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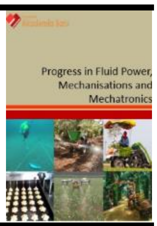

Design of Marine Fluid Power: Anchor Windlass and Boat Lift

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ABSTRACT

Fluid power has many applications in marine field such as rudder control, towing and mooring winch, hydraulic gangway and deck crane. This paper discusses two fluid power systems proposed to be used for anchor windlass and boat lift. Efficient, safe and reliable anchor windlass and boat lift hydraulic systems are critical to successful operations. Thus suitable hydraulic circuits have been proposed. Component sizing has been made based on flow rate and torque requirements. The two systems have been tested on hydraulic bench. The systems work as expected and meet the industry standard.

1. Introduction

Fluid power systems are used in a wide range of applications. The system may use either liquid or gas as transporting media. The last few decades have witnessed vast research on new candidates of hydraulic fluid [1-6]. Wan Nik *et al*. [7] has performed lubricity or rheology study using plant oil. The aim of the study was to propose environmental friendly fluid to be used at sea in order to reduce water pollution. Many hydraulic machines for marine applications are also designed and improved in order to improve system efficiency [8-11] or increase its mechanization level.

High level of mechanization is required for ship and offshore applications. Due to large distance from land, not many people can work on shipboard or offshore platform. Thus automation or mechanization is required to replace or to reduce the requirement for manpower. With just a push button signal, machine will do its work in synchronization. People working on ship or platform need to be tough to handle large or heavy equipment. In order to overcome this problem, hydraulic systems are used widely to operate deck machinery. In this paper two systems commonly used on ship are designed and discussed.

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1.1 Anchor Windlass

When a ship is at port or before she unload or offload cargo, she has to be in stationary position. This can be achieved by a ship anchor gripping to the seabed. The ship is secured against the wind and wave force by the weight of chain and anchor. A ship anchor windlass system is a machine that is used to lower or raise the ship anchor. This is done by manipulating the anchor chain or rope on ship deck (Figure 1). Once the ship is anchored properly, she is bound to remain in a certain circular area which is defined by the length of loose chain.

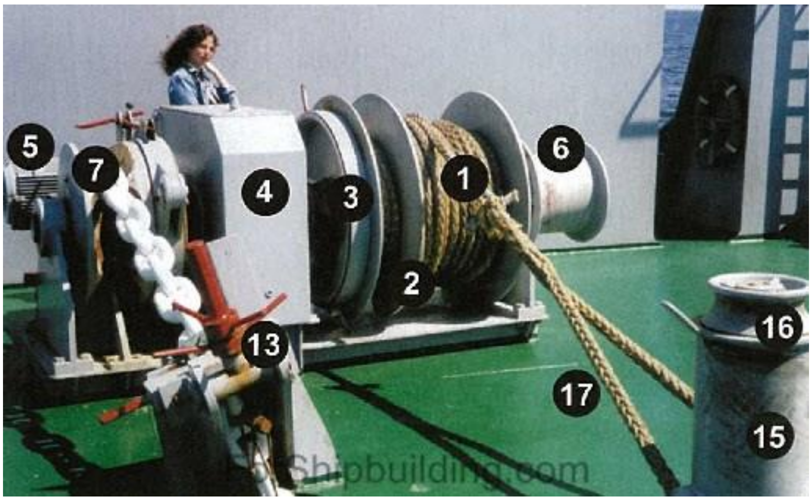

Fig. 1. Anchor windlass system [12]

Figure 2 shows the application and location of windlass system on naval ship. The figure shows some hydraulic system on main foredeck of both vessels. Two anchors can be seen on each side of the ship hull.

Fig. 2. Application of windlass system on military ship

1.2 Boat Lift

Figure 3 shows a life boat on a cargo or civilian ship. Figure 4 shows a rescue boat on a military or patrol ship. On some other ship, life rafts are provided on the port or starboard of the ship. The small craft or boat aboard the ship is be used for emergency escape or rescue purposes, or special missions. If a ship has some problem, about to capsize as an example, a small craft is used for sea rescues. It is required by law for a medium to large ship to have a number of emergency boats on board. Thus life raft, life boat or rescue boat need safe and fast mechanism before the boat or raft ready to be deployed at sea.

