Oil Hydraulics and Pneumatics
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Modeling and Simulation in Hydraulic Components
Lecture - 94
Part 1: Introduction, Need for modeling and simulation and jet pipe electro hydraulics servo valve

My name is Somashekhar, course faculty for this course.

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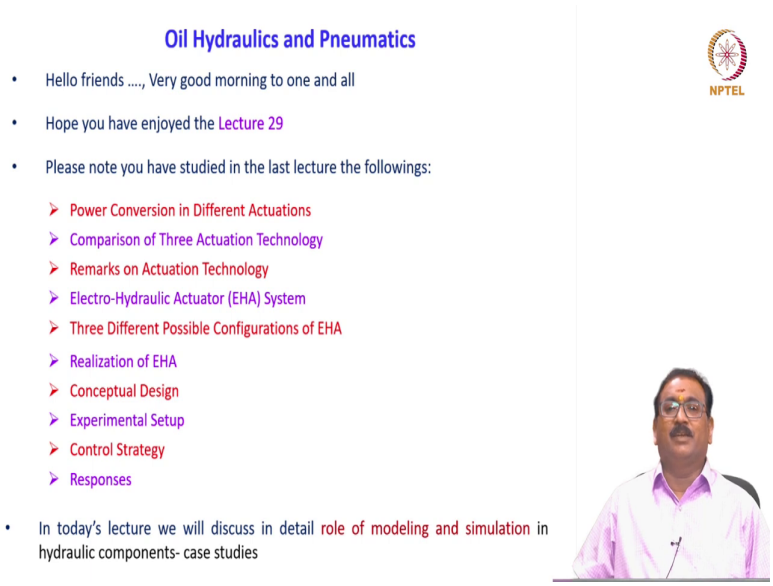

Hello, friends. Very good morning to one and all. Hope you have enjoyed the lecture 29. Please note you have studied in the last lecture the followings: power conversion in different actuations; comparison of three actuation technology; remarks on actuation technology;

electro-hydraulic actuator also known as EHA. Three different possible configurations of EHA based on the motor and a pump configurations.

Then how to realize the EHA for a particular application, how to select the pump, BLDC motor, sensors, non-return valve, pressure relief valve, actuators and many more. Conceptual design – how to achieve through the CAD model I have shown; experimental setup built with all these components as a single unit. Control strategy, various responses for the step inputs and also tuning has been done through the PID controller for GPD.

In today's lecture we will discuss in detail the role of modeling and simulation in hydraulic components – a case studies. Here I am taking you one of the main valve jet pipe electro hydraulic servo valve, which consists of a numerous parts, how to carry out the system modeling and simulation, to predict the performance parameters including static and dynamic characteristics.

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Let us we will see the organization of presentation. Quickly we will recap on the syllabus now and how much syllabus we covered as of now. Introduction to modeling and simulation; role of modeling and simulation; detailed modeling and simulation of jet pipe electro hydraulic servovalve – here methodology adapted in the current study is finite element method. Here first we are using for stiffness analysis of precision and dedicate components at their validation through experiments.

Extended to steady-state FE analysis and torque motor and a feedback spring assembly. Dynamic analysis here complete valve dynamics, here I am bringing the modeling concept of fluid structure interaction, design of feedback loop and implementation in the FEM. Frequency response very important in the servo valves – predicting the operating bandwidth of the valve and ultimately we must know the natural frequency of the valve.

Finally, I will conclude today's lecture. Please note friends, I have made the mathematical analysis as much as much simple, but most of the work is published in the book modeling and analysis of jet pipe electro hydraulic servo valve in 2010 which will give you the complete dynamics mathematical analysis theoretical approach of the jet pipe electro hydraulics servo valve, but as a last class it is I will make the modeling and simulation very simple.

As because in 15 minutes it is difficult to cover the entire modeling and simulation of the jet pipe electro hydraulic servo valve. Who are interested to know more about this, you may get in this book also the many papers are there on the steady state analysis of the jet pipe electro hydraulic servo valve. Mathematical modeling of servo valve and actuator dynamics using the MATLAB Simulink lot of materials are available written by me only it is. Please go through it.

But, as of the hydraulics and pneumatics is concerned, this is the subject, this is the chapter we introduced to you the some basics how modeling and system simulation is used to predict the dynamic behavior. That is a main motto, please remember friends.

