HYDRAULICS AND PNEUMATICS

Chapter – 1

UNIT III HYDRAULIC CIRCUITS AND SYSTEMS

Accumulators, Intensifiers, Hydrostatic transmission, Electro hydraulic circuits.

ACCUMULATORS

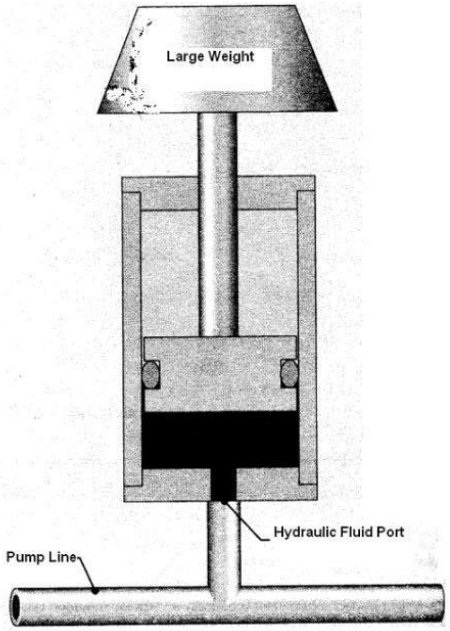
Accumulators are devices that store hydraulic fluid under pressure. Storing hydraulic fluid under pressure is a way of storing energy for later use. Perhaps the most common application for an accumulator is supplementing the pump flow in a hydraulic system in which a high flow rate is required for a brief period of time.

Types;

1. Weight loaded accumulator
2. Spring loaded accumulator
3. Gas charged accumulator
4. Piston type
5. Bladder type
6. Diaphragm type

WEIGHT LOADED ACCUMULATOR

It is basically a vertically mounted cylinder with a large weight as show in Figure.



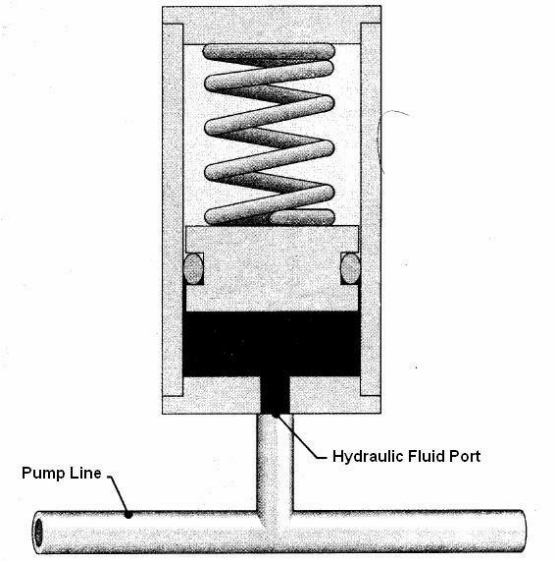
When hydraulic fluid is pumped into this accumulator, the weight is raised. The weight then applies a force to the piston, which generates a pressure on the fluid side of the piston. The advantage of this type of accumulator over all of the other, it applies a constant pressure on the fluid throughout its entire range of motion. The disadvantage is that a very large weight must be used to generate enough pressure. Because of that this type is seldom used.

SPRING LOADED ACCUMULATOR

A spring loaded accumulator stores energy in the form of a compressed spring as shown in figure.

Hydraulic fluid is pumped into the accumulator, causing the piston to move up and compress the spring. The spring then applies a force on the piston that exerts a pressure on the hydraulic fluid. The

pressure is constantly decreasing as hydraulic fluid is drawn out because the spring decompresses and therefore exerts less force on the piston. This type is not commonly used in hydraulic circuit because a large spring must be used to generate enough pressure.

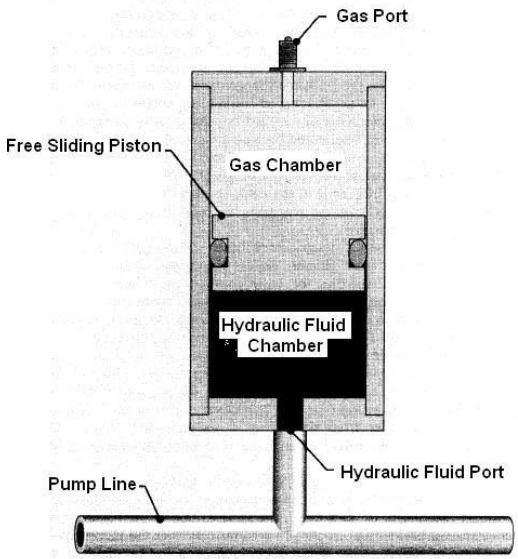


PISTON TYPE ACCUMULATOR

The basic construction of a piston type, gas charged accumulator is shown in Figure.

