DESIGN AND FABRICATION OF POLYVINYL CHLORIDE TIE-ROD CYLINDER FOR LOW PRESSURE WATER HYDRAULIC SYSTEM

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical engineering (Thermal-Fluids)"

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DECLARATION

"I hereby declare that the work in this reports my own except for summaries and quotations which have been duly acknowledged."

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ABSTRACT

This thesis presents a study about water hydraulic cylinder. The main purpose of this project is to fabricate a hydraulic cylinder which can be used in the water based hydraulic system. Water hydraulic system is not a new technology. The use of water in hydraulic system is increasing due to the risk of fire, intolerable contamination, and non-environmental friendly. Water hydraulic system can be used to replace the oil hydraulic due to its safety and health issue. Furthermore, it is a sustainable, pollution free, clean, fire retardant hydraulic system. However, water hydraulic has the disadvantages such as corrosion, ease to freeze, low viscosity, microorganism, high bulk modulus, and poor lubrication. This project involved designing and fabricating cylinders which obtain anti-corrosion element and good lubrication property during operation. Some material has been used to replace the existing cylinder, especially PVC block. A hydraulic circuit had been designed to help in the experiment setup. This project involved 5 experiments, the first test was the test on original pneumatic cylinder, by using oil hydraulic system, and the second test was the test on PVC barrel cylinder, by using oil hydraulic system. The third test was the test on PVC cylinder (fully modified) by using oil hydraulic system and the fourth experiment was the test on PVC cylinder by using Oil-Air adapter. The last experiment was the test on PVC cylinder by using Oil-Water adapter. The results of the 5 experiments have been discussed in this thesis. The observations focused on the movement, leakage and corrosion of the PVC cylinder.

ABSTRAK

Tesis ini menerangkan kosep sistem hidraulik air. Objektif utama projek ini adalah menghasilkan satu selinder yang akan digunakan di dalam sistem hidraulik air. Minyak hidraulik tidak digalakkan diguna kerana ia senang bakar, kotor, dan tidak selamat. Air digunakan sebagai medium dalam hidraulik system kerana air adalah bersih, tidak membawa bahaya kepada orang dan alam sekitar. Selain itu, air tidak meletup dan tidak terbakar, dengan sebab diatas, air hidraulik akan bertembuh dalam masa hadapan. Walaubagaimanapun, air membawa sesuatu masalah kepada sistem hidraulik iaitu karat, tidak licin, senang beku, dan sebagainya. Projek ini adalah menbuat satu silinder yang tahan karat dan kelincinannya adalah baik. 5 kajian telah dibuat, pertama adalah mengaji pnuematik selinder dalam sistem.hidrualik Kedua ialah mengaji PVC pipe selinder dalam hidraulik sistem. Ketiga ialah mengaji PVC selinder (PVC selinder yang telah disiap) dalam sistem.hidrualik. Keempat adalah mengkaji PVC selinder dalam Minyak-Udara Adapter. Kelima adala mengkaji PVC selinder dalam Minyak-Air adapter. Data dan perbincangan telah dikumpulkan dan dibincangkan dalam tesis ini. Kelima-lima kajian terus dibuat akan pentingkan pengerakan selinder, kebocoran selinder dan ketahanan karat selinder.

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A	=	Cross Section Area
D	=	Diameter of cylinder
F	=	Force
N	=	Angular Speed
P	=	Pressure
Power	=	Power that generated
Q	=	Flow rate
S	=	Distance moved by piston
t	=	Time
V	=	Volume
v	=	Velocity
W	=	Work

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CHAPTER 1

INTRODUCTION

1.1 PROBLEM STATEMENT

The main problem for the water hydraulic system is **Corrosion**. Water caused corrosion in the piping and component of the water hydraulic system due to dissolved gases in the water, e.g oxygen, chlorine, carbon dioxide. High chlorine content in water is the main reason for the corrosion to be occurred in stainless steel. Due to the presence of micro-organisms in the water, microbial induced corrosion adds to further problems. (S.K.Chua G. W., 2004) This leads to the use of more expensive corrosion resistance materials and even corrosion inhibiting chemicals. This raised the cost of the water hydraulics systems. On the other hand, the poor lubrication of water had caused a problem in the water hydraulic system. Therefore, the problem need to solve is **Corrosion and Lubrication**.

