

Oil Hydraulics and Pneumatics
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Part 1: Introduction – Circuit design and analysis, Main parts needed for design and construction of oil hydraulic circuit, Power Pack
Lecture - 67
Oil Hydraulics Circuits: Design and Analysis

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Oil Hydraulics and Pneumatics



- Hello friends, Very good morning to one and all
- Hope you have enjoyed the **Lecture 20**
- Please note you have studied in the last lecture the followings:
 - ✓ **Hydraulic accumulators** - characteristics, basic functions, desirable properties
 - ✓ **Broad classification** of accumulators
 - ✓ **Applications of accumulators** in fluid power circuits
 - ✓ **Accumulator physics** - governing equations while designing the accumulators
 - ✓ **Numerical Problems**
 - ✓ **Maintenance, repair, reconditioning, troubleshooting and safety aspects**
- Now we will devote 4 lectures on Fluid Power Circuits- Design and Analysis
- In today's lecture we will discuss in detail about the **Power pack - design consideration, selection of various components and power saving circuit**



My name is Somashekhar course faculty for this course. Hello friends, very good morning to one and all. Hope you have enjoyed the last lecture 20. Please note you have studied in the last lecture the following contents. Hydraulic accumulators, characteristics, basic functions, desirable properties. Broad classifications of accumulators, applications of accumulators in a fluid power circuits.

Accumulator physics, governing equation while designing the accumulators. Also, we have seen some simple numerical problems to ascertain the properties of the accumulator dynamics.

Also, we have seen maintenance, repair, reconditioning, troubleshooting and a safety aspects while handling the accumulators in fluid power system. Friends, now we will devote 4 lectures on fluid power circuits design and analysis. In today's lecture, we will discuss in detail about the power pack, design considerations, selection of various components and power saving circuit.

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Lecture 21

Organization of Presentation



- Recap on course content - where we are now?
- Introduction - circuit design and analysis
- Power pack - design consideration, selection of various components and its circuit
- Some typical circuits like Unloading circuits and Pilot-operated circuit
- Concluding Remarks



Keeping in mind, we will discuss organization of presentation of today's class. Quickly we will see the recap on course content where we are now. Next, we will move on to introduction, some basics about the circuit design and analysis.

Next, we will move on to the power pack, design considerations, selection of the various components and its circuits. Also, we will see some typical circuits like a unloading circuits and pilot-operated circuits for power saving futures incorporated in the fluid power system. Finally, I will conclude today's lecture.

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Sl. No.	Particulars	Lecture Hours
1.	Introduction to Oil Hydraulics and Pneumatics: Power Transmission Methods, Scopes, Application areas, Components and Subsystems, Merits and Demerits, Research Challenges	2
2.	Basic Laws and Symbols	2
3.	Pumps: Types, Characteristics, Operations, Efficiencies, Torque and Power, Numerical	3
4.	Compressed Air Generation, Preparation and Distribution: Compressors- Types, Characteristics, Operations, Efficiencies, Torque and Power, Pressure Drop and its Calculations	2
5.	Air Driers: Types, Characteristics, and Applications	1
6.	Valves: Constructional Details, Operations and Application Areas of Various Types of Directional Control Valves, Pressure Control Valves, Flow Control Valve, Numerical	4
7.	Actuators: Rotary and Linear Actuators - Types, Characteristics, Operations, Efficiencies, Torque and Power, Numerical	3
8.	Subsystems: Reservoirs, Hydraulic Fluids, Seals, Filters, Accumulators, Maintenance	3
9.	Circuit Design and Analysis: Development of Single Actuator Circuits, Development of Multiple Actuator Circuits, Cascade Method for Sequencing	4
10.	Hydrostatic Transmission and Control: Different Configurations and Analysis, Pump and Motor Characteristics	2
11.	Servo and Proportional Valves: Constructional Details, Operations, and Applications	3
12.	Role of Modeling and Simulation in Hydraulic Components- Case Studies	1



Friends, we have seen many things in the fluid power system basically, the main elements involved in the oil hydraulics and main elements involved in the pneumatics and also we have seen the basic laws and a symbols to represent various fluid power components.