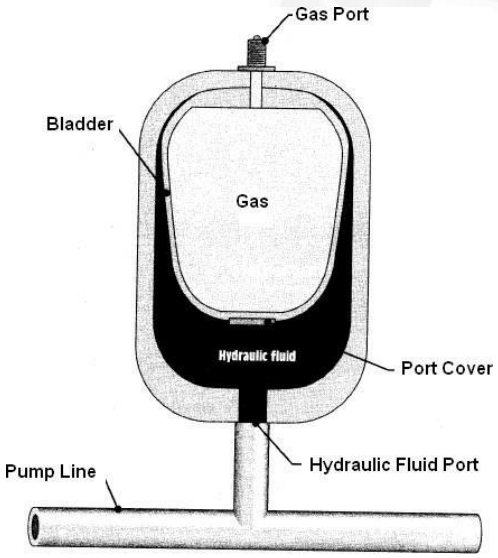
Its operation begins when the gas chamber is filled with a gas to some predetermined pressure called the pre-charge, which causes the free-sliding piston to move down. Once the accumulator is pre- charged, hydraulic fluid can be pumped into the hydraulic fluid port.

As the hydraulic fluid enters the accumulator, it causes the piston to slide up, thereby compressing the gas. Compressing the gas increases its pressure, and this pressure is then applied to the hydraulic fluid through the piston. Because the piston is free sliding, the pressure on the gas and the hydraulic fluid is always equal. Whenever the pressure in the system drops below the pressure in the accumulator, fluid will flow out of the accumulator and into the system. As the hydraulic fluid flows out of the accumulator, the gas decompresses and loses pressure, which in turn causes the pressure on the hydraulic fluid to be reduced. The gas used to pre-charge accumulator is usually nitrogen because it is an inert gas and does not support combustion.



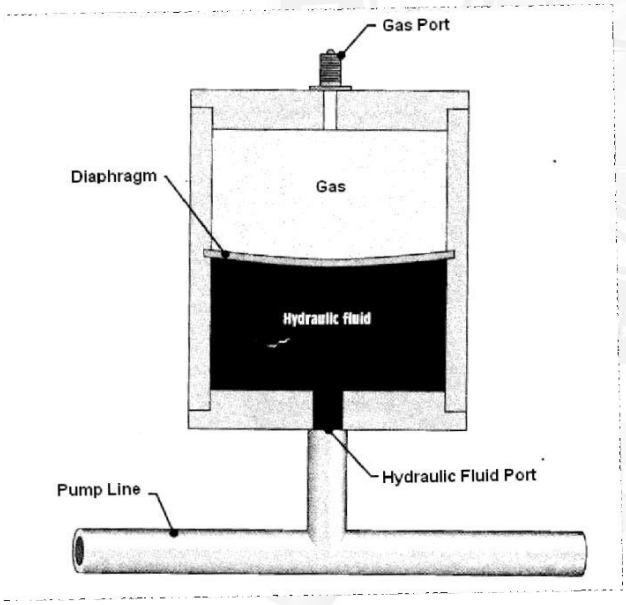
BLADDER TYPE ACCUMULATOR

The basic construction of a bladder type accumulator is shown in Figure. These accumulator functions in the same way as a piston accumulator, storing energy in the form of a compressed gas. However, instead of the gas and hydraulic fluid being separated by a piston, they are separated by a synthetic rubber bladder. The bladder is filled with nitrogen until the desired pre- charge pressure is achieved. Hydraulic fluid is then pumped into the accumulator, thereby compressing the gas and increasing the pressure in the accumulator, just as with the piston type. The port cover is a small piece of metal that protects the bladder from damage as it expands and contacts the hydraulic fluidport.



DIAPHRAGM ACCUMULATOR

The vessel is separated into two components by a flexible diaphragm. One compartment is connected to the hydraulic system and the other to the high pressure gas system. Thus the diaphragm serves as an elastic barrier between the oil and the gas. When the oil is delivered into the accumulator, it deforms the diaphragm. The gas is compressed when the charged oil pushes the diaphragm against it. This gas pressure is used as the potential energy to force the oil out when it is required in the circuit. The advantage of bladder and diaphragm accumulators over the piston type is that they have no sliding surface that requires lubrication and can therefore be used with fluids with poor lubricating qualities. They are also less sensitive to contamination due to lack of any close fitting sliding components.



