

Oil Hydraulics and Pneumatics
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Subsystems: Hydraulic accumulators, Classifications, Applications, Accumulator physics, Maintenance, Numericals

Lecture - 65

Part 2: Some typical applications of accumulators, Accumulators physics – dictated by compressed gas laws, Stored energy

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Some Typical Applications of Accumulators

- Different types of accumulator have been discussed in the previous slides and each having its own advantages, disadvantages and application
- From the application point of view, the accumulators mainly used as an
 1. Auxiliary power source or secondary power source or Supplementing pump flow
 2. A leakage compensator or to makeup a leakage
 3. A hydraulic shock absorber or surge dampening
 4. An emergency power source
- 1. **Supplementing pump flow** (Here accumulator acts as a auxiliary power source or secondary power source)
- This is probably the most important application in a hydraulic system
- During resting periods of the pump, when oil is not needed to move a cylinder, the pump can store oil under pressure in an accumulator
- Later, when the cylinder is ready to move, oil from the accumulator can add to the normal flow from the pump to produce a faster speed from the cylinder than with pump oil alone



My name is Somashekhar course faculty for this course. Now we will move on to some Typical Applications of Accumulators. Different types of accumulator have been discussed in the previous slides and each having its own advantages disadvantages and applications.

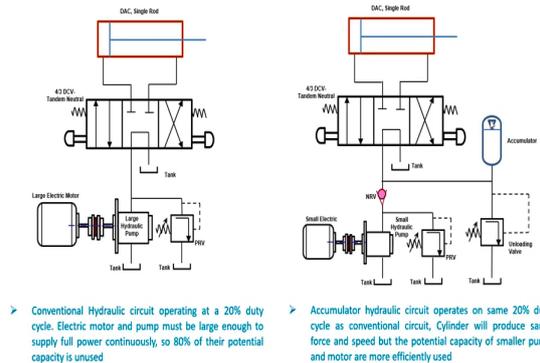
From the application point of view the accumulators mainly used as an auxiliary power source or secondary power source are also supplement to the pump flow, all comes under the same category meaning supporting the main power supply from the pump flow.

A leakage compensator or to make up a leakage, a hydraulic shock absorber or a surge dampening, an emergency power source as and when required these applications we will see one by one in the next slides. First we will see the how accumulator supplementing the pump flow, this is probably the most important application of accumulator in hydraulic circuits.

During resting periods of the pump when oil is not needed to move the cylinder the pump can store oil under pressure in an accumulator. Later when the cylinder is ready to move oil from the accumulator can add to the normal flow from the pump to produce the faster speed from the cylinder than with the pump alone.

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- Because of the cost of the accumulator and accessory equipment, this application is worthwhile only on applications where the pump remains idle for a large percentage of total working time- that is, while the cylinder is retracting and when parts are being loaded and unloaded from the machine
- As a rule-of-thumb, an accumulator should be considered if the pump is working at full load less than 20% of the time and is unloaded more than 80% of the time



Because of the cost of the accumulator and accessory equipment this application is worthwhile only on applications, where the pump remains idle for a large percentage of total working time.

That is while the cylinder is retracting and when parts are being loaded and unloaded from the machine, that time no working strokes. Meaning all are the ideal strokes for load the part or unload the parts or when the cylinder is retracting no actual work is not going on that time how to overcome such problems. Meaning the pump flow is very very important.

As a rule of thumb an accumulator should be considered if the pump is working at full load less than 20 percent of the time and is unloaded more than 80 percent of the time. You will

see here friends I have drawn the hydraulic circuit here with and without the accumulator, to understand the role of accumulator in supporting the fluid powers circuit.

You will see here in the first figure the double acting cylinder single rod which is controlled through the 4 by 3 directional control valve at tandem neutralities. Because pump flow is connected to the tank in the middle position, it is the push button actuation spring centered. Here it is a I am using the large hydraulic pump. In the meaning it will eject the large quantity of fluid flow to do this we require the large electric motor, then it is a pressure relief valve to control the system pressure.

But you will see friends here when the cylinder is extending to do the useful work we require the large quantity of fluid to overcome the resistances and also the speed of the actuator that time the pump is sending the flow to the head side and tail side it will go to the tank in the parallel configuration. But when the cylinder is retracting after doing the useful work again the pump flow is going to the tail side and head side flow is going to the tank in the crossed configuration.

