ORIGINAL RESEARCH ARTICLE

Design and Realization of Hydraulic Cylinder

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ABSTRACT

A device that converts hydraulic energy from a hydraulic cylinder to mechanical energy is known as actuator. The actuator is a direct performer, and has the opposite role of the hydraulic pump from the point of view of energy conversion. According to principle of energy conversion, the actuators can be divided into three types: hydraulic motors, hydraulic cylinders, and swing hydraulic motor (also called swing hydraulic cylinder). The hydraulic motor is a hydraulic actuator that continuously rotates and outputs torque; and the hydraulic cylinder is a hydraulic actuator for reciprocating linear motion and output. This manual is of the hydraulic cylinder working environment and requirements to determine the pressure of the hydraulic cylinder, carrying capacity which determine the cylinder diameter, wall thickness and piston rod diameter. The process of parts is determined based on the requirements of the hydraulic cylinder parts. Based on the precision requirements of parts, the processing method is determined and is used in the making of process cards to complete the processing of parts.

KEYWORDS: hydraulic cylinder, mechanical energy, torque, actuator

1. Introduction

Hydraulic transmission is a discipline that studies the fluid pressure (liquid) as a transmission medium to achieve a variety of mechanical transmission controls. Hydraulic transmission is based on the basic principles of fluid mechanics, where fluid pressure is used in energy transfer and movement control of various mechanical parts.

At present, hydraulic technology has been widely used in a variety of applications, such as machinery manufacturing, engineering, construction, mining, metallurgy, ships and other machinery from the industries of aviation, aerospace, mining, to marine minerals and mining development. The applications of hydraulic technology are summarized as follows:

(1) A variety of lifting and handling tasks. Hydraulic transmission has become a major method especially in the operating machinery that requires large driving powder, such as cranes, windlass and etc.

(2) Devices that performs the various tasks such as pushing, squeezing, and excavating, where a large amount of forces is required. For examples, vatious hydraulic machines and plastic injection molding machines.

(3) Controls of high precision and responsiveness.. Attitude control devices of aircrafts and missiles and etc.

(4) Automatic operation and control of a combination of several work programs such as combined machine tooling and automatic machining line.

(5) Special working places such as underwater and explosion.

2. Execution Elements for Hydraulic Drives

2.1. Type and structure of hydraulic cylinders

There are many types of hydraulic cylinders. According to the action can be divided into single-action and double-acting two; according to the structure can be divided into piston, plunger, modular and swing four categories.

Among them, single-acting hydraulic cylinders are divided into: single piston rod hydraulic cylinder, double piston rod hydraulic cylinder, plunger hydraulic cylinder, differential hydraulic cylinder and telescopic hydraulic cylinder.

However, differential hydraulic cylinders and plunger cylinders can only act independently. Combined hydraulic cylinders include: spring return type, rack type, series type and boost type four. Swing hydraulic cylinders are divided into: single-leaf and double-leaf two. Using a typical hydraulic cylinder as an example, the basic components of a hydraulic cylinder is shown as the following figure.

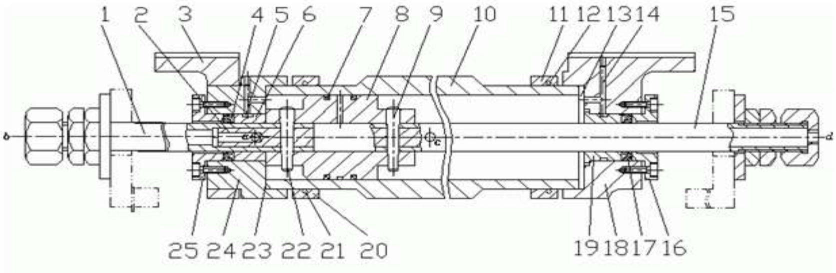


Figure 2-1 Hollow Piston Hydraulic Cylinder Structure

1,15-piston rod 2-plug 3-bracket 4,7,17-seal 5-vent 6-lead sleeve 8-piston 9-taper pin 10-cylinder 11-plate 12-wire ring 13 , 23-paper pad 14-vent 16, 25-gland

