Journal of Mechanical Engineering Research and Developments
ISSN: 1024-1752
Website: http://www.jmerd.org
Vol. 39, No. 1, 2016, pp. 226-233

Improved Design of Rotary Controlled Lift Aircraft Hydraulic Mechanism

Q. L. Du[†*], W. S. Tang[‡], & L. A. Pan[§]

[†]Special Education College of Changchun University, Changchun, Jilin, 130022, China,
*Email: apriljuan@hotmail.com
[‡]Scientific Research Administrative Dept of Changchun University, Changchun, Jilin, 130022, China
[§]Mechanics Engineer College of Changchun University, Changchun 130022, China

ABSTRACT: This paper presents improved design method for the hydraulic parts of existing bending machine, based on its general structure. The paper proposes analogous argumentation among several schemes of bending machine hydraulic parts' design and contrastive analysis of hydraulic parts, where the related calculation of hydraulic cylinder and confirmation of final scheme is put emphasis on. The accuracy and work efficiency of the improved hydraulic bending machine is improved, and it is especially important that it is of simple operation, reliable performance and greatly improved safety factor, so that the bending machine can get more extensive application in the industry.

KEYWORDS: Hydraulic; Rotate; Lift aircraft; Improved design.

INTRODUCTION

Rotary controlled lift aircraft is a large entertainment facilities, common to start switch, aircraft can automatically rotate in park surrounding playground equipment at home and abroad as well as spindle level, while pulling lever inside aircraft, aircraft can do uniform reciprocating lift movement. Mounting market controlled rotary lift aircraft based primarily on size of installation site needs, according to size of site can be divided into 3 arms, 4 arms, arm 6, 8 and 10 arms are generally medium-sized aircraft needs to be installed on circumference of inner diameter of about 10m. Rotary lift aircraft controlled by motor drive bevel gear intermediate gear axis motion control, so that entire round site rotation, and then drive hydraulic pump driven by motor cylinder movement, so that entire aircraft to achieve repetitive lifting movement. In every movement, accompanied by sound of analog circuitry aircraft continued takeoff run, climb, dive, landing analog electronic sound, while center of shield decorative lights accompanied by sound and rhythmic flashing, after aircraft runs, to stop within stipulated time. The design is based on institutions and structures existing products to improve and optimize design of its hydraulic lifting portion repeatedly to raise efficiency and safety factor of product.

HYDRAULIC SYSTEM DESIGN REQUIREMENTS

Hydraulic system design, it is designed with a host of closely related, often at same time, hydraulic system should be designed to meet host of drag, recycling requirements. It should also meet composition structure is simple, safe and reliable, manipulation easy maintenance, and good economic conditions.

Rotary controlled lift aircraft hydraulic system design requirements can be summarized as follows:

Aircraft movement at main hydraulic drive, optional remote or wireless control, lifting movement by hydraulic lift cylinder telescopic movement transformed to become an aircraft taking off and landing, its workload ranged $0 \sim 2500Kg$ with steady load, no shock loads during operation action, speed is low, hydraulic actuator cylinders have set for motion, asking them to work smoothly, reasonable structure, excellent safety, for use in a variety of different occasions, working accuracy requirements are generally [1].

DETERMINATION OF HYDRAULIC CYLINDER MAIN DIMENSIONS

DOI: 10.7508/jmerd.2016.01.031

Determination of Hydraulic Cylinder Working Pressure [2]

Main cylinder working pressure is determined according to type of hydraulic equipment, for different uses of hydraulic equipment, due to different working conditions, commonly used pressure ranges are different, calculate rotary-controlled lift aircraft operating according to Table 1 and Table 2 with pressure of 8MPa.

Table 1. Selection of system operating pressure according to device type.

