquid vibration taken place will be shown in this paper. Some of suggestion about decreasing or avoiding this kind of vibration on the oil pipe line will be given in this paper based on the conclusion of investigation.

Keywords: Valve, Vibration, Noise, Pipe line, Temperature

1. INTRODUCTION

Oil can deduce the friction between moving parts of the machine. It can clean the parts of machine and cool down the temperature of machine. Oil not only should be easy to flow for cleaning and cooling down but also has ability to adhere to the surface of machine parts as oil film to protect the machine parts from friction. It is not allowed that the temperature of oil gets too low or too high. If the oil temperature were to be too low, oil might be difficult to flow because of the high viscosity of oil. Because the lower the temperature is the higher the viscosity of oil is. If the oil temperature were to be too high, oil film on machine part surfaces might be easy to be destroyed and the machine parts might be damaged by friction. So there are auxiliary cooling equipment and heating equipment in the oil system. The thermostat control valve in the oil system can play an important role to decide cooling or heating the oil automatically according to the practical oil temperature.

The key part of thermostat control valve is a slide valve 1 linked with the thermal rod 3, as shown in figure 1. To control the oil temperature of channel A, the slide valve could be moved up or down by thermal rod and pre-pressed spring 2. Expanding with heat and contracting with cold of thermal rod and push-back of the spring can decide the place of the slide valve to adjust the opening degrees of heating channel B and cooling channel C for heating oil when oil is cold or cooling oil when oil is hot. But at the beginning of change state from heating to cooling, valve and pipe near the valve may often be excited to vibrate. We shall discuss the mechanism of this kind of vibration in this paper.



a) At full heating position b) At full cooling position

Figure 1 - Sketch of thermostat control valve

Many investigators have studied the objector of vibration and noise from valve and pipeline. Sun Danfeng *et al.* (1) have investigated the pipe line resonance property with flow. The result shows that natural frequency of the pipe line would increase slightly because of the action of fluid-structure interaction. Liu Li *et al.* (2) have developed mechanism of pipe line vibration caused by flow and found that the main excitation is the plus from fluid behind the valve. Fang Chao *et al.* (3) have studied the sea valve noise caused by flow and compared the quantity of flow noise to that of vibration noise induced by flow. They described the reason of sea valve noise based on the principle of sound generation. Chen Guiqing *et al.* (4) have investigated the relationship between parameters of flow in the pipe and vibration of the pipe. He obtained the conclusion that pipe vibration is linked with the velocity of flow in the pipe directly. Yin Jianwu *et al.* (5) have finished some experiments about control air pipe vibration and developed some methods about deducing air column impulse, optimal designing pipe line and deducing vibration by balance. In order to investigate the phenomena of valve dynamic property, Lu Liang *et al.* (6) have shown some examples and methods about watching, measurement and simulation. All of above studies describe a fact that the main excitation of valve vibration is flow which passing through it because of the relaxation property of fluid. But there is different valve vibration characteristic excited by flow to different valves. If you want to control the valve vibration noise you must take a special analysis to the particular valve. The best way to control vibration noise is deal with the vibration noise source based on the mechanism of vibration noise generation. In this paper, we shall analysis the mechanism of thermostat control valve noise in the oil system and give some suggestions based on the analysis.

2. How the thermostat control valve controls the oil temperature and when the noise is obvious detected

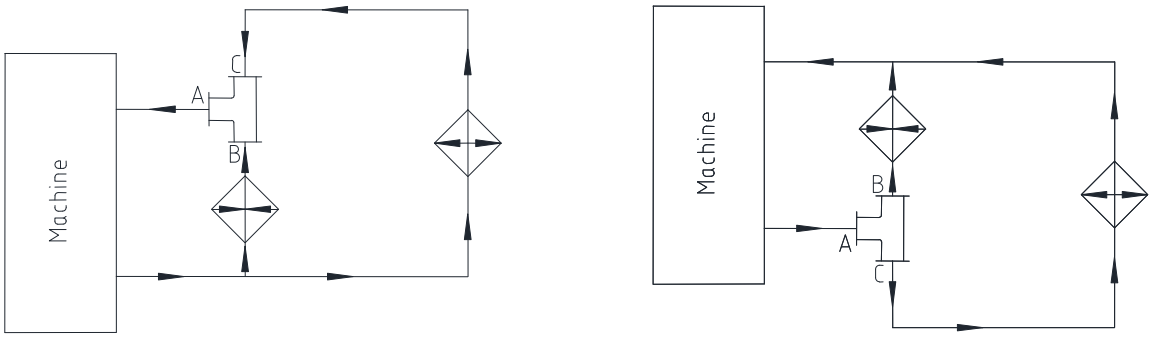
The key part of thermostat control valve is a slid valve component, as shown in figure 1. The component consisted of slide valve 1 and thermal rod 3 is touched with compressed spring 2 and the hand adjusting shank 4. When the oil temperature is lower and need to be heated, the thermal rod gets shorter because of low temperature. Then the slide valve moves to open the heating channel until full open and to close the cooling channel until close off with the spring stretching, as shown in figure 1 a). When the oil temperature is higher and need to be cooled. The thermal rod gets longer because of high temperature and the spring is compressed. Then the slide valve moves to open the cooling channel until full open and to close the heating channel until close off, as shown in figure 1 b). If the thermal rod fails in function, the hand adjusting shank can be turned to adjust the position of the slide valve to control the oil temperature.