But during the ideal work the pump is ejecting the fluid more that is not required. So, what to do now? To overcome such type of situations, I am using the power pack very smaller power pack which will ejects the small quantity of fluid to do the working stroke, then to supplement to return stroke or any idle thing I am drawing the fluid from the accumulator. Now we will see here in the circuit when the cylinder is extending through the parallel configuration the fluid is stored in the accumulator also along with the cylinder stroke.

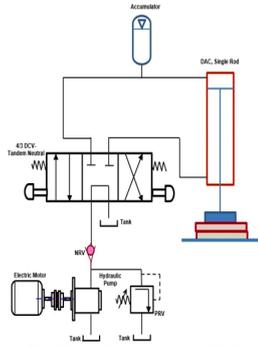
Meaning here the hydraulic fluid enters the accumulator and compresses the gas, meaning it will stores to the system pressures. Once the system pressure is reached in the accumulator here you will see unloading valve is there then it is bypassing the flow to the tank.

When it is returning stroke taken place that time no work no load that time the small pump is supported with the accumulator flow to make the same force to return, this is the beauty of accumulator it supports the pump flow.

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2. Accumulator to makeup Leakage

- On hydraulic presses used for moulding, laminating, bonding, curing, etc., it may be necessary to hold pressure on the work during the curing period
- Active pressure must be maintained on the work during this time; otherwise, the piston force will relax due to small leakages across piston seals and valve spools
- A pressure compensated pump can be used and it will reduce its pumping rate to just enough to make up leakage
- Or if using a fixed displacement pump an accumulator across the cylinder port will supply leakage oil and permit the pump to be unloaded
- The pump should not be allowed to discharge across a relief valve during this period
- Circuit operation is as follows: When the operator shifts the 4-way valve, the press closes and at stall, pressure builds up



► An accumulator can supply make-up oil to replace leakage losses in cylinder piston seals and 4-way spool valves



Next application is Accumulator to makeup a Leakage, this is also very important application of accumulator when the leakage takes place between the piston and cylinder or a valve. What happens? The whatever the force is required to hold the work piece goes on reducing. How to do this?

If you are using the pressure compensated pumps that will support the extra flow leakage flow to support it, if you are using the positive displacement pump there is a flow that time the additional flow is supplied through the accumulator that is a beauty of accumulator. When there is a leakage between the moving parts.

Some application like on hydraulic presses used for molding, laminating, bonding, curing etcetera, it may be necessary to hold pressure on the work during the curing period. Active

pressure must be maintained on the work during this time otherwise the piston force will relax due to small leakage across the piston seals and valve spools.

A pressure compensated pump as I have told you can be used and it will reduce its pumping rate to just enough to make up a leakage or as I have told you if you are using the fixed displacement pump an accumulator across the cylinder port will supply the leakage oil and permit the pump to be unloading.

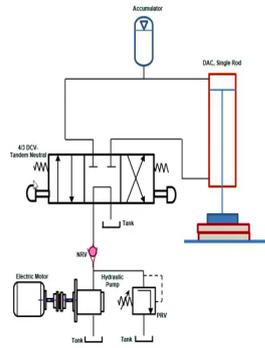
You see here in the head side I am putting the accumulator. Already we know that in the working stroke the flow is coming from the hydraulic pump that time it is charging and then once it is touched the work piece then the flow will cut off.

But due to the leakage between the various parts this pressure holding pressure is goes on decreasing, then we have to supply the extra flow this is drawn through the accumulator that is why it is known as accumulator to make up a leakage, to maintain the constant pressure during the operations.

The pump should not be allowed to discharge across a relief valve during this period. Circuit operation as I have drawn you here is as follows, when the operator shifts the 4 way valve the press closes and at stall pressure builds up.

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• Accumulator to makeup Leakage



- When full pressure has been reached the accumulator is in a charged condition
- The operator may then shift the valve to neutral position to unload the pump
- Leakage from the circuit will be made up from the accumulator
- But remember that as oil discharges from the accumulator its pressure will fall according to the amount of oil fed out into the circuit



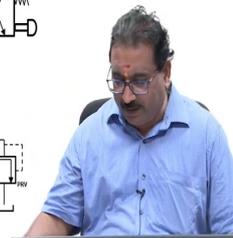
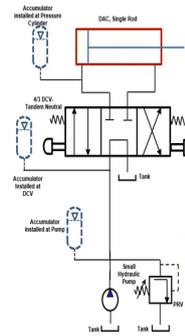
When full pressure has been reached the accumulator is in the charged condition, the operator may shift the valve to the neutral position to unload the pump because it is in the middle position it is a tandem center.