NON-SEPARATED TYPE ACCUMULATOR

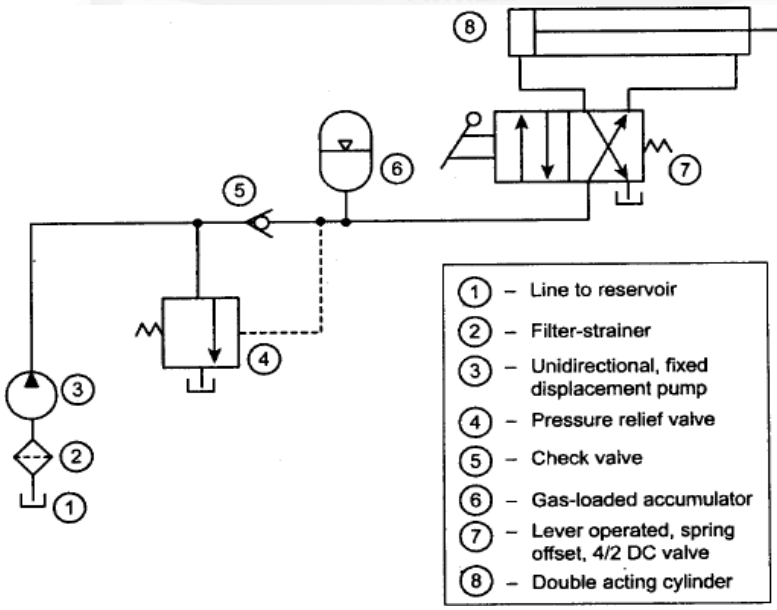
It consists of a fully enclosed shell containing a gas charging valve on the top and an oil port on the bottom. The confines at the top and oil remain at the bottom and there is no physical separator between them. Since the gas has direct contact with the oil, this type is termed as non separator type accumulator. Due to the absence of separator, the gas is absorbed and also entrapped in the oil. This accumulator type is not preferred for use with

high speed pumps because the entrapped gas in the oil may cause cavitation and damage to the pump. The problems of aeration of the oil often limit their use in hydraulic system.

ACCUMULATOR CIRCUITS:

1. ACCUMULATOR AS LEAKAGE COMPENSATOR

The stored energy of the accumulator can be used to compensate any possible loss of energy due to internal or external leakage in a system. This application is extremely helpful in circuits, such as are used for hydraulic presses, which require high pressure for long periods. First operator places work piece on the press and shifts handle of the 4/2 DC valve. Now the oil flows to blank end of cylinder and piston extends. The pressure builds up and oil fills the accumulator. When maximum pressure is reached, the pressure switch stops the pump motor. In these applications, the cylinder and piston arrangement is required to press the work piece for a longer period of time. During this period, the internal and external leakage may reduce the cylinder pressure. The leakage oil is replaced with the oil from the accumulator. This leakage replacement of oil is carried for a longer period of time. The maximum length of time is determined by the volume of the accumulator and the rate of leakage in the cylinder. When the pressing cycle has been completed, the operator shifts the handle of the 4/2 DC valve to original position. Thus a cycle is completed.



2. ACCUMULATOR AS AUXILIARY POWER SOURCE

As we know, the electric motor or pump motor is a primary power source. In this application, the accumulator stores the oil during one portion of the work cycle and releases the oil during the remaining cycle. Thus accumulator serves as a secondary power source. Figure shows the circuit using accumulator as a secondary power source. After placing the work piece on slide table and shifts handle of 4/2 DC valve. Now oil flows from the accumulator to blank end of slide cylinder. This extends the piston until slide table reaches end of stroke. When the cylinder is in the fully extended position, the accumulator is charged with the oil by the pump. Then the operator shifts the handle of 4/2 DC valve for the retraction of the cylinder. Now the oil flows from the pump as well as from the accumulator to retract the cylinder quickly.

3. ACCUMULATOR AS EMERGENCY POWER SOURCE

In some hydraulic applications, it is necessary to retract the pistons of cylinder to their starting position; even there may be an electrical power failure. In such applications, the accumulator can be used as an emergency power source to retract the piston of the cylinder. When operator depresses push button energizing solenoid of the 3/2 DCV, oil flows to blank end of cylinder. At the same time, the oil also unseats check valve. So the oil under pressure flow to rod end of cylinder and into the accumulator. When there is a power failure, the solenoid will de-energize. In the absence of solenoid energy, the spring pressure forces the valve to shift to its spring offset mode. Now the oil stored under pressure is forced from the accumulator to the rod end of the cylinder. Thus the piston of the cylinder retracts to the starting position.

4. ACCUMULATOR AS HYDRAULIC SHOCK ABSORBER

In many high pressure hydraulic systems, the sudden stoppage of a hydraulic fluid flowing at high velocity in pipelines can cause considerable damage to the piping. This hydraulic shock, also known as water hammer, may snap heavy pipes, loosen fittings and cause leaks. By