When oil system which serves for machine starts to work, the oil temperature is lower in general, so the heating channel of the thermostat valve is always full opened and cooling channel is closed. After machine and oil system running for a while, as the oil temperature gets higher, the heating channel will be closed little by little and cooling channel will be opened little by little. At that time when channels start to change, an obvious vibration noise would appear at the thermostat control valve and the pipe near the thermostat control valve. But as the time goes by, the vibration noise would disappear. This kind of vibration noise is harmful to the safety and reliability of operation of oil system. The reason of this vibration noise generation must be investigated and the phenomenon should be avoided as far as possible.

3. Investigation

3.1 Forces on the slide valve

When thermostat control valve adjusts the oil temperature by moving slide valve there are three forces on the slide valve: Spring force F_S of spring, thermal force F_T of thermal rod caused by expanding with heat and contracting with cold and hydrodynamic force F_H of oil flow. The thermostat control valve can be used in oil system in two ways, shown in figure 2. One is confluence type, as shown in figure 2 a). This type is fit to control the input oil temperature of machine. The other is shunt type, as shown in figure 2 b). This type is fit to control the output oil temperature of machine.



a) Confluence type b) Shunt type

Figure 2 - How to apply thermostat control valve

Linked with sketch of thermostat control valve, figure 1, the spring force F_S always tends to close the cooling channel. But the direction of thermal force F_T is always opposite to that of spring force. Either in confluence type or shunt type, spring force and thermal force can't make thermostat control valve vibrate because these forces are all semi-static force, their quantities can only change very slowly. The excitation must be fluctuating hydrodynamic force F_H.

3.2 Mechanism of self-excited vibration of thermostat valve

According to the Bernoulli equation, formula (1) (regardless of the difference of highness), pressure P will be changed by the variation of velocity v of flow. When opening area of channel is increased, the resistance of flow would be decreased, the velocity of flow would be increased and the pressure of fluid would be decreased; but when opening area of channel is decreased, the resistance of flow would be increased, the velocity of flow would be decreased and the pressure of fluid would be increased.

$$P_0 = P + \frac{1}{2}\rho v^2 \tag{1}$$

After machine start to work for a while, the temperature of oil will be increased, the thermal rod will be extended and the spring will be compressed more. So the slide valve would be moved to open cooling channel and to close heating channel for decreasing the oil temperature. When opening area of cooling channel is increased then opening area of heating channel is decreased, the velocity of cooling channel would be increased and the pressure would be decreased but the velocity of heating channel would be decreased and pressure would be increased. The sum of hydrodynamic force generated by changing opening areas of channels would tend to decrease cooling channel opening area and increase heating channel opening area. If cooling channel opening area was decreased and heating channel opening area was increased, there would be a hydrodynamic force on the valve to change both two channel opening areas in opposite direction. It will cause the valve to vibrate that the hydrodynamic force opposite the direction of movement of slide valve is forced to the valve continuously. In the same way, if the oil temperature was decreased, the slide valve would be forced to vibrate by the hydrodynamic force which is tended to the opposite direction of movement of slide valve. When the slide valve is forced to vibrate, the oil pressure will be fluctuated. The pipe line noise would be generated by the slide valve vibration and oil pressure fluctuation. The thermal rod linked with the slide valve would be damaged because of fatigue and lose effectiveness early by this kind of vibration.

Based on the characteristic curve of thermostat valve (7), as shown in figure 3, for the same quantity change of flow, the larger the original flow is, the higher the change of oil pressure is. So when slide valve is at one of positions as figure 1, i.e. heating channel opening area starts to be decreased from full open or cooling channel opening area starts to be decreased from full open, the hydrodynamic force on the slide valve will get the largest quantity. After machine starts to work for a while, the oil would be cooled from heating process as the oil temperature gets higher. So the heating channel open area would be decreased from full open state and the vibration would be taken place intensely. After the oil system continuous works for a while, the phenomena of vibration would get weekly as the oil temperature gets lower and the quantity of flow gets lower with the heating channel

area gets smaller. Because oil system can't be allowed to work in setting highest temperature, cooling channel open area can't get full open position, as shown in figure 1 b). So intensely vibration will not take place when oil system turn to heat from full cooling state. It just takes place when oil system turn to cool from full heating state.