Fig. 3. Life boat [13]

Fig. 4. Rescue boat

During emergency or drills sessions, the life boat has to be lowered and can be used in a short time. Thus automation is required for the fast motion. The main purpose of the system is to ensure safe opening of the ramp and launching the craft with people inside. The safety factor is that the launching speed is uniform even in the condition of lack of energy supply from ship's power network.

2. Methodology

2.1 Component Selection Criteria

Before building the anchor windlass and life boat hoisting systems, hydraulic circuits have to be designed. The workability of the circuit has to be either tested on hydraulic test bench or simulated using software. Then components selection has to be made. Component sizing is also critical so that the required job can be accomplished. General requirements for shipboard systems are dealt within ISO Standards 3730 and 7825.

For fluid power, the most important component is pump (for hydraulics) or compressor (for the case of pneumatics). The pump is selected based on maximum operating pressure, flow rate whether fix or variable, types of control, pump drive speed, types of fluid, contamination tolerant, noise level, size and weight of the pump. Table 1 shows selection criteria for piston, vane or gear pump for the two systems under study.

Table 1
Selection criteria for positive displacement pump

Criteria	Gear	Vane	Piston
Pressure	Moderate	Moderate	High
Flowrate	Fixed	Fixed/variable	Fixed/variable
Weight	Light	moderate	High
Cost	Low	Low	High
Contaminant tolerant	High	Moderate	Low

Table 2 shows some important components of a ship windlass system. Some of the components are located on the forecastle deck, while some other components cannot be seen since it is kept in chain locker room or located below the deck.

Table 2
Description of windlass main components

Item No (refer to Fig 1)	Part name
1	Mooring Drum
3	Brake
4	Gear Box
5	Electro hydraulic motor
7	Chain

2.2 Mathematical Equations

Theoretical pump flow rate, Q_{pt}, was calculated by using Equation 1 [14, 15].

$$Q_{pt} = D_p W_p \quad (1)$$

where D_p is pump displacement (in cc/rev) and W_p is the pump rotational speed (in rpm). Actual pump flowrate, Q_{pa},was calculated with the incorporation of pump volumetric efficiency (η_{pv}) as shown in Equation 2.

$$Q_{pa} = \eta_{pv} \times Q_{pt} \quad (2)$$

Theoretical torque, T_{pt}, required to rotate the pump shaft was calculated using Equation 3 [16].

$$T_{pt} = PD_p \quad (3)$$

where P is the system pressure.

At the pump output, the fluid power, $\dot{W}_{pout}$, was calculated by the determining the actual flow rate and the pressure downstream of the positive displacement pump, and is given by Equation 4.

$$\dot{W}_{pout} = PQ_{pa}. \tag{4}$$

The second most important component for marine fluid power is the actuator. Depending on the exact location, either linear actuator or rotary actuator is used. Semi rotary actuator is seldom used in marine fluid power application. In achieving the rotary motion, hydraulic motors are used. The most important output from the hydraulic motor is the torque and speed. Equations 1-3 were modified and used to calculate the required pressure and flowrate in order to achieve the output torque and speed, respectively.

Double acting actuators are used to operate and provide linear motion. Different piston and rod diameters were selected to achieve the required force and speed. The following equations were used [17]

$$F_e = P_pA_p \tag{5}$$

$$V_e = Q/A_p \tag{6}$$

where F_e, P_p, A_p are the extending force, piston pressure, piston area, respectively.

3. Results

Different hydraulic systems were designed to run hydraulic windlass system and boat lift systems. Prior to system fabrication, the respective hydraulic circuit was built and tested on a hydraulic test bench (Figure 5).

