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Analysis on hydraulic clamping fault diagnosis and countermeasures

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ABSTRACT

The hydraulic clamping faults frequently occur during the operation of hydraulic equipment system. Through comprehensive analysis, the causes of the hydraulic clamping faults are various. Therefore, the essay focuses on the hydraulic clamping fault diagnosis and then proposes countermeasures.

KEYWORDS

Hydraulic clamping; Fault; Countermeasure.

INTRODUCTION

In the hydraulic system, liquid passes through the clearance between valve core and valve body. When the force on the valve core is unbalanced, the valve core will be clamped, which causes hydraulic clamping faults. If different hydraulic steering valves in the hydraulic system occur the hydraulic clamping fault, the imbalance of radial force may cause the friction force from the movement of valve cores is increased, which leads to the system operation is delayed and the automatic circulation system malfunctions. When the problem gets worse, the service life of equipment will be reduced, and the system may be paralyzed and the operation may be blocked. Therefore, when hydraulic clamping faults occur, it is necessary to diagnose the causes and find out countermeasures. This essay focuses on the causes of hydraulic clamping faults in actual manufacturing process and common countermeasures.

THE DEFINITION OF HYDRAULIC CLAMPING

The hydraulic clamping refers to the clamping caused by pressure imbalance in the clearance of piston or spool. The unbalanced pressure laterally pushes the piston, leading to the block of the friction of axial movement. Hydraulic components are generally cylindrical rotary piston structure, and in theory Valve core and valve body should be totally concentric. Therefore, no matter how large the pressure is, the force required to move the spool should just overcome the viscous friction, with a small numerical value (0.5～5N). However, the actual circumstance is quite different, especially in the high-voltage systems, when the valve core stops to operate for a period time (average 5 min); the resistance can reach hundreds of N, which makes the movement of valve core very hard. That is so-called the hydraulic clamping of spool valve.

The hydraulic clamping in the hydraulic system increases the degree of wear of spool valve and reduces the service life of hydraulic equipment. In the control system, the movement of valve cores needs electro-magnets and springs that have smaller force. When the valve core gets blocked by the hydraulic clamping, it will exert negative impact on the system operation. For example, the valve core of compression release valve keeps working under high pressure, there will be reset time delay or reset failure after the distressing. The solenoid directional control valve may have slow reversing switch because of the hydraulic clamping, even has switch failures.

FACTORS THAT RESTRICT THE OPERATION OF HYDRAULIC CLAMPING SYSTEM

Radial imbalance mainly effects the hydraulic system

In general, the radial imbalance may cause by the concentricity error and the spool shape error. It means that when the liquid passes through the cone of eccentric annular clearance under the high pressure and the clearance will dilate with the direction of fluid flow, the hydraulic clamping occurs. The factors causing the radial imbalance will be explained below:

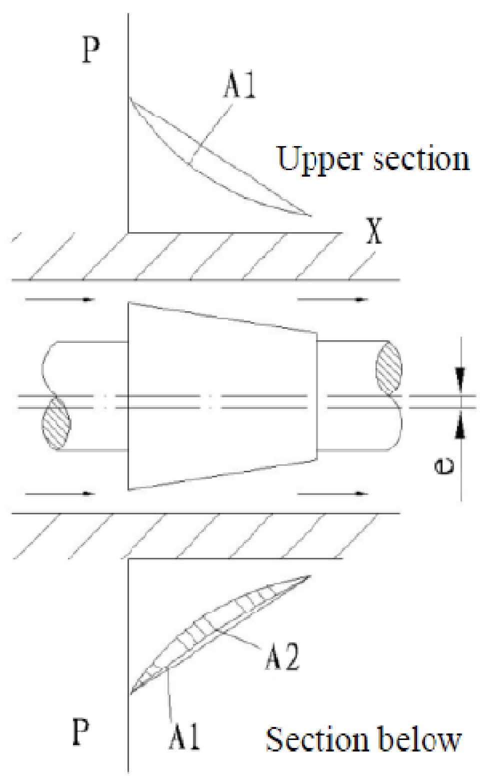

Figure 1: hydraulic clamping caused by form and position errors

First, there is no geometry errors between the hydraulic valve hole and hydraulic spool valve. However, the spool valve may be skewed in the hole during the assembly of hydraulic system, or external particles enter into the clearance of spool valve, making the spool valve skewed. All these may cause a great radial imbalance in the hydraulic system or the torque.

Second, during the manufacturing process of valve core, there are different errors. Under the unbalanced radial force (as is shown in the shadow part of curve chart A1 and A2), the deviation range between the valve core and valve hole becomes wider. When their surfaces touch each other, the hydraulic clamping occurs. In this time, the unbalance radial force reaches the maximum and the dry friction occurs too.