Equipment type	Machine tool, die-casting machine and car	Agricultural machinery, mining vehicles, marine machinery, transportation machinery, engineering machinery and metallurgical machinery	Hydraulic machine, metallurgical machinery, excavator and heavy machinery	Diamond press, pressure testing machine, aircraft, hydraulic machinery
Pressure range/ MPa	<7	7-21	21-31.5	>31.5
Pressure level	Low pressure	Medium pressure	High pressure	Extra high pressure
Explanation	Low noise and high reliability system	General system	Limited space, high response speed and high power cost reduction	Pursuit of higher force and lower weight

Table 2. Selection of system operating pressure according to load.

load（KN）	<5	5-10	10-20	20-30	30-50	>50
Working pressure/ MPa	<0.8-1	1.5-2	2.5-3	3-4	4-5	>5-7

Determination of Hydraulic Cylinder Inner Diameter D and Piston Rod Diameter D

1) determination of additional load

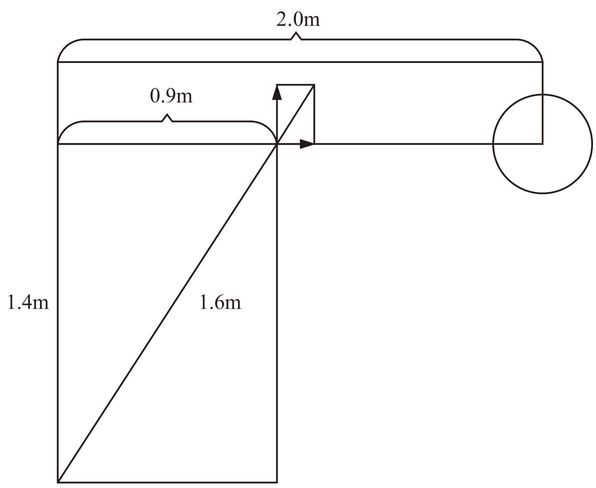


Figure 1. Stress analysis.

It can be shown from Figure 1 that

$$F_y = F_{aircraft} + F_{human} + F_{rod} = 3500\text{N}$$

$$\because \frac{F_y}{F} = \frac{1.4}{1.6}$$

$$\therefore F = \frac{3500 \times 1.6}{1.4} = 4000N$$

2) Determination of hydraulic cylinder inner diameter D

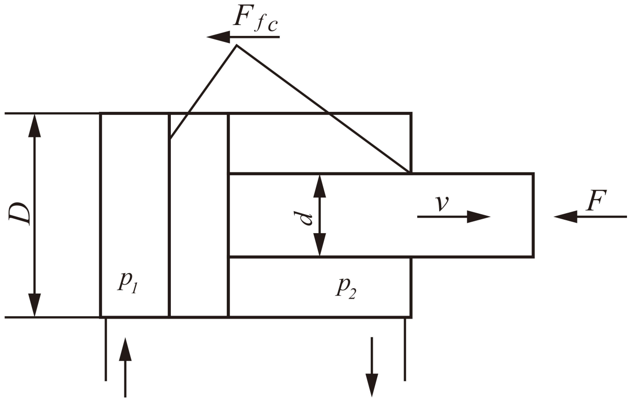


Figure 2. Hydraulic cylinder schematic diagram.

It can be shown from Figure 2 that

$$\frac{\pi}{4} D^2 p_1 = F + \frac{\pi}{4}(D^2 + d^2)p_2 + F_{fc} \quad (1)$$

$$D^2 = \frac{4(F + F_{fc})}{\pi p_1} + (D^2 + d^2)\frac{p_2}{p_1} \quad (2)$$

Where

p_1 - Hydraulic cylinder working pressure, select system operating pressure at first count p_p = 8 MPa;

p_2 - Hydraulic cylinder return oil chamber back pressure, can not be accurately calculated at first count, estimated worth p_2 = 0.5 MPa;

d/D - Diameters of piston rod and cylinder inner diameter are based on relationship information with piston rod hydraulic cylinder diameter D and diameter d can be obtained, $d/D = 0.7$;

F- F is maximum duty cycle of applied load;

F_{fc} - Hydraulic cylinder seal friction, its exact value is not determined, mechanical efficiency of hydraulic cylinder commonly estimated.

$$F + F_{fc} = \frac{F}{\eta_{cm}}$$

Where η_{cm} is mechanical efficiency of hydraulic cylinder, and generally η_{cm} = 0.9~0.97. This design takes $\eta_{cm} = 0.95$

Substitute η_{cm} into $D^2 = \frac{4(F + F_{fc})}{\pi p_1} + (D^2 + d^2)\frac{p_2}{p_1}$, D can be gained as follows.

$$D = \sqrt{\frac{4F}{\pi p_1 \eta_{cm}\left\{1 - \frac{p_2}{p_1}\left[1 - \left(\frac{d}{D}\right)^2\right]\right\}}}$$

$$= \sqrt{\frac{4 \times 4000}{8\pi \times 0.95[1 - 0.625(1 - 0.49)]}}$$

$$= 31.5\text{mm}$$

Substitute value of D = 31.05 mm, and calculated D rounded to similar standard diameter of 32 mm, thus using standard sealing elements.