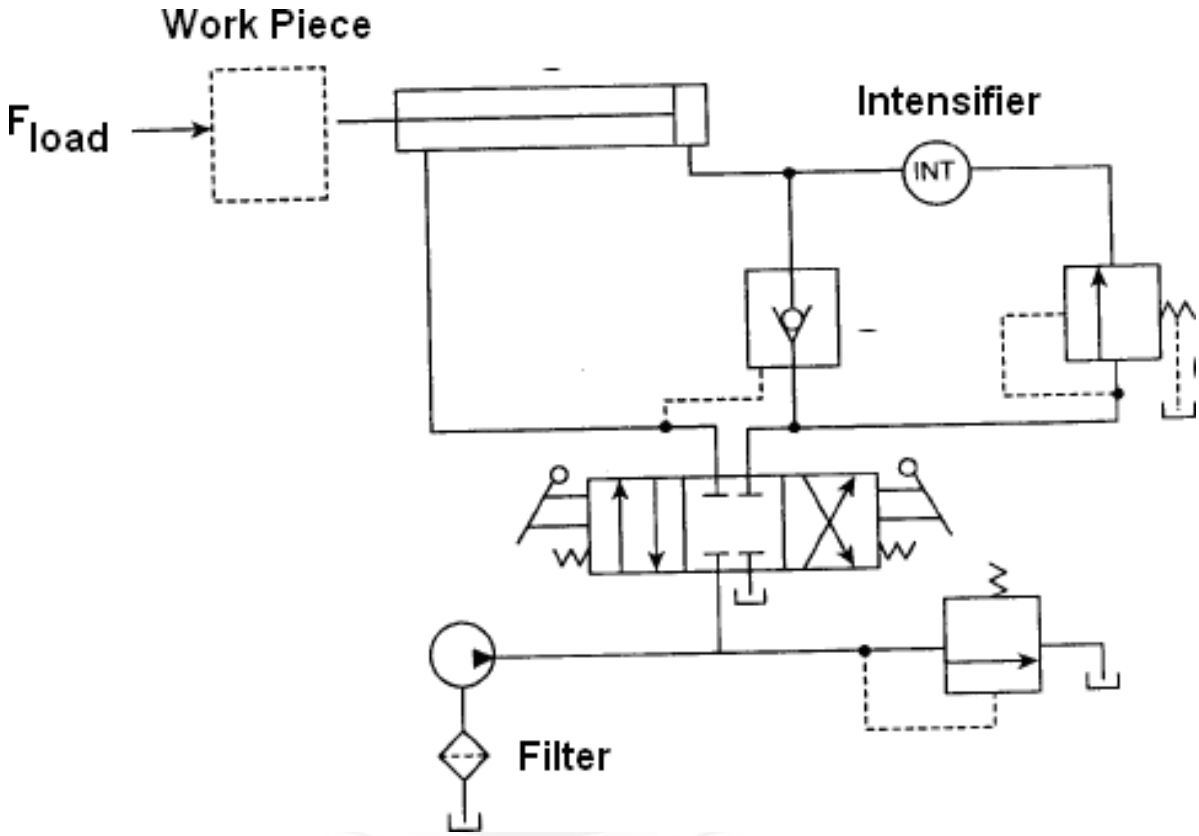
installing an accumulator, this high pressure pulsations or hydraulic shocks can be absorbed. Figure shows the circuit employing accumulator for serving as a hydraulic shock absorber. The accumulator installed near the shut-off point in order to be more effective in quickly absorbing the shock wave. When the system demands to shut-off the supply suddenly, a 2/2 shut-off valve is used for the purpose. When operator shifts handle of the 2/2 emergency shut-off valve, the fluid flow is stopped suddenly. This results in high-pressure pulsations or hydraulic shock. The pressure pulsation is blocked by check valve. The surges between the check valve and the shut-off valve are used to store the oil in accumulator and thus the pressure pulsations of the oil in the pipe line are absorbed.

INTENSIFIER

Pressure intensifier or boosters are devices used to generate pressure greater than those achievable with standard hydraulic pumps alone. They take the inlet flow from the pump and intensify the pressure.

The intensifier is shown on the forward stroke. In this situation, the pump flow (Q pump) is fed into port A of the intensifier, which applies a pressure (P pump) to the piston, causing it to more right. This in turn generates a force that is applied to the rod. The force on the rod then creates pressure and flow at the outlet to the system. When the four way directional control valve is shifted to the opposite position, the pump flow is sent to port B of the intensifier, causing the piston to move left. This causes fluid to be drawn into the rod chamber which completes one cycle. The Figure shows the usage of intensifier in the punching machine. After placing the work piece in the fixture and shifts handle of 4/2 DCV to the right side, the oil flows to the blank end of the cylinder through the check valve. When the pressure in the cylinder reaches the sequence valve pressure setting, the sequence valve opens and supplies the flow to the intensifier. Now the intensifier starts to operate and gives high pressure output. This high

pressure output of the intensifier closes the pilot check valve and pressurizes the blank end of the cylinder to perform the punching operation. When the 4/2 DCV is shifted to the left side position, the oil flows to the rod end of the cylinder. When it builds-up the pressure, the pilot signal opens the check valve. Thus the cylinder is retracted to the starting position.