The hydraulic clamping caused by machining quality

First, the sharp edge of valve core may be damaged during the machining process or the hydraulic operation transfer. After being damaged, parts of valve core may show bulges in different degree and there is a relatively obvious pressure drop. Under this circumstance, there must be a torque that distributes pressure from the bulge to the valve hole.

Second, during the design of the hydraulic system, some ring grooves will be set above the valve core in order to reduce the pressure of the radial imbalance. However, the ring groove should be processed before its heat treatment, so various deformation will occur during the precision machining on valve cores, which may cause the big errors in ring grooves. (shown in Figure 2).

Third, as for the diversion valve that has combined multiple sections, there often are graphic errors and bulge damages on its combined surface. Or the hydraulic valve hole may be deformed because of overweighed preload of bolt in the hydraulic system. Then the hydraulic clamping occurs.

Forth, when the manual steering valve is used, under the influence of steering valve structure, the valve core and valve hole is long, which is subject to being impacted by the remnants of the residual stress to make the valve core skewed and parts of shoulders deviated. There will be a large contact stress between the valve hole and valve core. During the movement of the valve core, there will be a large friction and a serious blocking. Then the hydraulic clamping occurs

Fifth, when the gap between the valve hole and valve core is large and the geometric tolerances have serious errors, the pressure will penetrate into the clearance causing radial imbalance. Then the movement of valve core is hard. In the meantime, molecules in the oil have polarity. When the smooth metal surface gets contact with the oil, these polar molecules will vertically align by their long axis and metal performance. After aligning layer by layer, the further the molecules are away from the metal surface, the more disordered their align will be. In the end, they will be close to the liquid state. Once a lateral push force occurs, the slide valve and the hole wall is squeezed together. The flowing liquid on both surface will be squeezed out until polarized molecules are attracted by each other with slide valve attaching on the hole wall. Then the resistance to axial movement of the spool valve is dramatically increased. It significantly increases the resistance to start of spool valve.

Sixth, when the perpendicularity error between the valve shoulder and the axis of the spool line is large, the rotation of valve core is influenced by the torque. If the valve core and valve hole cooperate and their gap is small, there will be a large tolerance, during which the rotation of valve core is more likely to block. (shown in Figure 3)

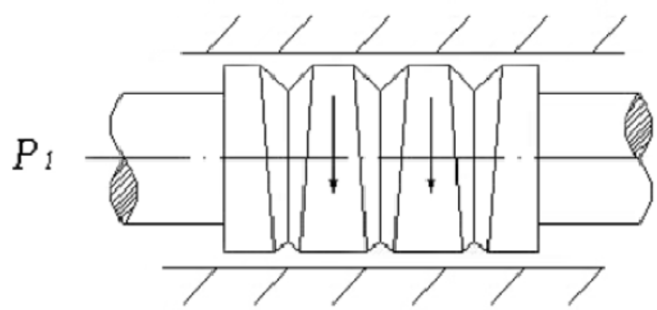

Figure 2 : Different shades of ring grooves

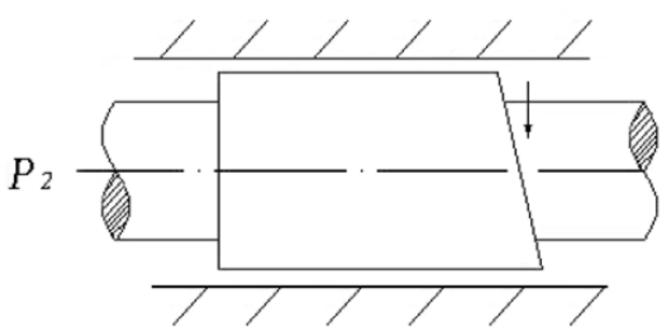

Figure 3 : Valve core shoulder errors

Other causes for the hydraulic clamping

First, under the high pressure, after the oil temperature rises, there will be an obvious distinction in the expansion coefficient between the valve core and valve hole.

Second, in general, the electromagnets push rods on dry-type solenoid valve use dynamic seals. There is a large resistance when the system friction occurs. At the same time, there are center bores between these two endpoints of valve cores, where some kinds of tilt occur too. It will reduce the response rate of the rotation of valve cores.

Third, generally speaking, many hydraulic components have varying degrees of disclosure. If the disclosures don’t have tunnels or tunnels have a small size, the oil return of hydraulic components will produce a certain amount of resistance, which causes oil return failures and reduces the response rate of the rotation of valve cores.

COUNTERMEASURES FOR HYDRAULIC CLAMPING

To improve the assembling of mechanical equipment and processing quality

First, when the hydraulic system is in progress, the distortion that generates during the heat treatment should be reduced as much as possible. These generally small valve cores use the steel 20Cr. So after the heat treatment, it is less likely to distort, and it can ensure the valve core will not distort for a long time.