Basically, we have seen in connection with oil hydraulics, pumps, various types and invariants, characteristics, operations, efficiency characteristics, torque and power calculations.

Similarly, we have seen in pneumatics compressors, compressor characteristics, different types of compressors, applications and also we have seen the very important thing pressure drop and its calculation in pipe line in pneumatic systems and also we have seen the air dryers which is one of the important element in air conditioning, types, characteristics, applications.

Next, the which is the central unit of the fluid power system is a control valves. Here, we have discussed constructions, operations, applications and also we have seen many circuitry related to the direction control valves, pressure control valves, flow control valves and also we have seen the numericals to calculate, the pressure, flow rate, speed, power, leakages and many things.

And then, we also study the actuator which are known as the working elements in the fluid power system based on the motion either a linear or a rotary, we have discussed these things in detail cylinders, different types of cylinders, constructional features, applications and how to predict the leakage, how to overcome the leakage and many things.

Similarly, also we have seen hydraulic motors, constructional features, operations, applications and how to predict the efficiencies basically, the volumetric efficiency, mechanical efficiency and overall efficiency of the system.

And in previous classes, we have seen the subsystems which are the essential elements along with the main components. Here, we have discussed the sizing of the reservoirs and how to select the hydraulic fluids based on the applications, different types of seals, filters, accumulators and how to maintain the whole subsystems.

Now, we are here friend's circuit design and analysis. As I have told you, another four class is completely on the circuit design and analysis. We will restrict our study based on the timings;

timing is very limited for us now, two lectures we will discuss on oil hydraulic circuits and two lectures on the pneumatics. Then, other things are their hydrostatic transmission and control, servo and proportional valves and a role of modelling and simulations. Still we have to move many classes.

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Introduction

- Fluid power circuit design and analysis includes both oil hydraulics and pneumatics : is an arrangement of hydraulic/pneumatic elements and devices interconnected symbolically using graphic symbols in such a way that they will perform a specific function or intended task
- It involves the selection of various elements and devices of required type, size, capabilities, efficiencies so that the selected elements or devices carry out its intended function as designed satisfactorily
- Elements and devices includes oils of certain grade and viscosity, pumps, valves cylinders/motors such as displacement, efficiencies, speed with suitable tubes/pipes/hoses/connectors/joints of desired characteristics so that the system as a whole to perform with possible peak efficiency
- Oil hydraulics and pneumatics circuit analysis: is the process of verifying performance of the built circuit as per design and specification
- Analysis is carried out both by theoretical approach and practical approach
- The main objective of a fluid power system designer is to find a specific and best possible solution to a position, power, sequence or speed problem of any mechanical system such as a machine tools, a hydraulic lifts and crane or similar other mechanical or electro-mechanical implements that are commonly used



Now, let us we will begin today's lecture on circuits. Fluid power circuit design and analysis includes both oil hydraulics and pneumatics, what is this? Is an arrangement of hydraulic and pneumatic elements and devices interconnected symbolically using the graphic symbols in such a way that they will perform a specific function or a intended task in efficient manner.

Meaning please remember friends here, we have selecting the power pack, valves and actuators. The main theme here in the circuit is how the fluid flow will take flow is from the

pump to the actuator passing through the various valves and then after doing the work, again it will return to the tank, the whole theme is in the hydraulic circuit is that.

But please remember friends what we have discussed the constructional features of the various elements, sectional views are not seen in the hydraulic circuits, all are represented using the symbols that is why I am requesting all the students again you will recap the lecture, previous lectures on the loss and the hydraulic symbols, these are the very basics in four important classes.

So, the hydraulic circuit design and analysis involves the selection of various elements and devices of required type, size, capabilities, efficiencies, so that the selected elements or a devices carry out its intended function as designed satisfactorily.