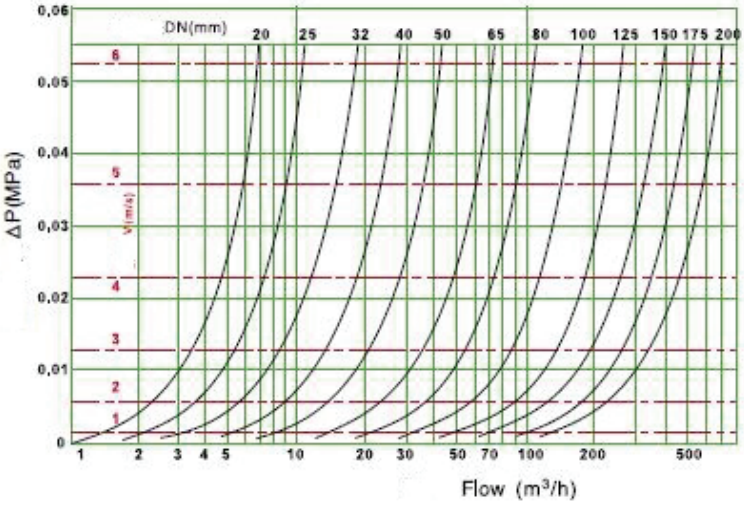


Figure 3 - Flow and pressure difference characteristic curve of thermostat valve

Based on the above outline we can know that the self vibration will be taken place on the slide valve caused by variable hydrodynamic force when the slide valve is moved to change the channel open area. Heavy noise and vibration will be excited on the oil system pipe line and thermostat valve by the vibration of slide valve.

4. Conclusion and improvement

Due to the property that change of velocity is opposite to the change of pressure in the fluid. Self excited vibration may easily be taken place on the valve when its channel opening area is changed. Because of the randomness of this kind self excited vibration, it is difficult to predict at the design stage. In this paper, based on the hydrodynamics basic principle, we have outlined the mechanism of known self excited vibration of thermostat valve which key part is a slide valve. According to the flow and pressure variation characteristic of this thermostat valve, the result of analyze is fit as same as the practical phenomenon.

It is not very difficult to solve this self excited vibration problem based on the flow and pressure variation characteristic of the thermostat valve. Because this vibration noise phenomenon is often taken place at the moment of channel opening area starting to be decreased from full open. If this procedure can be passed quickly by hand the obvious vibration noise would be avoided. It is the suggestion that turn the hand adjusting shank of thermostat valve when the heating channel opening area starts to be decreased. Let the procedure of closing heating channel and opening cooling channel pass the time of intense vibration noise quickly.

REFERENCES

1. Sun Danfeng, Ma Yongmei, Feng Chengde, Sun Sizhong. Analysis on the Natural frequency and resonance vibration for pneumatic conveying, Machine Design and Manufacturing Engineering, 2015;10: 7-10.
2. Liu Li,Zhang Xiaobin, Qiu Limin, Mechanism of valve-induced vibration in a gas pipeline with large flow rate, Cryo Engineering, 2016;4: 50-55.
3. Fang Chao, Ma Shihu, Cai Biaohua, Yu Jian. Numerical Simulation Contrastive study on flow noise and flow induced vibration noise of sea valve based on BEM, Ship Science and Technology, 2018;3: 30-34.
4. Chen Guiqing, Hao Tingyue, Qi Zhendang, Influence of Physical Parameters on Vibrating Natural Frequency of Pressure Pipeline, Journal of Tangshan College,2005; 4: 96-99.
5. Yi Jianwu, Yang Weiqun, Yuan Qinglu, E Weibo, Vibration Cause and Anti-vibration Method of Gas

Piping of a Compressor, Compressor Technology, 2002; 4: 38-39.
6. Lu Liang, He Chengpeng, Introduction of Representative Flow Oscillations and Experiment Visualization Methods in Hydraulic Valves, Chinese Hydraulics & Pneumatics, 2018;4: 1-7.
7. Nanjing TP Thermal Engineering Co., Ltd. (2015) Temperature Control Thermal Valve and Valve Core. [Online.] available: http://www.cn-ntec.com/db/productshow.asp?id=9