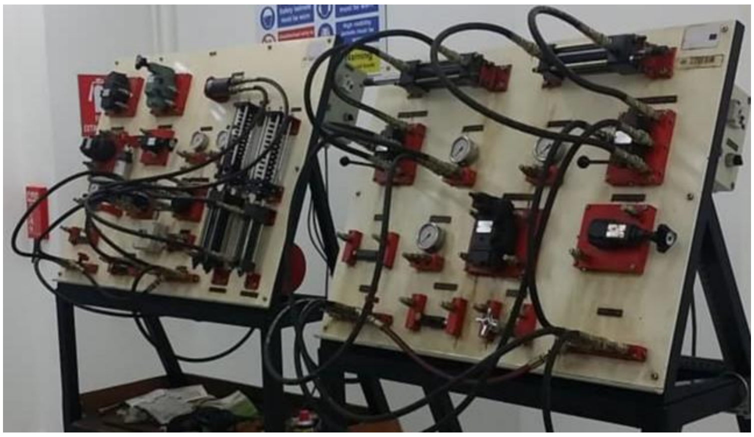

Fig. 5. Hydraulic test bench

3.1 Anchor Windlass Hydraulic System

For this windlass, hydraulic system is preferred over electrical since hydraulically operated windlass can provide larger torque capacities. Figure 6 shows a hydraulic system for anchor windlass. Since the hydraulic power pack is located under the main deck, close to ship steering gear power pack, the electrohydraulic directional control valve (DCV) is operated by solenoids for each operation. The system is then operated by an operator on main deck by pushing respective button.

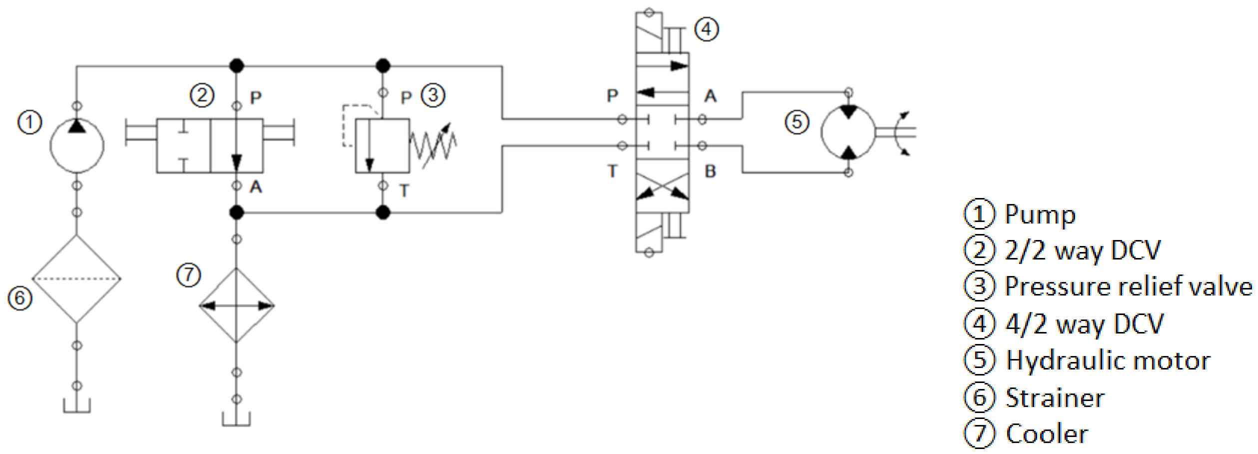

Fig. 6. Anchor windlass hydraulic circuit

Each anchor windlass is operated by bidirectional hydraulic motor. The hydraulic motor can be run or stop by using a double solenoid valve. The four-three way close centre DCV can rotate the motor either in clockwise or counter clock wise rotation.

The hydraulic oil is supplied by a fixed capacity positive displacement piston pump. In order to protect the pump and the system from contamination, a strainer is provided. A pressure relief valve which has capacity setting of 200 to 250 bar is used to protect the whole system from over pressurised.

In this paper, for anchor windlass system, only calculation of electro hydraulic motor and piston pump are presented. In this work, anchor windlass is designed for very low speed between 5-10 rpm. Nominal mooring speed is 15m/min. Drum diameter is 0.5m and the drum capacity is 80mm x 150m. Holding load on the first layer of mooring drum is 450kN.