Elements and devices includes oils of certain grade and viscosity, pumps valves, valves include direction control valves, pressure control valves, flow control valves and many times the non-return valves, what you can call it as the check valves, then cylinders and motors such as a displacement, efficiency, speed with a suitable tubes, pipes, hoses, connectors, joints of desired characteristics so that the system as a whole to perform with possible peak efficiency that is a objective in the hydraulic circuit.

Oil hydraulic and pneumatic circuit analysis is a process of verifying performance of the built circuit as per the design and specification. Analysis is carried out both by theoretical approach meaning by calculating the pressure, flow, velocity, rotation, power all these thing knowing the geometry and the flow rate and pressure requirements are also practical approach.

The main objective of the fluid power system designer is to find a specific and best possible solution to a position, power, sequence or a speed problem of any mechanical system such as a machine tools, a hydraulic lifts and cranes or similar other mechanical or electro-mechanical implements that are commonly used in many industries, construction sites, auto motives, aerospace ships and many places.

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- The most common problems encountered by designer may be the movement of a machine tool table, machine slide, press ram or mechanical transfer of load
- For example, in case of a machine tool itself, composite activities are involved like clamping and de-clamping of various jobs, feeding of material and tools, selecting the sequence of operations such as cutting, drilling, milling, pressing, forming, drawing, finishing, unloading or ejecting the finished jobs or tools etc. Each of the events or activities constitute a cycle
- The designer has to synchronize all these cycles into a single cycle called **work cycle** or **total machine cycle** taking into account the following important factors:
 1. Conformity to the **desired functions**
 2. Level of **performance efficiency**
 3. **Safety and reliability** of the system
 4. Ultimate **cost benefit** in terms of maintenance and higher life expectancy
- Please note, the fluid power control system is used to control the position and speed of the load with a driving force/torque which comes from an actuator either linear type or rotary type
- Let us we will devote 2 lectures on "oil hydraulics circuit " and 2 lecture on "pneumatic circuits"



The most common problems encountered by the fluid power designer may be the movement of a machine tool table, machine slide, press ram or a mechanical transfer of a load.

For example, in case of machine tool itself, a composite activities are involved like a clamping and de-clamping of various jobs, feeding of materials and tools, selecting the sequence of machining operations like a cutting, drilling, milling, pressing, forming, drawing, finishing, unloading or ejecting of the finished jobs or a tools. Each of the events or activities constitute a cycle.

The designer has to synchronize all these activities or a cycles into a single cycle called a work cycle or a total machine cycle taking into account the following important factors.

Conformity to the desired functions, level of performance efficiency, safety and reliability of the system, ultimately cost benefits in terms of maintenance and higher-level expectancy.

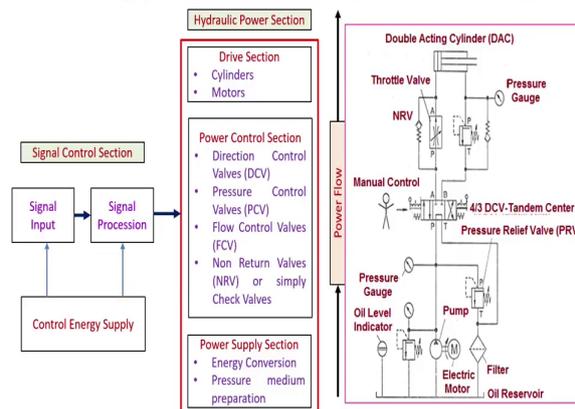
Please note, the fluid power control system is used to control the position and speed of the load with a driving force or a torque which comes from an actuator either a linear type or a rotary type. As I have told you let us we will devote 2 lectures on oil hydraulic circuit and 2 lectures on pneumatic circuits.

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- The main parts which are essentially needed to design and construct an oil hydraulic circuit are shown in Figure below along with power flow direction and may be grouped as follows...



1. Power supply section; 2. Power control section; 3. Drive section & 4. Accessories



- Let us discuss briefly as follows...