18, 24 - cylinder head 19 - guide sleeve 20 - press plate 21 - wire ring 22 - taper pin

The hollow piston hydraulic cylinder is shown in Figure 2-1 above. It consists of cylinder block 10, piston 8, piston rod 1, 15, cylinder head 18, 24, sealing ring 4,7,17, guide sleeve 6,19, pressure plate 11,20 and other major components. This hydraulic cylinder piston rod is fixed, the cylinder drive the table for reciprocating motion. The piston is connected to the hollow piston rod by means of taper pins 9, 22 and the plug 2 is used to block one end of the piston rod. The outer ends of the cylinders are provided with steel wire rings 12, 21 for preventing the press plates 11, 20 from moving outwardly so as to connect the cylinder heads 18, 24 to the press plate by means of bolts (not shown) Pressed at both ends of the cylinder. In order to reduce the leakage, in the hydraulic cylinder may occur in the leakage of the joint surface of the seal and paper pad. The hollow piston rod and the oil port a, c provide the inlet and outlet ports of the hydraulic cylinder. When the cylinder moves to the left and right terminals, the opening degrees of the ports a and c are gradually reduced, resulting in the gradual increase of the oil return resistance and the braking cushioning effect on the moving parts. The cylinder head is provided with exhaust holes 5, 14 which are connected to the exhaust valve (not shown), and the air in the hydraulic cylinder can be discharged to make the movement more stable.

2.2. The composition of the hydraulic cylinder

From the above hydraulic cylinder structure can be seen: hydraulic cylinder can be divided into cylinder components, piston components, sealing devices, buffer devices and exhaust device five parts.

(1) Cylinder block

The cylinder assembly consists of a cylinder and a cylinder head. The connection of the cylinder and the cylinder head is related to its working pressure. When the working pressure p <10MPa, the use of cast iron cylinder; working pressure p <20MPa, the cylinder using seamless steel pipe; working pressure p> 20MPa, the use of cast steel or forged steel. The following are several common forms of cylinder and cylinder head connection:

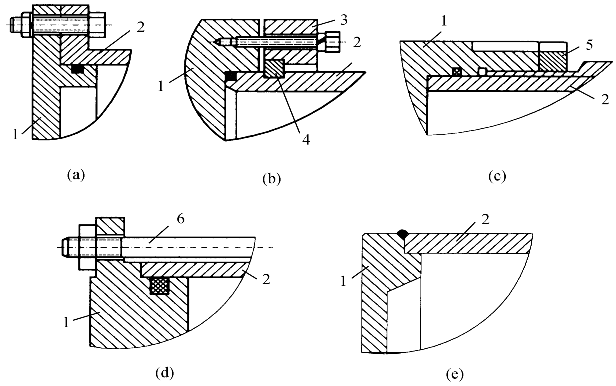


Figure 2-2 cylinder and cylinder head construction

(A) Flanged connection (b) Semi-loop connection (c) Threaded connection (d) Tie rod connection (e) Welded connection

Figure 2-2 (a) shows the flange connection, simple structure, easy processing, but also easy assembly and disassembly, but the size and weight are larger, commonly used in cast iron cylinder. Figure 2-2 (b) shows the half-ring connection, and its cylinder wall due to open the ring groove and weaken the strength, which sometimes thicker cylinder wall, it is easy to process and dismantling, lighter weight, Commonly used in seamless steel pipe or forged steel cylinder. Figure 2-2 (c) shows the threaded connection, and its cylinder end structure is complex, the outer diameter processing to ensure that the inner and outer diameter concentric, assembly and use to use special tools, its size and weight are smaller, Commonly used in seamless steel pipe or cast steel cylinder. Figure 2-2 (d) shows the rod connection, the structure of the versatility, easy processing and assembly and disassembly, but the larger size, and heavier. Figure 2-2 (e) shows the welded connection, simple structure, small size, but the cylinder bottom diameter is not easy to process, and may cause deformation.

It can be seen that the cylinder material generally requires sufficient strength and impact toughness, the welding of the cylinder, also requires a good welding performance.