1.2 OBJECTIVE

The objective of this project is to study about the problem encountered when using water hydraulic system. The main objective of this project is to design a Tie-Rod cylinder which can be operated in the water hydraulic system. Besides, this project is carried out to fabricate a Tie-Rod cylinder that can extend and retract smoothly, with non-corrosive material for 15 bar of pressure.

1.3 SCOPE

The scope of this project includes the finding of material which is suitable to replace the oil hydraulic cylinder. The material should be non-corrosive. At the same time, the cylinder should extend and retract smoothly. The scope use PVC pipe to replace the cylinder barrel and PVC block is to replace the HEAD and the END part of the cylinder. On the other hand, the piston should also be replaced with PVC block and the piston rod should be replaced with stainless steel rod.

1.4 EXPECTED RESULT

It is expected that the PVC cylinder can be successful designed and fabricated on time. The PVC cylinder should function normally and free from corrosion when using water power unit. Furthermore, the PVC cylinder should be testing by water power unit. The water power unit should be successful prepared by the other PSM student.

1.5 THESIS OVERVIEW

In the chapter 1, problem statement and objective of the thesis had discussed. Literature review had shown in chapter 2. In addition, background of water hydraulic system, components of cylinder, theory of cylinder also included in chapter 2. In the chapter 3, the methodology had been discussed. Step for prepare apparatus or testing kit had been included in chapter 3. The results of 5 experiments had been discussed in chapter 4. Last but not least, the conclusion and recommendation were discussed with detail in chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW

In this section, introduction of water hydraulic will be reviewed through published journals. Besides that, the problem faced on the water hydraulic and the components of the cylinder will also be reviewed by the same way.

2.2 BACKGROUND OF WATER HYDRAULIC SYSTEM

According to the study (S.K.Chua G. W., 2004), water hydraulic actually is not a new chapter in the field of hydraulic system. Industrial of water hydraulic is earlier than oil hydraulic and water is a main medium in the hydraulic system. In 1700 years, the first water hydraulic system was introduced as a power transmitter.

However due to some negative characteristic of water toward transmitter system, water hydraulic has been replaced by oil hydraulic. The negative characteristic of water such as corrosion, freezing, lower viscosity, microorganism, higher bulk modulus and poor lubrication had cause many problem in the hydraulic system. So the water hydraulic is substituted by oil based hydraulic system for continuity development.

In the 1970 years, human started with concern of environmental problem and safety and health issue, pollution, renewable energy, and environmental contaminations. Because of explosion and fire accidents caused by oil hydraulic

systems rise up, then human awareness to search for alternative solution. In 2000 years the water hydraulic systems had standing again and develop for using water as a medium in the hydraulic system. Figure 2.1 shows the comparison about the application trend for the recent years between oil and water hydraulic.