The main parts which are essentially needed to design and construct an oil hydraulic circuit are shown in figure below along with power flow direction and may be grouped as follows. I will show you the figure which includes the power supply section, power control section, drive section and many accessories. Figure looks like this.

See friends here, hydraulic power section I am showing you here and the left-side, here you will see power supply section is there, power control section is there, and a drive section is there. Then, you will see power supply section includes energy conversion, pressure medium preparation conditioning. The power control section various types of valves. Drive section includes evacuator, cylinders and motors.

Please note friends here, power direction you will see always from power supply section to the power usable area that is why fluid power transmit one power into the another power that is what we can call it as. Here, signal control section also have shown here; signal input, signal processing through the control energy supply.

And at the right-side you will see friends, I have shown you the simple circuit diagram no need to worry how to draw, how to design this, I will tell you, but you will understand this all these things. The power supply section, what is the power supply section? Here you will see what it includes? The pump, motor, pressure relief valve, oil level indicators, filters, pressure relief valves, pressure gauges.

Then, you will see here friends from the pump fluid will enters to the valves, here I have shown you the 4 by 3 directional control valve tandem centre it is, we have discussed already in detail this, then it will go to the throttle valves, then here NRV is there to control the flow direction of the fluid, free flow in the reverse, forward through the throttle valve, here also I am using the pressure relief valve, pressure gauges, this is a power control section, next later is a drive section, here I have shown you the double acting cylinder, here it may be the motor also.

Now, my objective here is to as I you people understand what includes in the power supply section, what includes in the control section, what includes in the drive section and also the power flow, power is always flowing from the pump to the actuator after doing the work, it will return to the tank that is my main objective.

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1. **Power supply section or simply a hydraulic power pack** – needed to convert mechanical energy into hydraulic energy
 - It comprised of **energy conversion part** and the **pressure medium conditioning part**
 - The **energy conversion part** includes pump, drive motor generally an electric motor or an IC engine, a mechanical coupling, pressure indicator, protective circuitry
 - While the **pressure medium conditioning part** includes oil reservoir, hydraulic fluid, strainers, filters, coolers, heaters, thermometer, oil level indicator, pressure gauges
2. **Power control section or hydraulic control elements** – it includes various types of direction control valves, pressure control valves, flow control/flow regulating valves
3. **Drive section or working section or power drive units** – needed to convert hydraulic energy into mechanical energy in the form of work. It includes cylinders, motors, etc
4. **System Accessories** – such as tubes, pipes, hoses, fluid conductors, accumulators, boosters, filters, additional safety devices etc
 - Please note the hydraulic designer **not only decides the type of components needed but also analyse their mutual compatibility** so that the ultimate design is comprehensive enough in terms of **functional efficiency** as well as **reliability and maintainability** of the constructed system
 - Please note hydraulic circuits **primarily do not contains the circuits for basic electrical control devices** such as push-button switches, limit switches, pressure switches, solenoids, relays, timers, and temperature switches. Electrical circuits are drawn with **ladder diagrams**



Now, let us briefly discuss these things. Power supply section or simply a hydraulic power pack needed to convert mechanical energy into hydraulic energy. It comprised of energy conversion part and the pressure medium conditioning part.

The energy conversion part includes as I have told you in the previous slide, pump, drive motor, generally an electric motor or an IC engine, a mechanical coupling, pressure indicator, protective circuitry. Protective circuitry means PRV is incorporated to safeguard the pump and various elements. While the pressure medium conditioning part includes the oil reservoir, hydraulic fluids, strainers, filters, coolers, heaters, thermometer, oil level indicator, pressure gauges.