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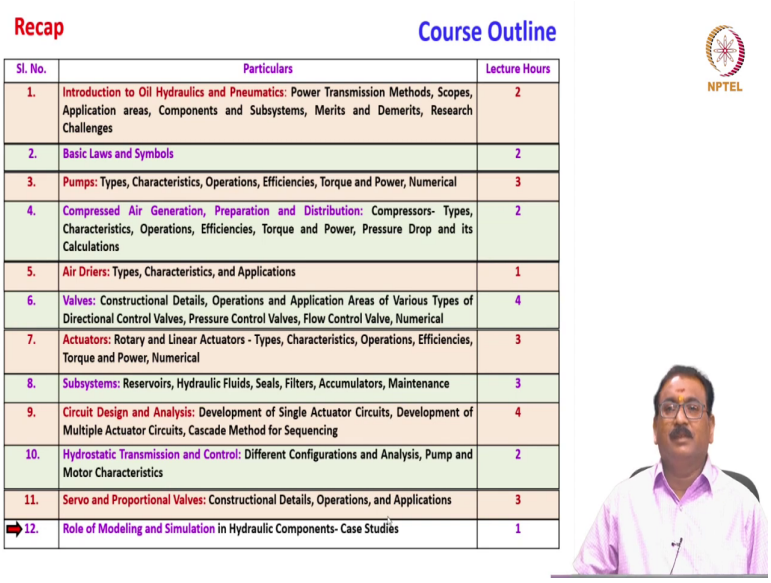

Sl. No.	Particulars	Lecture Hours
1.	Introduction to Oil Hydraulics and Pneumatics: Power Transmission Methods, Scopes, Application areas, Components and Subsystems, Merits and Demerits, Research Challenges	2
2.	Basic Laws and Symbols	2
3.	Pumps: Types, Characteristics, Operations, Efficiencies, Torque 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

See friends, now here we have made a long journey from the Introduction, Basic Laws and Symbol, Pumps, Compressed Air Compressors, Air Driers, various Valves, Actuator, various Subsystems, Circuit Design and Analysis meant for both hydraulics and pneumatics and their Hydro Static Transmission, correct? Servo and Proportional Valves.

We will see here there are many lecture hours I am taken to cover all the things. These are the heart of the oil hydraulics and pneumatic course. Later I introduce servo valve and proportional valve and modeling and simulation. These are the complete course in IIT, Madras on the servo and proportional valves.

Here what I made? I made a very very simple to give you the glitch on the you know electro hydraulic servo valve, proportional valves and modeling and simulation. That is a main motto, friends to motivate you to read much further on the these concepts.

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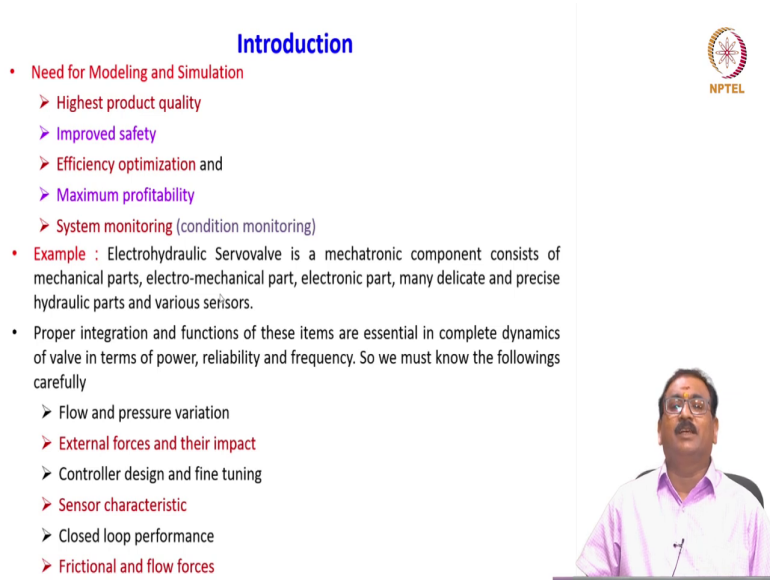

Introduction, already we know that what is a need for modeling and simulation. Modeling means there are various methods are there for modeling. You know mathematical modeling is there, empirical modeling is there, heuristic modeling is there, many many more are there, correct? Based on the requirement prediction of the parameter you may use any modeling and simulation technique.

But, you will remember whatever it may be the highest product quality is ensured before manufacturing the product. Similarly, improved safety, efficiency optimization and maximum

profitability is ensured. If you will adopt modeling and simulation and system monitoring meaning condition monitoring is possible once the process model is complete.

Example I will tell you what is the system modeling and simulation. Here I am taking an example of electro hydraulics servo valve. Already we know that is a mechatronic component consists of mechanical parts are there, electro mechanical parts are there, electronic parts are there, many delicate and a precise hydraulic components are there, along with that there are the various sensors. So, how to model all these things as a single unit? That is a motto of the work today.

Proper integration and functioning of these items are essential in complete dynamics of valve in terms of power, reliability and a frequency. So, must know the followings carefully. Flow and pressure variation this is a very very heart of the hydraulic component analysis. You must know how the flow and pressure variation taking place in all the parts of the hydraulic circuits.