Second, in general, that valve cores have more holes in the center is the process benchmarking in many processing procedures. Therefore, after the heat treatment of valve cores and before the precision machining, valve cores should be polished and trimmed. It helps get a smaller shape and position tolerance, and the surface quality can be guaranteed as well.

Third, during the machining of valve cores, the machining accuracy of valve cores and valve holes should gain more attention during the precision machining, when the center hole and spool valve core should not be ignored. For example, the center hole of shaft parts is the process benchmarking in all procedures including vehicle processing. The valve components have higher requirements for surface finish and geometric accuracy, so the center hole machining should attract attention. Because valve components are relatively small, the center hole can be drilled out by a compound center drill with 120 ° protective taper. After the heat treatment, the center hole may distort, or the process benchmarks may be damaged because of oxide layer on center hole surface and residual salt impurities. Therefore, before the precision machining, a careful calibration should be done first. So far, the calibration includes manual grinding, carbide top lapping and grinding by forming grinding wheels on special machine tools.

Forth, before the precision machining of valve components, the burrs on surface should be carefully eliminated, and the sharp edges should be blunted. In the processing, there should not be chamfer and rounding behavior. If it is over processed, the axial dimension may be impacted.

Fifth, when the valve hole is under precision repair, the grinding techniques are always used. When valve holes are processed in bulk, the diamond can be used in the reamer processing, which can effectively improve the shape and position tolerances and the precision of valve holes.

Sixth, different interfaces should be reinforced by different screws. When we exert force on the screws, it should ensure that the force is exerted evenly to avoid too large preload on the compound bolts.

Seventh, the process of hydraulic system assembly should be carried out in accordance of the procedure. Before the assembly, all components should be cleaned up. During the cleaning, they cannot be wiped by staple fiber such as cotton fabric, which may bring fabric into components and cause system contamination. Meanwhile, during the preparation, the size of different accessories and tolerances on dimensions and shape should be measured. The porosity will be selected depending on the actual sizes. It is forbidden to use hard metals to beat components and it should avoid napping collision.

Eighth, the precision of valve hole and valve core in the processing should be strictly measured. In general, the roundness and cylindricity of valve cores should be controlled in the context of 0.003mm.

To open an annular pressure groove above the spool valve

An annular pressure groove should be opened above the spool valve. The advantages of annular pressure groove can be seen from the Figure 4. Without an annular pressure groove, the area of unbalanced radial force is like the one between A1 and A2. After the completion of an annular pressure groove, the pressure in P1 and P2 will be effectively divided, turning the area of unbalanced radial force into the shadow one between B1 and B2. It is obvious that the unbalanced radial force decreases.

To make the valve core and valve body vibrate to reduce the control force

Currently in close hydraulic system, the circumferential motion of the valve core and valve cover or the axial reciprocating motion is widely used, which is the vibration as we usually call it. General vibration frequency is in 20-100Hz and the amplitude is in 0.1-0.3mm. By vibration and rotation, 20-25 times resistance can be reduced and the control force can be decreased too. Many experiments have confirmed that the consistent rotation of the valve core and valve cover is more effective. In the hydraulic pressure servo mechanism with more complex structure and higher sensitivity, the electromagnetic or mechanical offset slider is usually adopted for the valve core vibration, which is more effective.

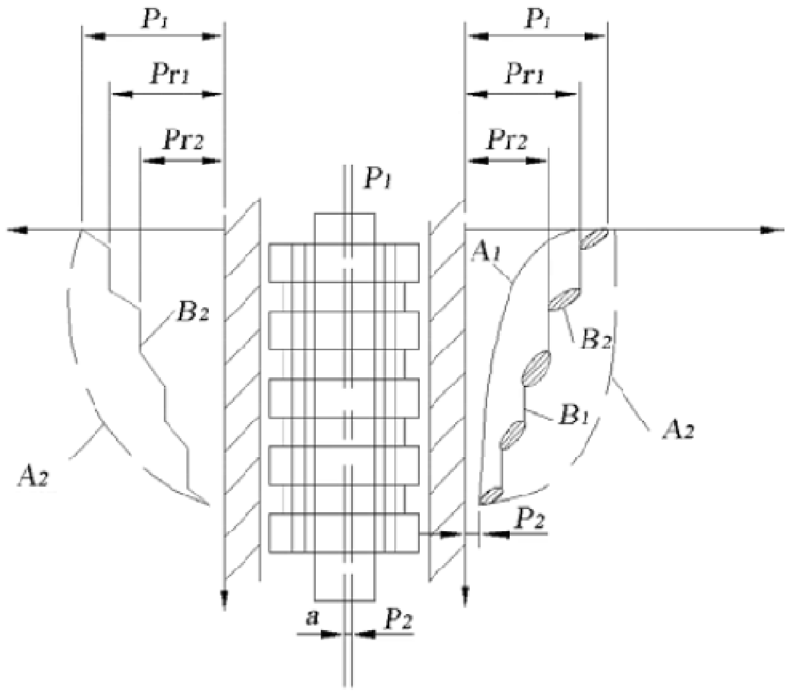

Figure 4: Annular pressure groove

The maintenance of hydraulic system equipment

The maintenance of hydraulic system equipment is essential. During the maintenance, all regulations should be implemented strictly, with no illegal operation or relaxed mood. It should be treated with cares, especially in the hydraulic system operation, the cleanliness of the hydraulic system should be ensured and the hydraulic oil contamination should be avoided. During the hydraulic oil filter, the numerical values should be within 0.01mm.