Power control section or hydraulic control elements includes various types of direction control valves, pressure control valves, flow control flow regulating valves. Third one is a

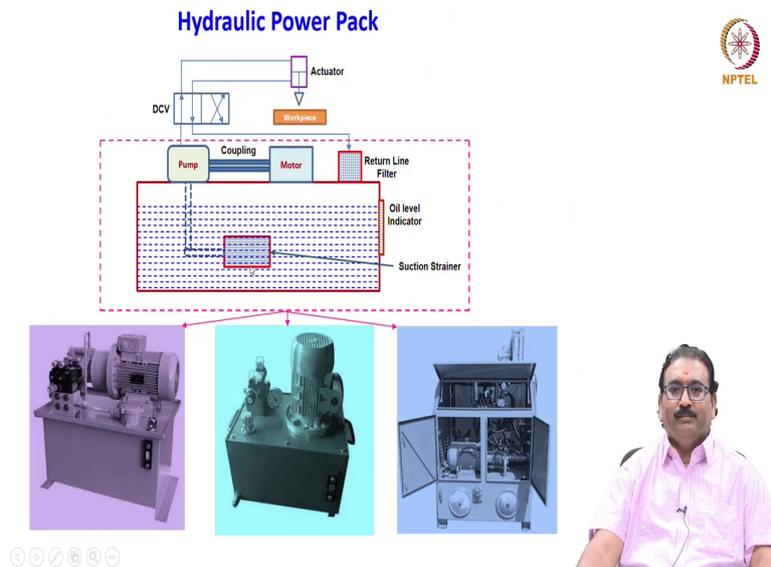
drive section, or a working section or power drive units needed to convert the hydraulic energy into mechanical energy in the form of work.

It includes cylinders and motors. Fourth one is system accessories includes tubes, pipes, hoses, fluid conductors, accumulators, boosters, filters and many additional safety devices. These are very very important elements in the fluid power system.

Please note, the hydraulic designer not only decide the type of components needed, but also analyse their mutual compatibility, so that the ultimate design is comprehensive enough in terms of functional efficiency as well as reliability and maintainability of the constructed system. Please note, hydraulic circuitry primarily do not contain the circuits for basic electrical control devices such as push-button switches, a limit switches, pressure switches, solenoids, relays, timers and temperature switches.

Please note friends, in hydraulic circuit, you will not see any electrical circuits imposed on it, but electrical circuits are drawn using ladder diagrams which will show the 0 volt, 24 volts and how they are connected using the various types of electrical elements like a solenoids, various things are there switches are there, some switches on, some switches are open, close, many configuration how the current will flow from one to another it is represented in the electrical circuit diagram what is known as a ladder diagrams. In hydraulic circuits, you will not see all these things.

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Now, we will begin our circuit design and analysis with the very very important element, what is this? Hydraulic power pack. Here, I have shown you the bounded dash line; this is a hydraulic power pack. Can you please identify how many components are there here? You will see here, this is a reservoir and then pump is there, motor is there electric motor to drive the pump through the coupling, mechanical coupling.

Then here I am using the filters, you will see the inlet of the pump is connected to the suction strainer and you will see here one more filter I am added here, the return line filter. Meaning after doing the work from the actuator, the flow will enter to the tank through the return line filter. Then, you will see friends here, from this pump, it will goes to the direction control valve and then to the actuator.

These are the pictorial representation of the power pack. Power pack includes the tank, pump, motor. Here, horizontally mounted, vertically. Here you will see in the bigger systems press tools or a rolling devices that time their enclosed chamber you will see here, here electric motor is there, pump is there on so many connections, then it will tap to the various components.

Now, we will concentrate more on the power pack. You know already is a power pack, what are the elements are there. How to decide for the specific applications, we will discuss in today's lecture ok.

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Hydraulic Power Pack

- Let us begin our study on **hydraulic power pack selection and some design considerations** on selection of main components
- Generally, a **user specifies the final output to be performed**
- Suppose a customer needs a **hydraulic power pack to lift a load of 3 tons**
- The application engineer immediately needs to get **several answers to basic questions** before making a suitable offer of hydraulic power pack that will ultimately meets the expectations of the customer
- We already know that hydraulic power pack is the **basic element needed to get a mechanical movement** – linear or rotary, with the help of hydraulic cylinder or hydraulic motor
- **If the customer needs a linear motion**, he requires a **hydraulic cylinder** and **if it is a rotary motion** then he requires a **suitable hydraulic motor**
- Ok let us we will assume, **the customer needs a linear motion of the load** and hence **he requires a suitable power pack unit** to be designed by us
- Then **you must obtain the following information** from customer
 - **For what application/equipment** the hydraulic power pack will be used?
 - **How many cylinders would be needed** to suit the customer's application?