Diameter of piston rod is calculated according to $d/D = 0.7$ and then rounded to a similar standard diameter of 28 mm.

After selected hydraulic cylinder bore D, must be minimum steady speed checking. To ensure that hydraulic cylinder throttle chamber effective work area A, must be greater than minimum speed guarantee a minimum effective area of stability A_{min}, that is $A > A_{min}$.

Calculate Cylinder Wall Thickness and Outer Diameter [3]

Wall thickness of cylinder is calculated by a hydraulic cylinder to strength conditions.

Wall thickness of cylinder structure generally refers to steel drums thickness at the thinnest. It is seen from mechanics of materials, to withstand internal pressure of cylinder, due to its internal stress distribution of different thickness. It can be divided into thin cylinder and thick-walled cylinder in general calculation.

Ratio of hydraulic cylinder diameter D and its wall thickness δ, $D / \delta \geq 10$ is called thin cylinder. In this design of hydraulic cylinder seamless steel pipe material, mostly belonging to thin-walled cylinder structure, and thin cylinder wall thickness calculated according to following formula $\delta \geq \frac{p_y D}{2[\sigma]}$

Where:

δ —cylinder wall thickness (m);

D—cylinder inner diameter (m);

p_y —test pressure, and generally (1.25 to 1.5) times of maximum working pressure (MPa);

$[\sigma]$ —cylinder material allowable stress. Its value: forged $[\sigma] = 100 \sim 120\text{MPa}$; cast steel $[\sigma] = 100 \sim 110\text{MPa}$; seamless steel pipe: $[\sigma] = 100 \sim 110\text{MPa}$; high-strength cast: $[\sigma] = 60\text{MPa}$; gray cast iron: $[\sigma] = 25\text{MPa}$.

In low-speed hydraulic system, wall thickness calculated is according to formula resulting cylinders tend to be small, so that cylinder rigidity is often not enough, and event card dead during operation or leakage. They are generally not calculated empirically chosen, according to formula to be checked if necessary.

This design selects seamless steel tubes as materials, and allowable stress is $[\sigma] = 100 \sim 110\text{MPa}$, test pressure $p_y = 8 \times 1.25 = 10\text{MPa}$, so according to thin-walled cylinder calculation formula:

$$\delta \geq \frac{p_y D}{2[\sigma]} = \frac{10^3 \times 32}{2 \times 100} = 16\text{mm}$$

Therefore, outer diameter of cylinder is

$$D_1 \geq D + 2\delta = 32 + 32 = 64\text{mm}$$

Hydraulic Cylinder Working Stroke

Hydraulic cylinder working stroke length, maximum stroke can be determined according to actual work of implementing agencies, and with reference to Hydraulic system design book, Table 2-6 series size to select criteria. Design of maximum stroke is 600 mm; according to standard value table after a 2-6 round is 630 mm.

HYDRAULIC CYLINDER STRUCTURAL DESIGN

Pressure of hydraulic cylinder systems can be transformed into mechanical energy, in this system, hydraulic cylinder of telescopic movement of plunger through a series combination of mechanical structure into aircraft lift.

After hydraulic cylinder determines main dimensions, it is necessary for structural design of each part, including a connection structure of cylinder block and cylinder head, piston rod connecting structure, structure of piston rod guide portion, sealing means, buffer means, exhaust means, and connecting structure mounting a hydraulic cylinder and so on. Due to different operating conditions, structure is not the same.

Cylinder Bottom Strength Calculations [5]

When cylinder bottom is plane, thickness can be calculated as follows:

$$\delta \geq 0.433D\sqrt{\frac{p}{[\sigma]}}$$

Where: δ - Cylinder bottom thickness, with unit of m ;

D - Cylinder diameter, with unit of m ;

p - Cylinder maximum working pressure, with unit of MPa ;

$[\sigma]$ - Block material allowable stress, with unit of MPa ;

Substitute data: $\delta \geq 0.433 \times 0.08 \times \sqrt{\frac{2}{100}} = 4.9mm$

Thickness of cylinder bottom should be based on requirements due process of thickening, such as setting oil port or exhaust valves in cylinder, and cylinder should increase bottom thickness.