Then external forces and their impact controller design and fine tuning of it to get the better results, meaning better settling time, correct? Better response, reducing the overshoot, many things you are seen in the previous classes. Sensor characteristics; closed loop performance – how it is, because electro hydraulics servo valve is a closed loop system.

Meaning you have to ensure the feedback from the actuator to the server to correct the given input I mean desired input and the final output should match each other, correct? We have seen already in the last class. Then fictional and a flow forces also try to incorporate this to make the model simple.

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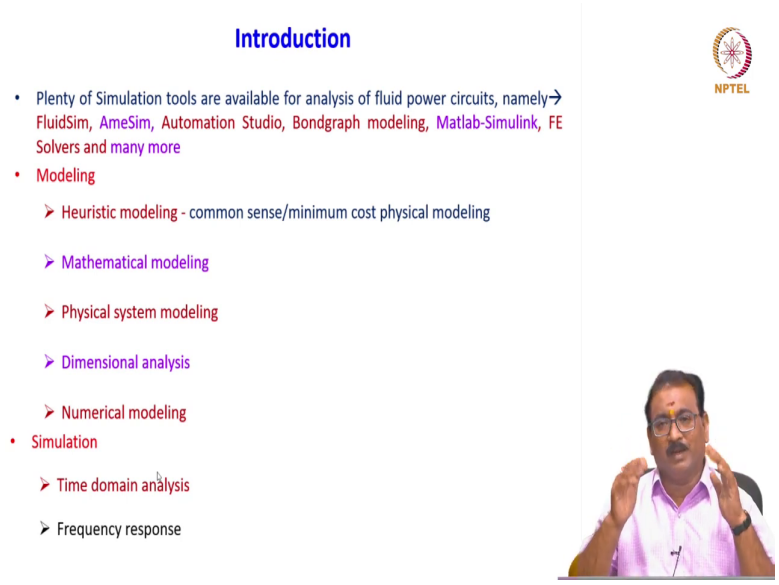

Already please we know that friends plenty of simulation tools are available for analysis of fluid power circuits namely – the FluidSim, AmeSim, automation studio, bondgraph modeling, Matlab-Simulink, FE Solvers and many more, friends. You know already people one or the other commercially available software based on the requirement they are using in the industry to solve the fluid problem.

Let us we will see modeling. Modeling as I have told you many things are there first and foremost thing people are adapting is a heuristic model. Heuristic model is nothing, but friends it is a common sense modeling. The minimum cost physical modeling it is. For example, as I have told you heuristic model it is a common sense one big almirah there in the small room and door is very small. How to take care of this almirah outside?

People are trying to bending, lifting, correct? Many ways to take this almirah out of the room by their initiatives how to take it out this is called a heuristic modeling approach. This is very essential when you have to tackle the some of the problems when the engineers are having the large number of experience they will adopt very quickly the heuristic modeling to solve the problem.

Next one is a mathematical model if you know the system of equations for the system whatever you will consider mechanical system, electrical system whatever the system. If you know the set of equations mathematically then it is very easy to simulate this. Next one is physical system modeling.

Next one is dimensional analysis which is very very essential when we are fixing the tolerances on the various delicate parts. Numerical modeling which is a very quick, but you may not guess 2 plus 2 equal to 4 numerical models are like a finite element models you were you know what will call the lumped simulations, correct?

They will approximated models, but they will give very quick result, but the user has to identify whether the simulated results, correct or not? When people are doing the numerical simulation, it requires the mathematical modeling or the experimental results to validate the numerical results.

Next, if you will see the simulation generally people are adapting the two ways to simulate once the model is ready in these. One is what we will call time domain analysis. Time domain analysis means with respect to certain time how my system developed behaves with respect to time it is. Time is a varying parameter or if you will go the frequency response for the signing solenoid inputs.

You have to sweep the frequency for 0.1 Hertz to 1000 Hertz and how my system will behave in terms of natural frequency, Eigen mode, whatever it is you have to predict both are playing a major role in the industry.

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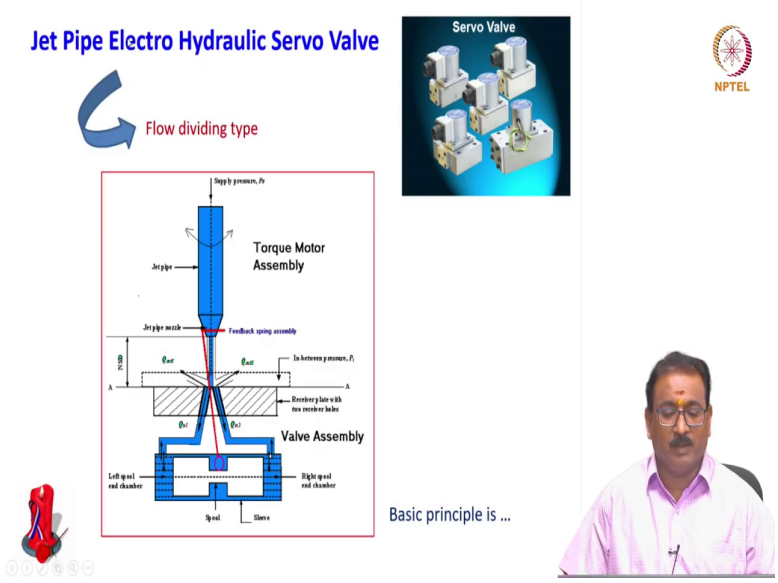