Improvement of design methods

First, during the design, when we put the radial pressure groove on the valve cores' shoulders, the slot location should be considered first and the closeness to the high-voltage side, groove width, depth and spacing of slots must be considered too. In the meantime, both sides of the oil groove should be vertical to the hole wall, and there is no chamfers in the intersection with the sliding surface of the valve. It can avoid impurities penetrating into gaps, can maintain tank pressure equal and can reduce the side thrust of hydraulic clamping. Two oil grooves can have a significant effect, but three or more grooves cannot increase the effect.

Second, in the manufacturing process of hydraulic valve cores, it should be aware of making parts of them tapered, turning smaller ports facing the high-voltage side and larger ports facing the low-voltage side, with diameter difference of 1~3μm. At this time, the valve core can adjust itself to the central valve hole, which can reduce unbalanced radial force. This process is more complicated and needs more cautions in the processing.

SAMPLE ANALYSIS

During the control valve assembly, the response rate of the rotation of valve core is high. However, when it is connected with the control panel, the valve core is stuck in the valve hole. According to analysis, we can explain this kind of hydraulic clamping failure in several ways as followed.

First, during the installation of the valve body, the focal point of mounting holes is larger than the central line location of the valve hole (shown in Figure 5). When the screws are installed, the valve hole deforms in varying degrees.

Second, the smoothness of the intersection between the control panels of the hydraulic system and the valve body is not high. The pre-compression of o-type sealing ring values are too large. When the screws are installed, the valve hole deforms in varying degrees.

Based on the hydraulic clamping, we can adopt several countermeasures as followed.

First, the focal point of valve body mounting holes of control panels can be installed under the valve hole center line (shown in Figure 6).

Second, the intersection between the valve body and the control panels should be maintained carefully, controlling their flatness as 100:1; the surface roughness should be met the equation as Ra=0.4.

The valve hole will not deform after being processed by these countermeasures above and the rotation of the valve core will be good. The hydraulic clamping can be avoid generally, and the system can operate normally.

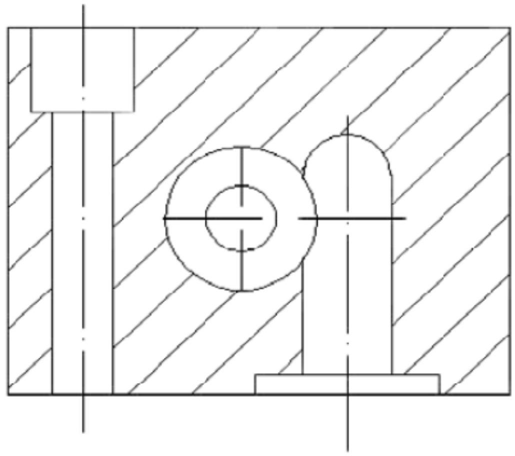

Figure 5 : Valve body under hydraulic clamping

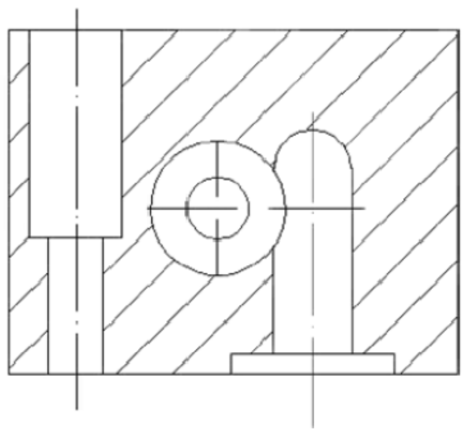

Figure 6: Revised valve body

CONCLUSION

There are various countermeasures to deal with hydraulic clamping in actual examples, so we should tackle the problem flexibly in accordance with the actual situation. Although the hydraulic clamping in the hydraulic system caused by the hydraulic directional control valve is general, this problem is not exclusive to directional control valves, but also to hydraulic valves. When the hydraulic clamping occurs, we should be calm. As long as we find out its causes and resort to right techniques to effectively control the gap, unbalanced radial force and eccentricity, the hydraulic clamping will be fixed. The effective solution of hydraulic clamping, spool valve wear, motion lag and failure can avoid series of security incidents.

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