In order to maximize the user to meet the needs of product performance and product design and economic and reasonable to ensure the safety of workers and equipment to improve the operator's working environment, Luoyang strong hydraulic Co., Ltd. produced by the cylinder blanks selected by the professional The factory has been provided within the circle has been drilling and cylindrical processing of high-precision cold drawn seamless steel pipe, to meet the following requirements:

A, cylinder diameter roundness and cylindrical degree can be selected 8.

B, the cylinder side of the vertical selection of 7-level accuracy.

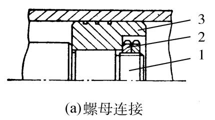
C, the end of the cylinder with a threaded connection, the thread should be selected 6 precision fine thread.

(2) Piston components

Piston components are piston, piston rods and connectors and other components, piston and piston rod connection depends on the working pressure, installation, working conditions and so on.

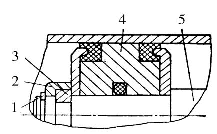
As the piston in the cylinder for reciprocating movement, must use high-quality materials. For the overall piston, the general use of 35 or 45 steel; assembly of the piston with gray cast iron, wear-resistant cast iron or aluminum alloy and other materials, special requirements can be installed in the steel piston outside the bronze, brass and Nylon and other wear-resistant sets to extend the life of the piston. Piston rods, whether hollow or solid, often use materials such as 35 or 45 steel, when the impact of vibration is large, can also be used 55 or 40Cr steel. Figure 2-3 shows the connection of several common piston and piston rods:

Figure 2-3 (a) shows the use of nuts between the piston and the piston rod connection, it is suitable for small load, non-impact hydraulic cylinder. Although the structure of threaded connection is simple, easy to install, but the thread on the piston rod will weaken its strength. Figure 2-3 (b) and (c) show the snap ring connection. In Figure 2-3 (b), the piston rod 5 is provided with an annular groove in which two semicircular rings 3 are fitted to clamp the piston 4, which is clamped by the sleeve 2 and the axial direction of the sleeve 2. The position is fixed with spring collar 1. The piston rods in Figures 2-3 (c) use two semicircular rings 4, which are respectively sandwiched by two sealing rings 2, and the semicircular piston 3 is placed in the middle of the seal seat. Figure 2-3 (d) shows a radial pin-type connection structure in which the piston 2 is fixed to the piston rod 3 by a taper pin 1. This connection is particularly suitable for dual-pole piston.



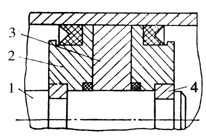
(a)螺母连接

1—活塞 2—螺母 3—活塞杆



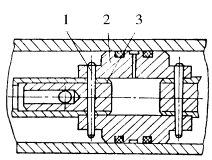
(b)卡环式连接

1—弹簧卡 2—轴套 3—半环 4—活塞 5—活塞杆



(c)卡环式连接

1—活塞杆 2—密封圈座 3—活塞 4—半环



(d)径向销式连接

1—锥销 2—活塞 3—活塞杆

Figure 2-3 Common piston assembly construction

(3) Sealing device

The sealing device is mainly used to prevent the leakage of hydraulic oil. Because the hydraulic cylinder is relying on the change of the volume of the sealed oil to transmit the power and speed, the advantages and disadvantages of the sealing device will directly affect the working performance of the hydraulic cylinder. According to the two need to seal between the coupling surface with or without relative movement, the seal can be divided into dynamic seal and static seal two categories. Design or selection of the basic requirements of the sealing device is: with good sealing performance, and with the increase in pressure can automatically improve its sealing performance, friction resistance, sealing oil resistance, good corrosion resistance, long life, the use of temperature Wide range, simple manufacturing, easy assembly and disassembly. Usually the hydraulic cylinder seal with a gap seal, piston ring seal, O-ring, Y-ring, V-ring and other sealing methods to prevent oil spills.