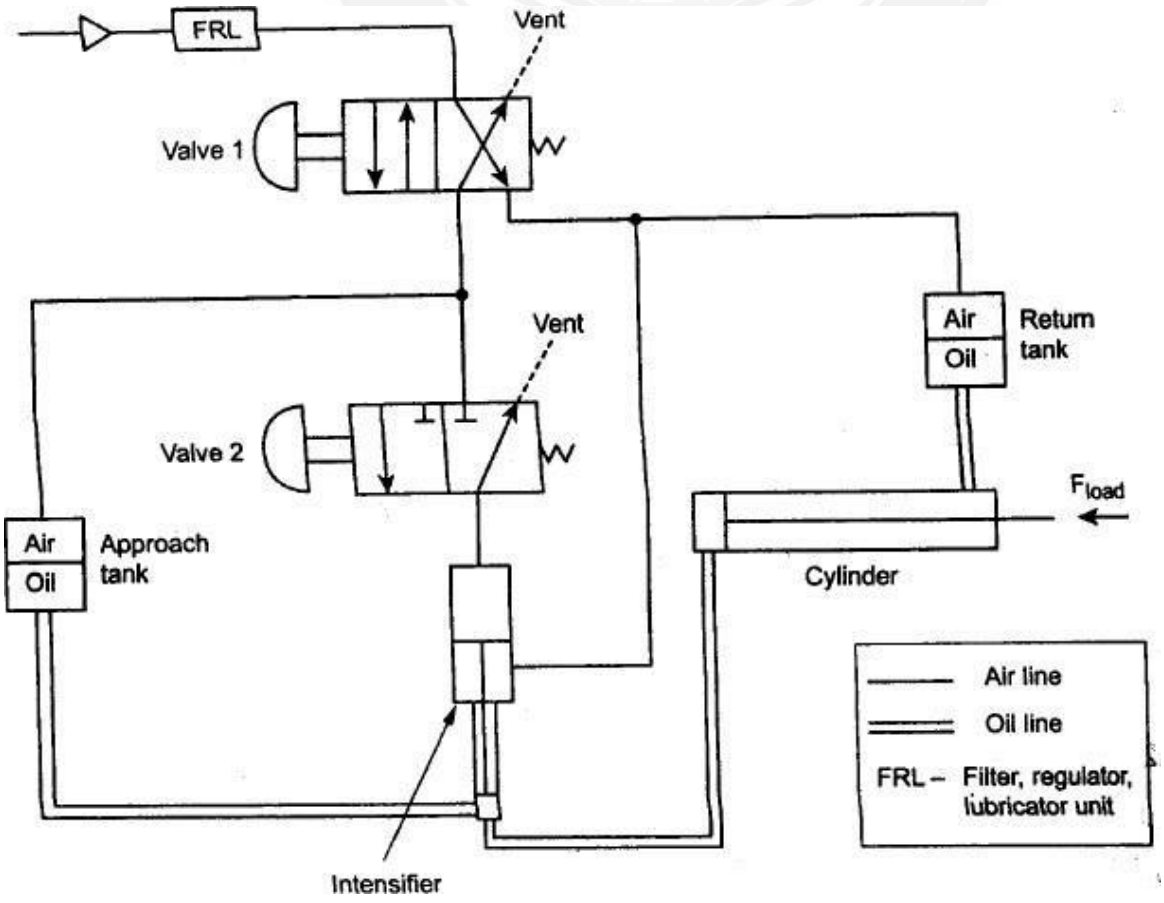
Pressure Intensifier Circuit

AIR-OVER-OIL INTENSIFIER CIRCUIT

In some applications, the hydraulics and pneumatics circuits are coupled to best use of the advantage of both oil and air mediums. This combination circuit is also known as hydro-pneumatic or dual pressure systems. Figure shows a typical air-over-oil intensifier. This circuit can be used for drawing a cylinder over a large distance at a low pressure and then over a small distance at high pressure. This circuit consists of two lines- air lines and oil lines. In the circuit the air lines are shown by single lines and oil lines by double lines. When the first 4/2 DCV valve1 is shifted to left mode,

the air from the reservoir flows to the approach tank. In the approach tank, the air forces the oil to the blind end of the cylinder through the bottom of the intensifier, as shown by double lines. Now the cylinder extends. When the cylinder experiences its load, the second 4/2 valve2 is actuated to the left mode. This valve position sends air to the top end of the intensifier. Now the intensifier moves down, and the piston of the intensifier blocks the path of oil from the approach tank. Now the cylinder receives high pressure oil at the blind end to perform the useful work such as punching operation.

When the valve2 is released, the air flow from the reservoir is blocked. The air from the top end of the intensifier is vented to the atmosphere. This completes the high pressure portion of the cycle. When valve1 is released, the air flow is diverted to return tank and also the air in the approach tank is vented. The diverted air flow pushes the oil to the rod end of the cylinder. This causes the cylinder to retract. The oil from the piston end of the cylinder is diverted back to the approach tank through the bottom end of the intensifier. This completes the entire cycle of operation.



HYDROSTATIC TRANSMISSION

The increasing demand for power transmission systems in military, industrial application, hybrid vehicles, wind turbine system, etc., is due to its higher power density, compactness, low cost and improved. overall efficiency. The Hydraulic transmission system, require a hydraulic motor with high power to weight ratio. Gangway et all presented an essential function of HST, which used to accept energy from input then transmit and regulate the energy within the HST and deliver energy to the output load which is connected to hydraulic motor. The pump is connected directly to the motor.