Block Material and Processing Requirements

Block materials usually use 20, 35 and 45 steel, or cast iron, steel, stainless steel, bronze and aluminum and other materials processing can also be used.

When cylinder and piston with rubber seals, which is $H9/f8$ with recommended, inner diameter of cylinder surface roughness to take $R_a = 0.1 - 0.4\mu m$, when use of a piston ring seal, $H7/g6$ is recommended with, surface roughness of inner diameter of cylinder to take $R_a = 0.2 - 0.4\mu m$.

Inner diameter of cylinder should be polished

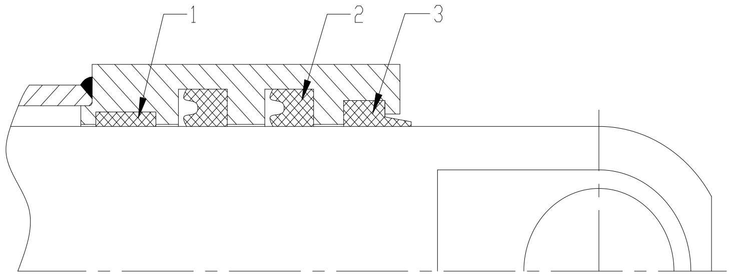
To prevent corrosion, increased life expectancy, and cylinder surface should be crossing chromium, and crossing chromium layer thickness should be polished at 30-40 μm , after crossing chrome cylinder surface.

Roundness and cylindrical error cylinder diameter is not more than half diameter tolerance, and tolerance of error in cylinder surface is not more than 0.03mm on 500mm size.

Plunger

1) Plunger structure form

Plunger structure should be based on form of sealing device to choose, design choice of form is shown in Figure 3.



1. guide sleeve 2. seal 3. dust-proof ring

Figure 3. Plunger structure form.

2) Plunger material and processing requirements

Plungers are made of 20, 35 or 45 steel.

Plunger diameter tolerance f8, with plunger H8/h8 generally, diameter roughness $R_a = 0.4 - 0.8\mu m$, outer diameter of plunger hole beating no more than half of diameter tolerance, roundness and cylindrical outer diameter of not more than half diameter tolerance.

Plunger end face plunger axis vertical error in not more than 100mm on 0.04 mm.

Determination of Oil Port Size

Oil port size is determined according to following formula: $d = \sqrt{\frac{4Q}{\pi v}}$

Where: Q - maximum flow through hydraulic cylinder, with unit of $L/\min$;

v - flow rate when oil comes into hydraulic cylinder , with unit of m/s;

Substitute values and get: $d = \sqrt{\frac{4 \times 2.31}{\pi \times 0.0109}} = 16.4mm$

Design Selection of Sealing Structure

YX-ring is sealed with a plunger; specific criteria used GB / T10708.1.

Connection form between Steel and Cylinder Cover

Ends of connection in form of a cylinder with a working pressure cap, cylinder materials and working conditions, according to cap design is connected in form of a rotary-controlled lift aircraft used in hydraulic cylinder. Using a small form factor, lightweight threaded connections.

Piston Rod and Piston Connecting Structure

A structured and reliable connection with taper pin is used.

SELECTION OF HYDRAULIC SYSTEM COMPONENTS

Selection of Hydraulic Pump [4]

Main operating conditions are to select hydraulic system, including parameters of pump pressure, flow, speed, efficiency. In order to ensure normal operation of service life of system, usually in fixed equipment systems, normal operating about 80% pressure of pump; requiring high reliability systems or equipment, system working pressure of pump rated about 60 % pressure. Pump flow to maximum flow rate greater than system work, choice of models is B14-1B gear pump.

B14-1B series gear pump made of aluminum alloy die casting forming, radial seal with addendum sweep boring, and axial sealing pressure balance with floating plates, which reached a high efficiency. Pump has a small size, light weight, high efficiency, good performance, reliable, low price, one-way operation of pump, axial available on user needs.