Leakage from the circuit will be able to available leakage from the circuit will be made up from the accumulator. But remember that as oil discharges from the accumulator its pressure will fall according to the amount of oil fed out into the circuit, then what happens? Once the pressure drops here again you will shift then again it is loading to the system pressure.

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3. Surge Dampening

- Accumulators, properly placed, may sometimes be effective for reducing (not eliminating) shock waves or pressure spikes which pass through the system
- To be most effective they should be placed *physically* as close as possible to the place or component where the shock is generated
- Most shock is generated at one of three locations : the pump, control valve, or press cylinder as the pressure on the cylinder is relaxed. These locations of the accumulator is shown in Figure:
- Piston pumps seem to generate more shock than other kinds
- An accumulator can often reduce shock intensity, and should be fed into the pump line as close as practical to the pump outlet port
- Directional control valves usually generate shock while the spool is being moved from a side position to center neutral, and is caused by the pump flow being momentarily deadheaded while the spool is in transit
- On a hydraulic press, a good part of the shock is produced as pressure is relaxed. Hence, accumulator is required at this position – Actuator side



Third one is Surge Dampening, accumulators properly placed may sometimes be effective for reducing not eliminating shock waves or pressure spikes which passes through the system.

To be most effective they should be placed physically as close as possible to the place or a component were the shock waves are generating, most shock is generated at one of the 3 locations the pumps side the control valve side and the press cylinder. If the operation is using for the press cylinder here also the surges are occurs.

So, these conditions calls for the accumulator you will see here I am placing the accumulator where this Surge Dampening is important. Here at the pump outlet I placed here accumulator installed at the pump, here you will see friends accumulator installed at the DCVs when they will switch over from one to another surges will takes place. To overcome this to give the

dampening the accumulators are there, similarly at the accumulators installed at pressure cylinders.

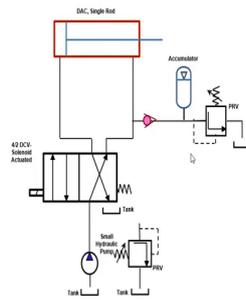
Piston pumps seems to generate the more shock than other kinds an accumulator can often reduce a shock intensity and should be fed into the pump line as close as possible to the pump outlet port. Directional control valves usually generate the shock while the spool is moved from one position to the central or a neutral position and is caused by the pump flow being momentarily dead headed while the spool is in the transit.

On a hydraulic press a good part of the shock is produced as a pressure is relaxed, hence accumulator is required at this position meaning at the actuator side is also required. To surge dampening you have to identify the major places where these surges will occur. Basically, in all the hydraulic circuit at the pump side, at direction control valve side and at the actuator side.

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4. Emergency Power Source

- Some hydraulic system demands for the retraction of the cylinder as a safety measure when the normal supply of oil pressure is lost either due to the failure of pump or power supply to the electric motor driving the pump stops suddenly.
- In such emergency situation, the accumulator supply the oil and retract the cylinder to its initial position



Let us we will see one more application in emergency power source, some hydraulic system demands for the retraction of the cylinder as a safety measure when the normal supply of oil pressure is lost.

Either due to the failure of the pump or power supply to the electric motor, driving the pump stops suddenly. Meaning when the pump will fails or a motor will fails then there is no flow to the actuator to bring back to the normal position. How to bring back it? Only is you have to support through the some external means to send the flow to the rod side to bring back to the actuator to the normal position.

In such emergency situation the accumulator supply the oil and retract the cylinder to it is initial position. You will see here friends in the normal position nothing will happen pump will send the flow to the actuator it will move retract all these things it will do.

But certain portion during the extension this accumulator will be charged to the system level pressure, then again here you will see once it reach the accumulator to the system level then what happens? It will sense the flow back to the tank.

But you will see when the failure happens to the pump or to the motor which is drives that time the piston is at the middle position or some position. But you will remember friends all hydraulic systems are high pressurized, meaning you how to bring back to the piston and piston rod to the normal position I mean retracted position. How to do it? You will drive the flow from the accumulator to the rod and you will bring back.