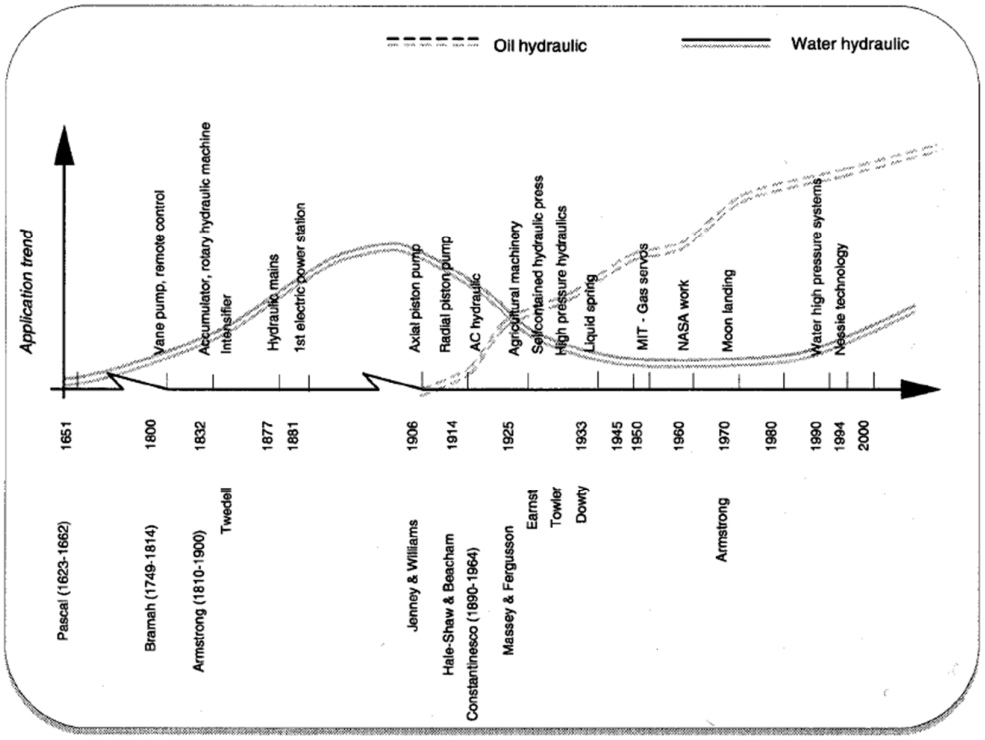

Figure 2.1: Application trend vs Year (source: (S.K.Chua G. W., 2004))

2.3 WATER HYDRAULIC SYSTEM AND COMPONENT

Water hydraulic system can be defined as a power transmitted system which used water as the medium further purpose of machine apparatus, stuff handling devices, transport and etc. The fire hazards, operating cost, and contamination can be reduced by using water hydraulic system. It is also redound to low volume applications and environmental friendly.

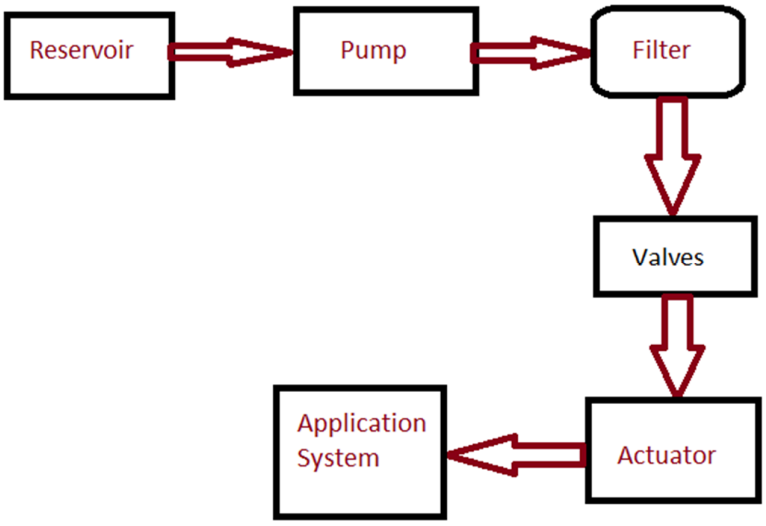

Figure 2.2: Schematic Diagram of Water

Patent (Roger, 1971), Figure 2.2 shown the main components within the water hydraulic system such as hydraulic fluid, reservoir, pump, filter, valves, actuator (cylinder), and application system. The function of each component was discussed below:

1. Hydraulic fluid

   In this system, water acts as working fluids because it is incompressible and easy to transmit power from one end of the system to the other end of the system. Water also act as lubricant which reduce the friction between moving parts such as cylinder and reduce the component's temperature in the system. On the other hand, working fluid assist in removing contaminant to the filter for prevent blockage. Lastly, it also plays role as seal against leakage inside a hydraulic component of the system.