The pump may be fixed or variable depending upon the applications. If the pump is variable displacement then it is easy to adjust the output speed of the motor in order to get the desired output speed or torque from the motor because power depends on torque and rotational speed. Then it is feasible to regulate the speed ratio between pump and motor.

Hydrostatic transmission system primarily can be classified as

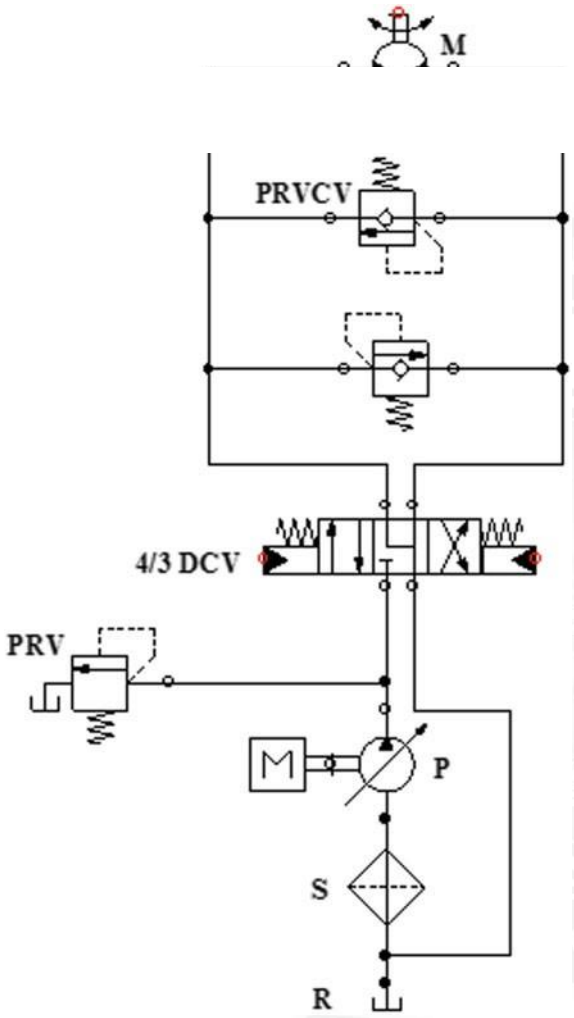
open loop HST and closed loop HST system.

Open Loop Hydrostatic Transmission System

Open loop HST is a system in which the pump is not directly connected to the hydraulic motor. It mainly consists of reservoir, filter, and pressure relief valve, fixed or variable displacement hydraulic pump or motors. A simple circuit diagram of an open loop hydraulic mechanism has been shown in Fig.

As shown above, in open loop hydraulic system, Gangway et al. said that electric motor or IC engine work as a prime mover that steer the fixed or variable displacement hydraulic pump. The fluid from reservoir flows to hydraulic motor that is controlled by directional control valve. The output shaft of hydraulic motor is connected to loads like flywheel, propeller or other mechanical devices. The PRV is used mainly for protection of the transmission circuit. The PRV is

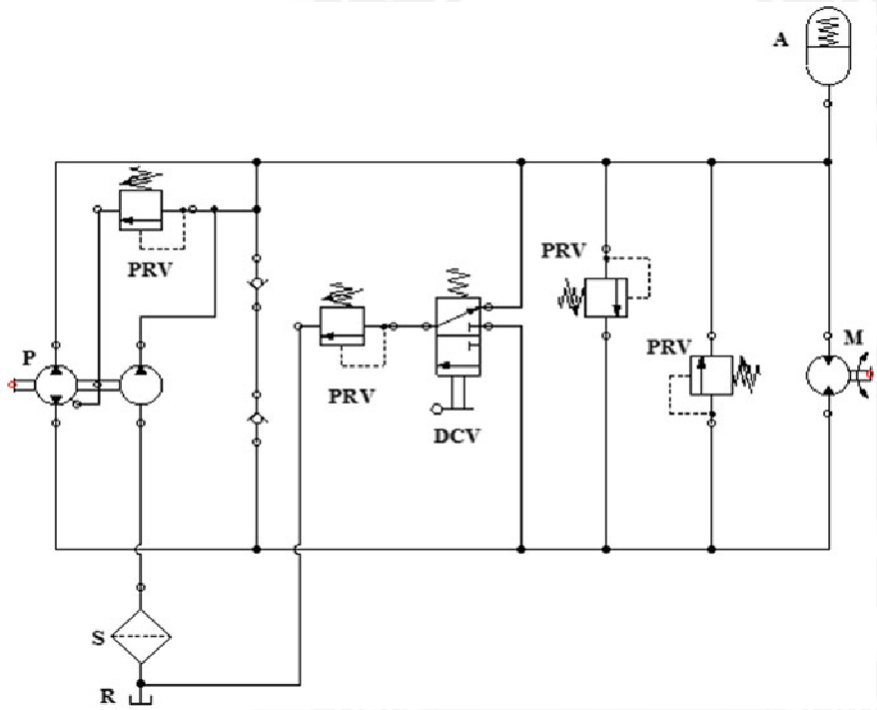
used to limit the pressure in the circuit up to a certain level and when the pressure in the circuit exceeds the maximum set value then the fluid comes back to the reservoir.