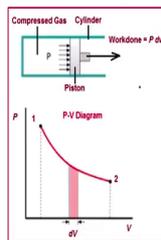
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Accumulator Physics → dictated by compressed gas laws

- Governing Equations for gas loaded Accumulators

➤ Basic thermodynamics of moving boundary

- Referring to Figure, The compressed gas pushes the piston outside and hence the mechanical work has been done in doing so ..



- Hence, work done is pressure (P) times the change in volume (dV) → PdV . So it follows:

$$W = \int_1^2 PdV$$

Ideal Gas

$$PV = mRT$$

Polytropic Process

$$PV^n = C$$

- The value of exponent n depends on process of compression i.e.,

$$\text{Isothermal } n = 1$$

$$\text{Adiabatic } n = \gamma = \frac{C_p}{C_v} = 1.4$$



You will see here the NRV and accumulator will not add a much cost. Now we will see friends Accumulator Physics dictated by the compressed gas loss, meaning now we will see the some of the governing equations for gas loaded accumulators. Here we are seeing some of the basic thermodynamics of moving boundary.

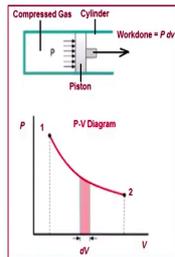
Here referring to the figure here you will see here the cylinder is there filled with compressed gas and then it will pushes the piston, when the piston will move the work has been done. How it is done? Through the compressed gas. To do this referring to this the compressed gas pushes the piston outside and hence the mechanical work has been done, in doing so the work done is pressure times the change in volume that is PdV .

So, it follows W equal to work done equal to from one position to another position the integral 1 to 2 PdV for ideal gas PV equal to mRT . Similarly, polytropic process PV raise to

n equal to constant, here finds the value of the exponent n depends on the process of compression and expansion. That is isothermal that time n equal to 1 adiabatic gamma is C_p by C_v equal to 1.4.

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Stored Energy



- The stored energy is calculated using the following relations..

Isothermal Case
 $PV = C$

$$E = W = \int_1^2 P dV$$

$$= \int_1^2 \frac{C}{V} dV$$

$$= C \ln \left(\frac{V_2}{V_1} \right)$$

$$E = PV \ln \left(\frac{V_2}{V_1} \right)$$

- Ratio of expanded gas volume to compressed gas volume ...

$$r = \frac{V_2}{V_1}$$

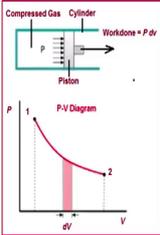
$$E = P_1 V_1 \ln(r)$$



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Accumulator Physics → dictated by compressed gas laws

- **Governing Equations** for gas loaded Accumulators
 - **Basic thermodynamics of moving boundary**
 - Referring to Figure, The compressed gas pushes the piston outside and hence the mechanical work has been done in doing so ..



➤ Hence, work done is pressure (P) times the change in volume (dV) → PdV . So it follows:

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Ideal Gas
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 $PV^n = C$

➤ The value of exponent n depends on process of compression i.e.,

Isothermal $n = 1$

Adiabatic $n = \gamma = \frac{C_p}{C_v} = 1.4$



Now will see the how to calculate the stored energy, now we will move on to study the accumulator physics dictated by compressed gas laws. We already seen the different types of laws Boyles law, Charles law, Gay Lussac's law, ideal gas laws in the previous class while studying the pneumatics. We have to determine some of the governing equation for gas loaded accumulators, here it requires the basic thermodynamics of moving boundary.

Referring to figure the compressed gas pushes the piston outside and hence the mechanical work has been done when the piston moves from the one position to another position. Here you will see friends here I have show you the PV diagram from first position to second positions. What happens friends here? You will see the change in volume takes place.

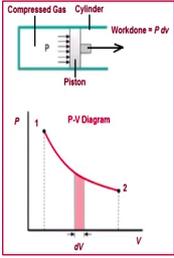
Correct. Meaning the work done is pressure times the change in volume meaning PdV . So, it follows the work done you have to integrate from 1 to 2, 1 to 2 area under the curve PdV for

ideal gas $PV = nRT$, polytropic process $PV^n = C$. The value of exponent n depends on the process of compression that is for the isothermal $n = 1$, in adiabatic $n = \gamma$, $\gamma = C_p / C_v$ that is equal to 1.4 for the air and nitrogen. Most of the working calculation we are using adiabatic γ is taken as 1.4.