2. Reservoir

   The function of reservoir is like a tank, it store the working fluid in the system. Commonly, the reservoir is fabricated by stainless steel or plastic or metal which can avoid the corrosion because in this case the water fluid is water. In the water hydraulic system, the size of the tank is larger than conventional hydraulic system.

3. Pump

Pump is used to create flow in the hydraulic system. Fluid is suck into the cavity of the pump during the half cycle and the push the fluid from the cavity of the pump closing for the other cycle. (Andrew, March 1999) Many types of the pumps are suitable for the water hydraulic system such as piston pump, gear pump, vane pump, axial piston pump, radial pump and etc.

4. Filter

This component is used to prevent the contamination or dirt in the hydraulic system. It filters the working fluid before the fluid go into the pump, and then the dirt will stay at the reservoir. This can prevent blocking in the components of the system and avoid from wear of those components. Filter can be installed neither in the reservoir nor before the components.

5. Valve

Control valve is used to control the direction of the flow, change the ports of the valve can change the direction of the flow. On the other hand, pressure valve also can use to relief pressure if the pressure of the system is too high then can reduce the broken of the components. So the function is depending to the type of valve. There have 3 main types which are control valve, flow valve, and flow control valve.

6. Actuators

Actuators in the hydraulic system normally are two types that are cylinder and hydraulic motor. Cylinder which is also called linear actuators and it is used to produce straight line motion for some application. There are two types of the cylinder such as single acting cylinder and double acting cylinder. The single acting cylinder has only one port for input the hydraulic fluid to produces one way force only. However for the double acting cylinder, it can produce two way forces because it has two ports for input the fluid hydraulic. Hydraulic motor called as rotary actuators which can produce rotary motion for the hydraulic pump.

2.4 FORMULA AND CALCULATION

Blaise Pascal (1648) had developed a basic physical law which is called “Pascal law” for fluid power system. Pascal’s law states that the pressure generated by exerting a force on a confined mass of liquid at rest acts undiminished in equal magnitude and in all direction normal to the inside wall of the fluid container. (Majumdar.S, 2002)

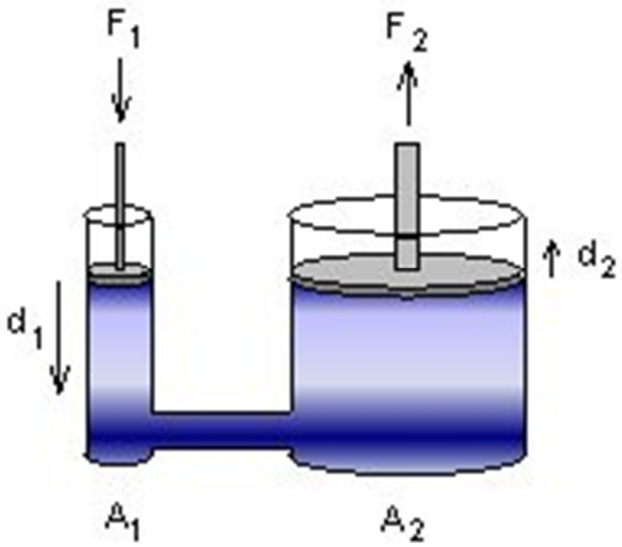

Figure 2.3: Pascal's principle

(Source: (Pascal's Principle.))