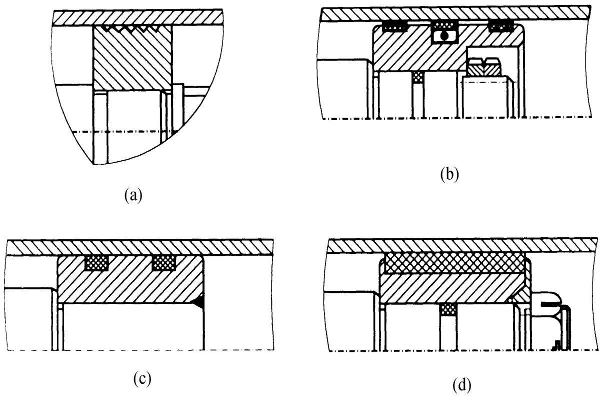


Figure 2-4 Sealing device

(A) Gap seal (b) Friction ring seal (c) ○ Ring seal (d) V-ring seal

The common sealing devices in the hydraulic cylinders are shown in Figure 2-4 above. Figure 2-4 (a) shows a gap seal that relies on a slight gap between the movements to prevent leakage. In order to improve the sealing capacity of such devices, often in the surface of the piston made several small annular groove, in order to increase the resistance of the oil through the gap. Its structure is simple, the friction resistance is small, can be high temperature, but the leakage is large, processing requirements are high, cannot restore the original capacity after wear and tear, only in the smaller size, lower pressure, relatively high speed cylinder and piston use. Figure 2-4 (b) shows the friction ring seal, it relies on the friction ring (nylon or other polymer material) mounted on the piston to close the cylinder wall under the action of the O-ring to prevent leakage. This material is better, the friction resistance is small and stable, can be high temperature, wear and tear after the automatic compensation capacity, but the processing requirements, loading and unloading more inconvenient, suitable for sealing between the cylinder and the piston. Figure 2-4 (c), Figure 2-4 (d) shows

Seal ring (O-ring, V-ring, etc.) seal, which uses rubber or plastic elasticity so that a variety of cross-section of the ring ring close to the static, moving between the surface to prevent leakage. It is simple in structure, easy to manufacture, wear after the automatic compensation, reliable performance, between the cylinder and the piston, between the cylinder head and piston rod, between the piston and piston rod, cylinder and cylinder head can be used between The

For the extension of the piston rod, because it is easy to bring dirt into the hydraulic cylinder, so that the oil contamination, so that the seal wear, so often in the piston rod seal to add a dust ring, and placed in the piston One end of the rod.

(4) Buffer device

When the moving parts drag the mass of the larger parts for reciprocating motion, the movement speed is high (v> 12m / min). The inertia force of the moving parts is larger, the piston movement to the terminal will be mechanical collision with the cylinder head, resulting in impact, noise, serious impact on the processing accuracy, and even cause destructive accidents. Therefore, the cushioning device should be provided at both ends of the hydraulic cylinder.

General buffer device consists of buffer plunger, buffer oil chamber, triangular throttle, check valve, throttle valve. Combination of the buffer with a cylindrical ring-shaped, conical ring-type, throttle variable adjustable mouth adjustable mouth.

The working principle of the cushioning device is to use a piston or cylinder to seal a portion of the oil between the piston and the cylinder head as it moves towards the stroke end, forcing it to be extruded from the orifice or slit to produce a great deal of resistance Working parts by the brake, gradually slow down the speed of movement, to avoid the piston and cylinder head against the purpose of each other.

As shown in Figure 2-5 (a) below, when the buffer plunger enters the bore on the cylinder head to which it is matched, the hydraulic oil in the hole can only be discharged through the gap δ to reduce the piston speed. As the gap with the same, so with the piston movement speed reduction, from the buffer effect. When the buffer plunger enters the mating hole, the oil in the oil chamber can only be discharged through the throttle valve 1, as shown in Figure 2-5 (b). Since the throttle valve 1 is adjustable, the cushioning action can also be adjusted, but still cannot solve the shortcomings of the weakening of the buffer after the reduction. As shown in Figure 2-5 (c), a triangular groove is formed in the cushion plunger. As the plunger gradually enters the fitting hole, the throttle area becomes smaller and smaller, and the buffer effect is too weak at the final stage of the stroke.