Selection of Hydraulic Motor [4]

Main performance parameters of hydraulic motor include torque, speed, pressure, displacement, volumetric efficiency and overall efficiency. System can determine a given design parameters calculated on basis of hydraulic motor axial piston motor, compact structure, small radial dimension, moment of inertia, high speed, easy-to-variable, which can be used in various ways to automatically regulate flow, applicable wide range. By searching Mechanical Design Manual, model choice is GY-A6V28HA2FS200200, whose meaning of this oblique axis variable piston hydraulic motor grades are: GY means Liyuan Hydraulic company; A6V means variable motor; specifications for 28; HA refers to high-pressure brake control, 2 means 2 series, sizes 28 to 225; F refers to the connection port SAE flange side; S refers to spline, international GB / T-3478.1; type 2 assembly.

Selection of Motor

Y series motors are totally enclosed fan-cooled or water-cooled three-phase cage induction motors for air, flammable, explosive or corrosive gas. Its applying voltage is 380V without any special requirements, such as pumps, motors and machine tools.

Calculated according to given parameters of hydraulic pump drive power is 6.4kw, and searching Mechanical Design Manual, selection motor type is Y132M-4 motor can be waterproof drop, iron and other objects fall inside motor in a vertical direction, it can be used as pumps, machine tools and other power source. The motor performances are shown as follows.

Rated power: 7.5 kw;

Synchronous speed: 1500 r/min;

Full load speed: 1440 r/min;

Rated torque: 2.2 N.m;

Voltage: 380 V.

HYDRAULIC TANK DESIGN

Acting hydraulic tank is to store hydraulic oil, hydraulic oil separating impurities and air, at the same time playing role of heat.

Determination of Hydraulic Oil

Content of a single hydraulic cylinder product size should be

$$V = \frac{\pi}{4} D^2 \mathrm{h} = \frac{\pi}{4} (32)^2 \times 1000 = 0.08\mathrm{m}^3$$

Therefore, volume of hydraulic cylinder with 12 arms for second arm is $0.76\,\mathrm{m}^3$

Hydraulic Oil Tank Effective Volume [5]

Hydraulic tank under different operating conditions, affect cooling of many conditions, usually in range of pressures to consider. Because of this design rotary controlled lift aircraft has 12 arms, 12 hydraulic cylinders at same time ability to meet application, so choose high power belongs to mailbox system. It can take

$$V = 12q_p$$

V is effective volume of hydraulic mailbox;

q_p is a pump rated flow.

It should be noted that device stops running, device in that part of oil due to gravity back into hydraulic tank, in order to prevent hydraulic oil spill from tank, hydraulic oil mailbox location is not too high, generally not exceed hydraulic mailbox 80%. and thus

V =0.76/0.8=0.95 m^3

Hydraulic system is designed so that election model BEX-1000 in order to ensure that entire tank to meet requirements.

V = 0.76 / 0.8 = 0.95

SUMMARY

Rotary controlled lift aircraft design basis is based on improvement of existing product structure, its design was modified hydraulic parts, using electro-hydraulic servo synchronized control technology, reliable performance, even under partial load force, still to ensure high synchronization accuracy. Aircraft movement at mainly by hydraulic cylinder telescopic movement transformed to become an aircraft taking off and landing, its workload ranged in $0 \sim 2500 Kg$ load steady work process without shock loads, low operating speeds, hydraulic actuator has a set of hydraulic cylinders to achieve campaign for its smooth, reasonable structure, excellent safety, for use in a variety of different occasions.

REFERENCES

[1] J.W.Wang, H.J.Zhang and Y. Huang. Hydraulic and pneumatic transmission. Beijing: Mechanical Industry Press, 2005, pp. 71-76.

[2] P.Y.Yang. Hydraulic system design book. Beijing: Mechanical Industry Press, 1996,pp.10-67.

[3] Q.L.Du and L.Jin. “ Improved Design of Hydraulic Bending Machine” Asian Journal of Chemistry, vol.26, no.11, JUN 2014, pp.3347-3350.

[4] X.L.Yu. Hydraulic machine. Beijing: Mechanical Industry Press, 1982, pp.65-66, pp.148-149.

[5] Y.Q.Tang. Design foundation of hydraulic transmission in forging machinery. Beijing: Mechanical Industry Press. 1980, pp.63-68.