The Figure 2.3 had shown the principle of the Pascal’s law. There are two cylinders which connected to each other and the two cylinder have difference sizes d1 and d2. The size d2 is bigger than d1 and the each cylinder have its own pistons rod in the system. According to the Pascal’s law, if the force F1 is applied on the smaller piston, a pressure p will be generated in the fluid and this pressure will constant apply to whole direction. Pressure can be define as force divide by area piston,

$$p = \frac{F_1}{A_1}$$

Where $A_1 = \frac{\pi}{4} D_1^2$

Pascal’s law says that the same pressure will also acting on the bottom of area A_2

$$p = \frac{F_2}{A_2}$$

Where $A_2 = \frac{\pi}{4} D_2^2$

Since the pressure that exert on both of the cylinders are the same, so F_2 can be found by using the equation below:

$$F_2 = P.A_2$$

By rearranged the equation, pressure can be equalizes to get the new equation as shown below:

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

From here, it proved that if a smaller force F_1 apply on the smaller piston, then the bigger force F_2will generated on the bigger piston.

Work done by the smaller piston = $F_{1,} S_1$

Work done by the larger piston = F_2, S_2

Where S_1: Distance moved by the smaller piston

S_2: Distance moved by the bigger piston.

In order to maintain flow, the velocity of a liquid change while flowing through a pipe of variable cross section. Flow rate is defined by volume dividing by time,

$$Q = \frac{V}{t}$$

Where Q: flow rate in l/min

V: volume in l

t: time in min

$$V = A.S$$

$$Q = A.\frac{s}{t}$$

$$v = \frac{s}{t}$$

Where S: distance moved

v: velocity

$$\boldsymbol{Fliud, Q = A.v}$$

From the continuity of the flow we know that,

$$Q_1 = Q_2$$

So,

$$A_1.v_1 = A_2.v_2$$

Power is work done per unit time,

$$P = \frac{Force\ x\ distance\ travelled\ by\ fluid}{time}$$

$$= \frac{F\ x\ S}{t}$$

$$= \frac{F\ x\ S\ x\ A}{t\ x\ A}$$

$$= \frac{F}{A} x \frac{S\ x\ A}{t}$$

$$= p\ x\ \frac{V}{t}$$

$$= p\ x\ Q$$

Where A= Area of cross section of pipe

S= distance travelled

t= time taken to travelled

$\frac{F}{A}$= pressure

$S\ x\ A$= volume of fluid

$$Q = \frac{V}{t}$$

So,

Fluid power, $P = p\ x\ Q$

Fluid work, $W = p\ x\ V$

Input power of pump, $W = 2\pi N_i T$

Output power of cylinder, $P = 2\pi N_o T$

Output force of cylinder, $F = p\ x\ A$

Output power of cylinder, $P = F\ x\ v$

2.5 APPLICATION OF WATER HYDRAULIC SYSTEM

Water hydraulic pump system can apply in many sites especially for those industries which put hygiene as the priority consideration. Water hydraulic system can be applied in food processing and packaging industry, pharmaceutical industry, high pressure water jet cleaners, water treatment plant, fertilizer plant, machine tools

and robotic system, dairy industry, agricultural industry and etc. (S.K.Chua G. W., 2004)

Water hydraulic system is utilized in the industries that mentioned above instead of pneumatic system and electrical system. The reasons are water hydraulic system has high efficiency, free of pollution and also easy to clean up after operation. Although pneumatic system is compact and light but it is low in efficiency and polluting the working environment. Working pollution will happen because oil mist and noise released which from the air actuation and valves switching during operation. While for the electric system, because of the electric motor needs a cover for water proofing, thus, leads to increase in the weight and poor ventilation of the motor. So, this explained why many other industries are trying to change from electric system and pneumatic system to water hydraulic system.

2.6 COMPONENT OF THE CYLINDER

In a cylinder, there have several components. Every component inside the cylinder is very important. The components such as head and end, cylinder barrel, barrel seal, cushion seal, piston seal, piston wear strip, piston, piston rod, cushion adjustable screw, rod wiper, tie rod, and nuts. The Table 2.1 Description of the component had shown the description of the component.