The mechanical and volumetric efficiencies for the hydraulic motor are assumed to be 96% and 94%, respectively. Based on Equations 1 and 2, modified for hydraulic motor purpose, the system hydraulic oil flow rate is calculated to be 224L/min. Modifying Equation 3, the system pressure required to operate the hydraulic motor is 19Mpa or 190 bar. 10 bar pressure drop is assumed in the main pressure line. Taking into account 15% safety factor, the single acting pressure relief valve is set at 230 bar.

The pump is expected to operate for 20 years. Thus a strainer is fitted at the pump inlet line to filter out large to medium size contaminants. In order to lengthen the oil lifetime, a cooler is install in the return line. By using Equation 4 and by assuming overall pump efficiency of 90%, the power input to run the pump is 86 kW or 115 HP.

Considering the system requirement, the technical specification of the pump systems are:

- Maximum capacity 5 cm^3/rev
- Minimum rotational pump speed – 800rev/min
- Maximum rotational pump speed – 2500 rev/min
- Maximum pressure – 26 MPa or 260 bar

3.2 Boat Lift

Two life boats are kept on this ship. Figure 7 shows the hydraulic circuit designed to operate the boat lift. The hydraulic system shows that two hydraulic motors and two hydraulic cylinders are used to handle one life boat. The hydraulic motors are used to release the life boat cable and the cylinders to tilt the system. Single acting cylinders are used to raise the object, while during retract, it is pulled down by gravity. The bidirectional motors are used since the boat need to be lowered during emergency or training drill and the boat need to be placed again at its original position after use.