Open loop HSTsystem

Closed Loop Hydrostatic Transmission System

Closed loop HST consists of two circuits— the main circuit and one frame or charge circuit. In main circuit prime movers like IC engine or electric motor, variable dis- placement pump, PRV, DCV, hydraulic motor is included and charge circuit mainly includes make-up pump. Esposito discussed about pressure reducing valve, which is used for safety purpose, i.e. avoid damaging of the circuit. If the pressure at output of pump or input of motor is larger than the set pressure, then the pressure reducing valve opens and the fluid flows to the reservoir through reducing or safety valve to stop exploding of the motor and main circuits, charge circuit or structure circuit, else, valve stays closed as shown in Fig.



Closed loop HST system

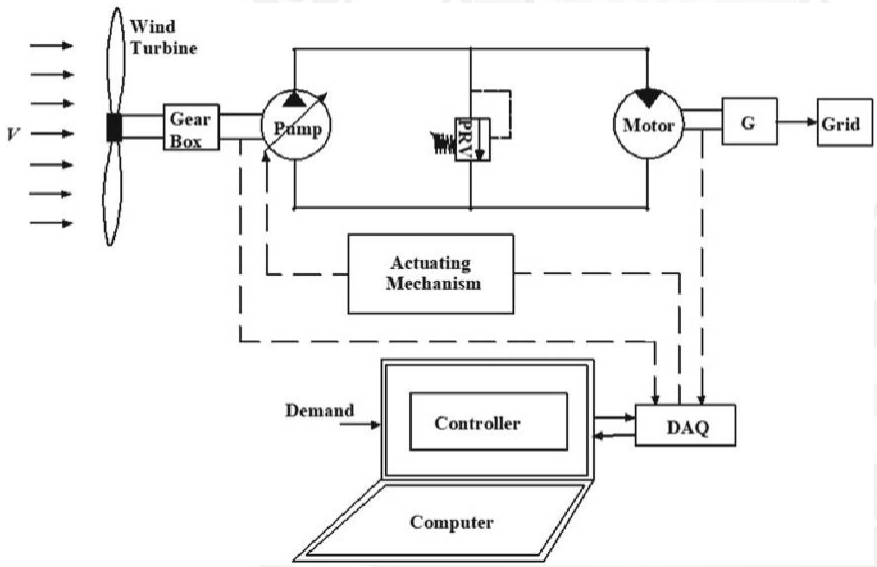
Application of Hydrostatic Transmission System in Wind Turbine System

This section presents the application of HST system. HST system used in most applications such as wind turbines, automobiles, heavy industries, etc., because of its high torque to inertia ratio. Figure shows the HST system used in a wind turbine. It consists of a variable displacement hydraulic pump, a fixed displacement hydraulic motor, pressure relief valve, check valve, controller and a generator.

The prime mover is the wind turbine which converts kinetic energy into mechanical energy and the hydraulic pump is directly connected to hydraulic motor

which converts hydraulic energy to mechanical energy at the output of the shaft. said that hydrostatic transmission system provides a different source to mechanical drives like gearbox applications in wind turbines. In a typical turbine, power transmitted from blade to low-speed shaft, to generator and then to high-speed shaft

by utilizing a gear case. discussed that PID controller and adaptive fuzzy sliding mode controller has been used in wind turbine. Data acquisition system (DAQ) measures the physical phenomenon such as wind velocity, etc., with a computer which consists of DAQ measurement hardware, sensor and a computer with programmable software. An actuating mechanism has been provided which has been connected to variable displacement hydraulic pump to control the rate of fluid flow. It has been generally noticed that the energy from wind has been fluctuating in nature thus leading to a varying power output with time.