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Let us begin our study on hydraulic power pack selection and some design considerations on selection of main components. Generally, a user specifies the final output to be performed. Suppose a customer needs a power pack to lift a load of 3 tons. The application engineer

immediately needs to get a several answers to basic questions before making a suitable offer of hydraulic power pack that will ultimately meets the expectations of the customers.

We already know that hydraulic power pack is the basic element needed to get a mechanical movement, a linear or a rotary, with the help of hydraulic cylinder or a hydraulic motor. If the customer needs a linear motion, he requires a hydraulic cylinder and if it is a rotary motion, then he requires a suitable hydraulic motor ok.

Let us we will assume that only this data is not sufficient 3 ton capacity what for it is? Where he is using? How he is using? What motion he want? All is requires to design the power pack. So, now, let us we will assume the customer needs a linear motion of the loads, 3 ton loads and hence, he requires a suitable power pack unit to be designed by us.

First one is we are assuming he required the linear motion, then our objective is to define the cylinder. Assume to be if his requirement is a torque and speed that time hydraulic motor. Now, let us we will see now he want the application of 3 ton capacity in the linear motion to work it out.

Then, you must obtain the following information from the customers. For what application or equipment, the hydraulic power pack will be used? Whether there is a construction or whether in industry or some of the machine tool for what where it is you have to get the information. Also, we will get the information how many cylinders would be needed to suit the customer's application? Only 1 cylinder, 2-cylinder, 3-cylinder, many you have to get the information from him.

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- What would be the nature of work to be done by each cylinder - lift load / push load / clamping or pressing the job etc.?
- Does the customer need the cylinder(s) to be double-acting or single-acting?
- In respect of each cylinder now we need to work out the following information:
 - a) Bore size of the cylinder (ID of the cylinder)
 - b) Rod size of the cylinder
 - c) Stroke length of the cylinder
 - d) What is the speed of movement required (m/min.) of the cylinder?
 - e) What is the load the cylinder is expected to take ?
- Many times, the customer may not be having any such information about bore/rod sizes of hydraulic cylinders. In such cases, the manufacturing's catalogue/brochure on hydraulic cylinders will give the details on of standard cylinders available
- Simple hydraulic power units can be made using manually-operated valves. In such cases it is better to get the clarification from customer whether he needs electrically-actuated valves (solenoid-operated) or manually-operated direction control valve
- A well-informed customer can assist in working out the above information and let us assume that the answers can be summarized as given in the following section...



What would be the nature of work to be done by each cylinder? For example lift the load, push the load, pull the load or clamping or pressing the job what it is? What for it is? You will collect the information from the customer. Does the customer needs to be a double acting cylinder or a double single acting cylinder? You have to get the information.

In respect of each cylinder, now we need to work out the following information, bore size of the cylinder that is what we will call ID of the cylinder, how much it is? Rod size of the cylinder, stroke length of the cylinder, speed of motion, what is the load the cylinder is expected to take? Full 3 ton. You have to collect information.

Many times, the customer may not be having any such information about bore or a rod sizes of hydraulic cylinders. In such cases, the manufacturers catalogue or a brochure on hydraulic

cylinders will give the details on standard commercially available cylinders in the market. Simple hydraulic power units can be made using manually operated valves.

In such cases, it is better to get clarification from customer whether he needs electrically actuated valves like a solenoid operated or manually operated direction control valves. A well-informed customer can assist in working out the above information and let us assume that the answers can be summarized as given in the following section.