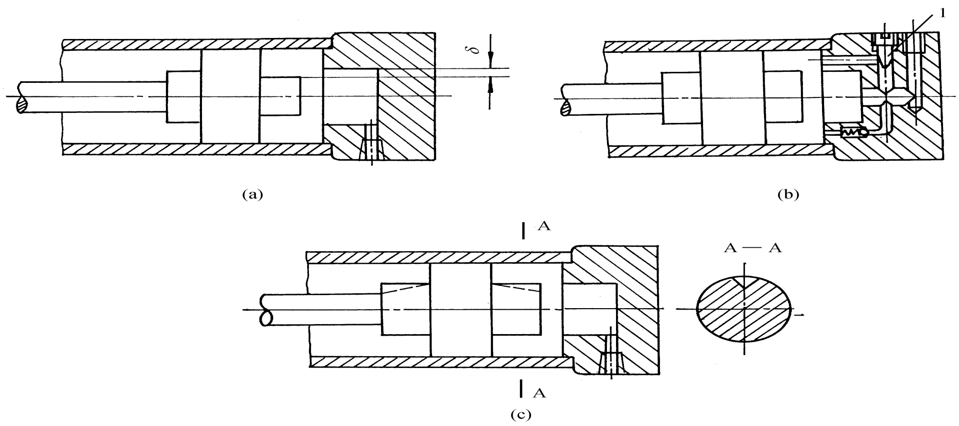


Figure 2-5 Buffer of hydraulic cylinders

1 - Throttle valve

(5) Exhaust device

When the hydraulic cylinder is in the process of installation or when it is re-operated for a long time, the hydraulic cylinder and the piping system will penetrate into the air. In order to prevent abnormal phenomena such as crawling, noise and heat, the air in the cylinder and the system The For the less demanding hydraulic cylinders, there is often no special exhaust, but the ports are arranged at the highest point of the two ends of the tank, which also allows the air to be discharged to the tank with the oil, Speed stability requirements of the higher hydraulic cylinders or large hydraulic cylinders, often in the highest point of the hydraulic cylinder into and out of the gas to take away, but also in the highest set of vent holes or special release valve.

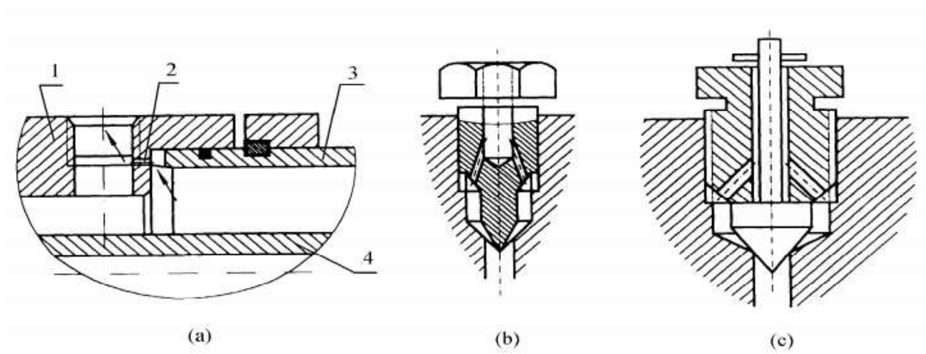


Figure 2-6 Venting device

1-cylinder head 2-bleed hole 3-cylinder 4-piston rod

3. Design of hydraulic cylinders

3.1. Introduction

The hydraulic cylinder is the working mechanism of the piston rod in the hydraulic system for reciprocating motion. Its structure are single piston rod double acting earrings installed. Mainly used for construction machinery, transport machinery, mining machinery and vehicles, such as hydraulic transmission. The hydraulic cylinder structure is shown in Figure 3-1:

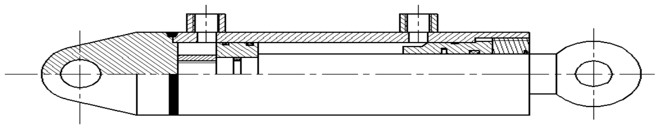


Figure 3-1 Hydraulic cylinder structure

3.2. Design of hydraulic cylinder

Hydraulic cylinder design calculation: As the hydraulic actuator and the host structure has a direct relationship, so the required hydraulic cylinder and the ever-changing structure. Although there are some standard parts available, but sometimes must be designed according to actual needs. The following describes the design of hydraulic cylinders.