Schematic diagram of HST system in wind turbine

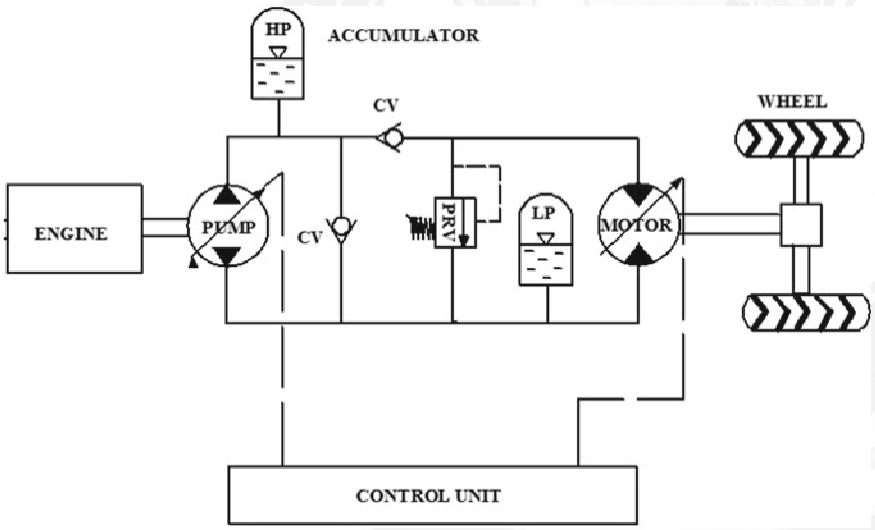
Application of Hydrostatic Transmission System in Automobile Sector

The design of the hydrostatic transmission system in automobiles consists of pressure relief valve, check valve, high pressure accumulator, hydraulic pump and hydraulic motor. proposed that pump generates a partial vacuum at the inlet of pump due to rotation of shaft which allows atmospheric pressure to power the fluid into the pump through suction line. The hydraulic pump thrusts the fluid

mechanically into hydraulically actuated devices like cylinder or motor.

The flow rate from the pump can be increased or decreased by varying the swash plate angle. When the swash plate is perpendicular to the drive shaft the piston stroke stops which does allow forced the fluid from the pump.

The gear pump has been used for the fluid power system of weight handle system like trucks, cranes, buses, etc., as the discharge per revolution has been fixed. In Fig. accumulator has been used to store energy in the form of potential energy. In this circuit, two accumulators are used—one is at high pressure line and the other at low pressure line as shown in Fig. When the power requirement in output shaft has not been sufficient then, it takes energy from the accumulators. Finally the output of motor shaft has been connected to the wheel.



Schematic diagram of HST system in automobile sector

ELECTRO-HYDRAULIC CIRCUIT

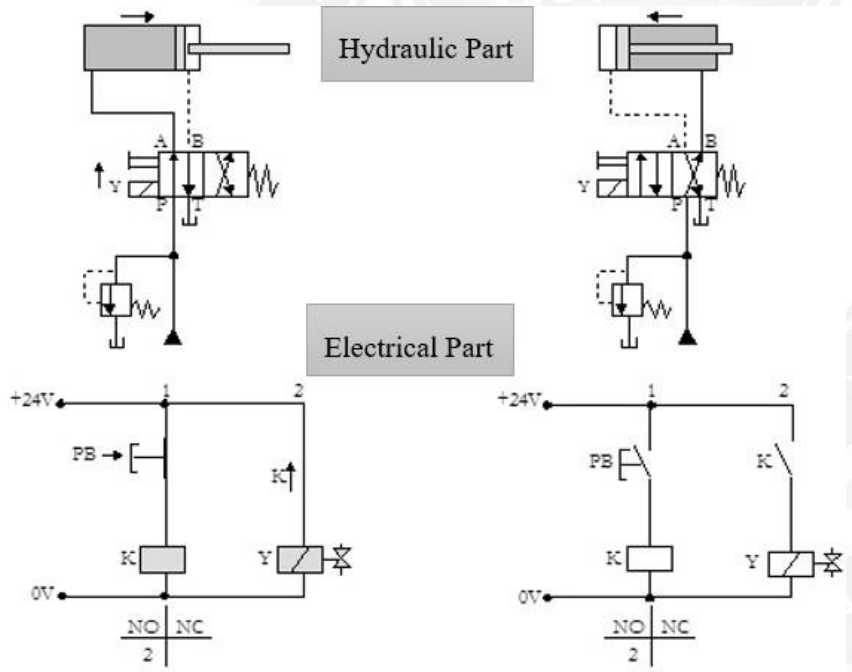
Electro-hydraulic circuit consists of different components such as electric motor which converts electric energy into mechanical energy, the pump which converts mechanical energy into hydraulic energy and the actuator convert back hydraulic energy into mechanical energy. Control elements like valves are used which controls the fluid in the circuit such as direction control valves, flow control valves, solenoid valves & pressure relief valves, etc

Relay-based Electro-hydraulic Systems

In the electrical actuation of a hydraulic valve, the necessary actuating force is obtained electrically with the help of a solenoid. The off- centre core of the solenoid coil is pulled towards the center of the coil when the electric current is passed through it. This discrete movement of the core is used to actuate the solenoid valve. The solenoid valve in an electro-hydraulic system acts as an interface between the hydraulic part and the electrical part of the system.

Indirect control of a double-acting hydraulic cylinder using a relay.

Two positions of a self-explanatory electro-hydraulic circuit for the indirect control of a double-acting hydraulic cylinder are given in Figure



(a) Position when cylinder is extended (b) Position when cylinder is retracted