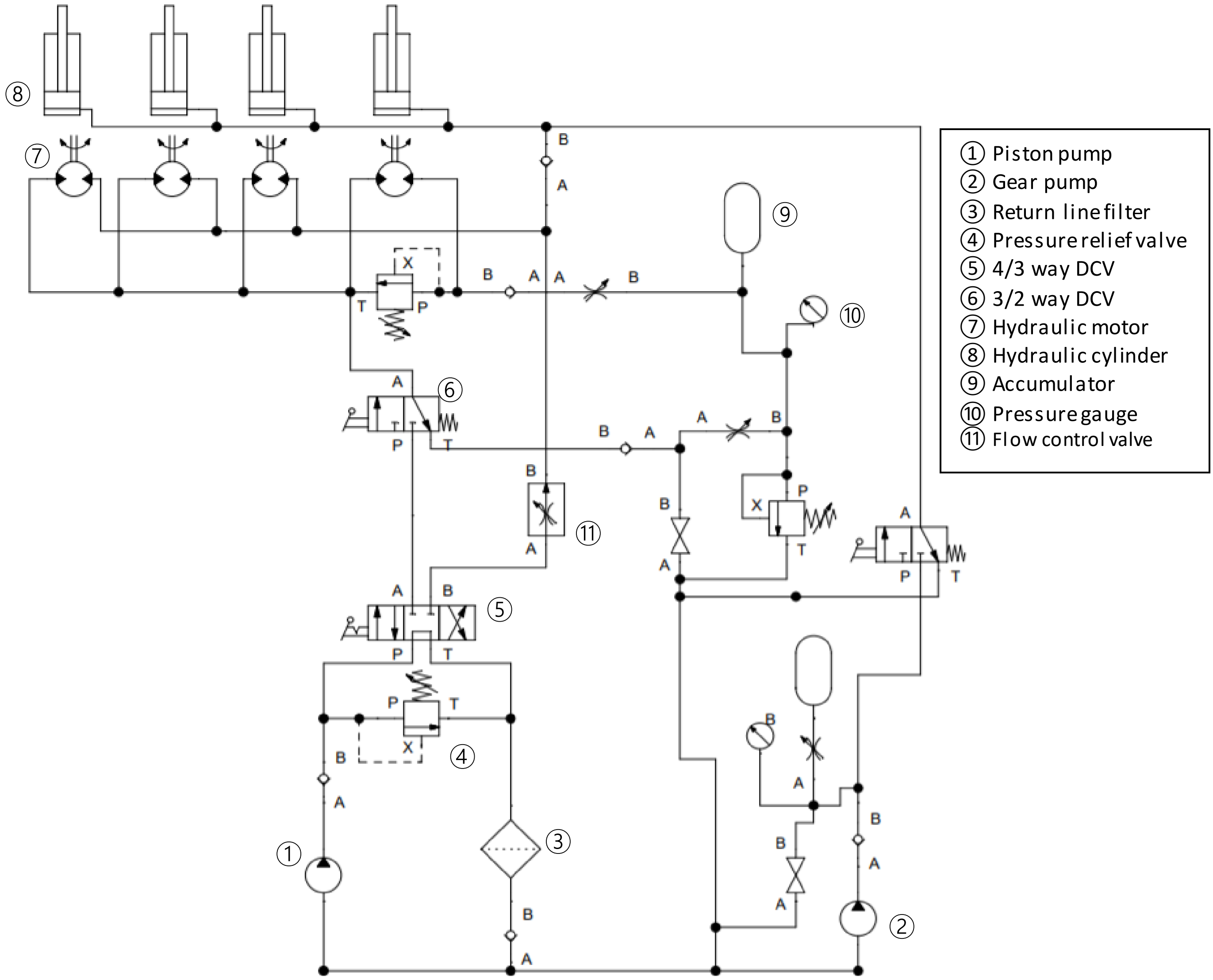

Fig. 7. Boat lift hydraulic circuit

Main 4/3 way directional control valve is used to ensure the hydraulic motor can be put in stationery position, rotating clock wise or counter clock wise position. Tandem centre position is chosen so that the hydraulic fluid is channel direct to tank without much resistance, thus eliminating the need for a heat exchanger.

Assuming the start and restart of the boat launching process can made from captain's bridge, the hand lever 4/3 way DCV and 3/2 way DCVs can be replaced with solenoid control.

The boat launching process comprises simultaneous lowering of the lifeboat in a row under gravity. When the lifeboats drop under gravity, slight acceleration is experienced. This requires additional flow rate supplied to the actuators. In order to cater for fast motion, extra flowrate is required close to the actuator. In this system two hydraulic-gas accumulators are used, one close to actuator and the other close to back-up pump. These accumulators can provide extra hydraulic oil for a short period. Based on criteria in Table 1, gear type is used as the back-up pump while piston type is selected to work as the main pump.

Before initiation of the evacuation process, the gate valves which secure it in voyage position, should be unblocked. The unblocking is realized by switching over the distributor. This results in oil flowing under pressure from the accumulator to the cylinders of the gate valve blockade and hook blockade.

The set of blockades is designed as to obtain the pressure value necessary to unblock the gate valves lower than that to unblock the hooks. This ensures the desirable sequence of triggering mechanisms. In normal conditions, the accumulators are charged by the second fixed displacement pump.

Starting and stopping process of the motor is controlled by the pressure transducer in such a way as to keep the pressure in the accumulator within a determined range of values. In order to increase reliability of the device in long-lasting failure conditions, the additional hand pump can be provided.

It is estimated that each boat weight of 2.5 ton with some passengers on board. With the use of two cylinders to handle each boat, the load is distributed 1.25 ton to each linear actuator. The system is designed to operate with 250 bar pressure. With the use of Equation 6, the suitable flowrate is calculated to be 50 lit/min. With this flowrate, the hoisting speed can reach up to 5 m/min maximum.

4. Conclusions

Fluid Power is widely used in offshore and ship application. Hydraulic system is more preferred as it can provide higher power due to its higher pressure. The proposed hydraulic systems for anchor windlass and boat lift have been designed and tested in Hydraulic Laboratory, Maritime Technology Department, School of Ocean Engineering, Universiti Malaysia Terengganu. The hydraulic systems was tested on a combined hydraulic bench. Various components are put together on the hydraulic test bench and workability of the system was examined. Flow rate and pressure were determined using respective pump and actuator equations. The systems work perfectly as designed.

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