Now, we have to know to calculate the stored energy. The stored energy is calculated using the following relations isothermal case $PV = C$, E work done is W as we have seen $\int_1^2 P dV$ then integral 1 to 2 you see here I am substituting the value of $P = C / V$ into dV .

Next $C = P_1 V_1^n = P_2 V_2^n$ E equal to PV and now I will substituting the value of C from the PV , here $PV = C / V^{n-1}$ ratio of expand that gas volume to compress the gas volume. We are taking as a small r which is a ratio of V_2 by V_1 . So, $E = P V$ meaning here from first stage $P_1 V_1 = P_2 V_2$ for the isothermal process.

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Compressed Gas Cylinder
Piston
Workdone = P dv
P-V Diagram
P
1
2
dV
V

Stored Energy

- Similarly the stored energy is calculated for the adiabatic case as follows:

Adiabatic case

$PV^\gamma = C \quad \gamma = 1.4$

$E = W = \int_1^2 PdV$

$= \int_1^2 \frac{C}{V^\gamma} dV$

$= \frac{C}{1-\gamma} (V_2^{1-\gamma} - V_1^{1-\gamma})$

$E = \frac{PV^\gamma (V_2^{1-\gamma} - V_1^{1-\gamma})}{1-\gamma}$

$r = \frac{V_2}{V_1}$

$E = \frac{P_1 V_1^\gamma (V_2^{1-\gamma} - V_1^{1-\gamma})}{1-\gamma}$

$E = \frac{P_1 V_1^\gamma (1 - r^{1-\gamma})}{\gamma - 1}$

Ratio of expanded gas volume to compressed gas volume ..

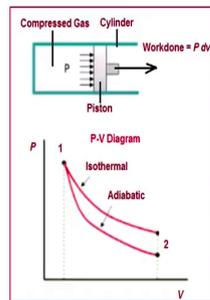
Similarly, we have to calculate the stored energy for the adiabatic, here adiabatic case we know that PV rise to n gamma what you can call PV by PV equal to C here gamma is 1.4. Same calculation we have to do work done W equal to integral of 1 to 2 PdV then you will get the P from here C by V gamma into dV, then C into V2 raise to 1 minus gamma minus V1 1 minus gamma divided by 1 minus gamma.

Later you will substitute C equal to here PV raise to gamma do all the calculation, finally we will get assuming this ratio of expanded gas volume to the compressed gas volume r equal to V2 by V1. Then we will get final equation for the energy stored for the adiabatic process E equal to P1 V1 into bracket 1 minus r to the power of 1 minus gamma divided by gamma minus 1, these are the 2 important equation.

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Expansion Process Matters

- Please note expansion process matters either it is a isothermal process (slow, constant/ same temperature) or adiabatic (sudden, temperature varies)



Now already we know that expansion process matters in the accumulator, whether it is isothermally expanded or isothermally pressed or adiabatically which process we are using that will matters. You are seen in the previous physics please note expansion process matters either it is a isothermal process already we know that which is a slow constant or same temperature or adiabatic sudden temperature varies here.

You will see here the PV diagram I have shown the 1 to 2 $P_1 V_1$ to $P_2 V_2$ the isothermal is like this very slow and a constant temperature or a same level temperature. But you will see here adiabatic is a sudden and temperature varies here. Now I will show you here the gas at rest, then so here the gas is compressed how it is compressed? The moving fluid enters here the gas is starts compressing adiabatically to a pressure. You will see the gauge temperature as well as pressure the pressure increased gas pressure is increased.

And you will see the temperature increased because adiabatically I am compressing. Now you will see the gas is compressed isothermally very slowly to the same pressure. What happens?

You will see friends the temperature remains constant, but pressure of the gas is increased this also isothermal process. Similarly, you will see the now it is gas is compress here friends now I am expanding; now we will see the pressure is high temperature you will note down here now you will see now gas is expanded adiabatically to certain pressure. Now you will see the pressure is coming down see the temperature also coming down.

But you will see the gas is expanded isothermally to a same pressure then what happens you will see? The temperature remains constant with the pressure. The volume you will see friends this is a very very important physics if you are expanded and compressing isothermally and adiabatically.