(A) Calculation of the main dimensions

The main dimensions of the cylinder include the cylinder bore diameter D, the piston rod diameter d and the cylinder length L.

According to the load size and hydraulic cylinder working pressure to determine the effective working area of the piston, and then according to the different structure of the hydraulic cylinder to calculate the cylinder diameter. Piston rod diameter is determined by the force of the situation, according to Table 3-1 preliminary selection. The length of the cylinder to determine the piston to consider the maximum stroke, piston thickness, guide and seal the required length and other factors. Normally, $L \leq (20 - 30)$ d. The results are rounded to the recommended values in the national standard. After the initial size of the initial determination, but also according to the speed requirements for verification. While meeting the requirements of force and speed before they can be determined.

Table 3-1 Hydraulic cylinder working pressure and piston rod diameter

Hydraulic cylinder working pressure p / MPa	<5	5 - 7	> 7
Recommended piston rod diameter d	(0.5 - 0.55) D	(0.6 - 0.7) D	0.7D

(B) Strength check

The strength check items include cylinder wall thickness δ, piston rod diameter d and cylinder head fixing bolt diameter ds.

In the medium and low pressure system, the cylinder wall thickness determined by the structural process, generally do not check. In the high-pressure system need to check the following circumstances.

1. Determination of cylinder wall thickness

When the D / δ> 10 for the thin wall, δ according to the following check:

$$\delta \geq \frac{p_y D}{2[\sigma]} \qquad 3\text{-}1$$

Where, D-cylinder diameter;

[Σ] - the allowable stress of the cylinder material, $[\sigma] = \sigma_b / n$, σb is the tensile strength of the material, generally take the safety factor n = 5;

Py-test pressure, when the cylinder rated pressure pn ≤ 16Mpa, py = 1.5pn; pn> 16Mpa, py = 1.25pn.

When the D / δ <10 for the thick wall, δ according to the following check:

$$\sigma \geq \frac{D}{2}\left[\sqrt{\frac{[\sigma]+0.4p_y}{[\sigma]-1.3p_y}}-1\right] \quad \text{3-2}$$

2. Piston rod diameter d

$$d \geq \sqrt{\frac{4F}{\pi[\sigma]}} \quad \text{3-3}$$

Where, the force on the F-piston rod;

[Σ] - allowable stress of the piston rod material, [σ] = σb / 1.4.

3. Cylinder head fixing bolt diameter ds

$$d_z \geq \sqrt{\frac{5.2kF}{\pi z[\sigma]}} \quad \text{3-4}$$

Where, the force on the F-piston rod;

K - thread tightening coefficient, k = 1.12 - 1.5;

Z - number of fixing bolts;

[Σ] - allowable stress of the bolt material, [σ] = σs / (1.22 - 2.5),

Σs is the yield point of the material. [Σ] - allowable stress of the piston rod material, [σ] = σb / 1.4.

(C) Piston rod stability test

When the piston rod by the axial compression load when the stability of the barthat is, when the compression force F exceeds a critical Fk value of the piston rod will lose stability. The stability of the piston rod is examined by the following formula

$$F \leq \frac{F_k}{n_k} \quad \text{3-5}$$

Where, nk-safety factor, generally take nk = 2 - 4.

When the elongation ratio of the piston rod $l / r_k > \psi_1 \sqrt{\psi_2}$,

$$F_k = \frac{\varphi_2 \pi^2 EJ}{l^2} \quad \text{3-6}$$

Where l - the installation length;

Rk - piston rod section minimum turning radius; $r_k = \sqrt{J / A}$

Ψ1 - flexible coefficient;

Ψ2 - the end coefficient determined by the hydraulic cylinder support mode;

Elastic modulus of E - piston rod material, steel: $E = 2.06 \times 10^{11} N / m^2$

J-piston rod cross-section moment of inertia;

A-piston rod cross-sectional area;

F - the test value determined by the strength of the material;

A-coefficient.

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