Let us quickly move on to the one valve jet pipe electro hydraulic servo valve which works on the flow dividing type. It basically consists of the torque motor assembly first stage, second stage is the valve assembly. As we know already this jet pipe we will carry the continuous fluid supply pressure you will see P s and it will expel from the nozzle. When it will hit the receiver plate has a two closely drilled holes connected to this spool end.

Whenever the jet pipe piece at the center equal amount of flow will go into the two receiver with some losses. Then spool will not move. Once the jet pipe will deflect, how it will deflect? By applying the torque on the armature it will rotate. That time more flow will come to the here and proportionately less flow will go here P 1 minus P 2 results in delta P and spool starts moving.

During this spool motion, this is the feedback spring is there. Feedback spring also push such a way that for the given torque input the spool will push the feedback spring meaning it is a restoring torque is developed through the spool moment to bring back the jet pipe to the null position. This I have already explained in the last class. Also, I will remember friend's nozzle standard of distance is also playing a major process parameter.

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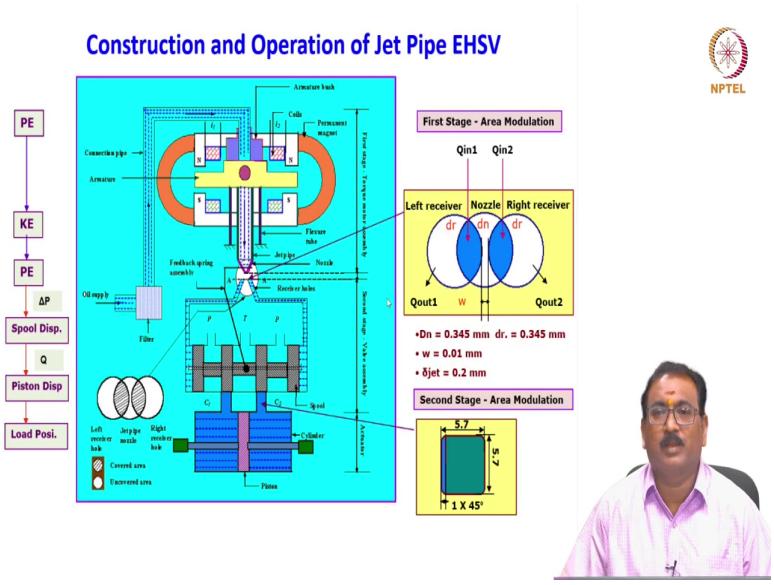

Quickly I will show you the one more slides already you are seen this slide in the previous class. The whole objective in the jet pipe electro hydraulic servo valve convert the pressure energy of the fluid into the kinetic energy of the jet here when it will expel. Then kinetic energy is re-converted into the pressure energy in the two receiver holes meaning which will create the delta p at the spool ends based on the jet pipe deflection either to the left or to the right.

Then what happen friends? Spool displacement takes place due to the delta P, then which will results to the flow Q to the actuator. Then piston displaces, which in turn controls the actuator load precisely. This is a basic principle as we have seen in the last class. Quickly we will see it consists of the first stage torque motor. Torque motor armature is there, north pole piece, south pole piece, permanent magnet coil i 1 and i 2.

If i 1 is greater than i 2, jet pipe will deflect in one direction; if i 2 is greater than i 1 it will deflect in the other direction. What for it is? To create the differential pressure across the spool valve. In term sending to the flow to the left side of the actuator or right side of the actuator, very important friends it is. You will remember.

Then to model this jet pipe electro hydraulics servo valve, first and foremost thing is you have to understand the theoretical concept in it how pressure recovery will takes place in the first stage when the jet pipe will deflect to the left side or a right side. This is what we will call it as a area modulation. What is the area modulation you will see? Left receiver, this is the left receiver then here it is a right receiver hole. On the top of it will see, it is a nozzle over it.

These receiver diameter, nozzle diameter play the very very important role to create the this areas A 1 and A 2. If nozzle is moved towards here, this area is increasing proportionately at the same time this area goes on decreasing and vice versa, please remember. Also please take care friends, many parameters are their design parameter all the receiver holes nozzle are on the same axis there should not be an offset; if it is the offset, this area will changes.

If this area will changes P 1 and P 2 are different across the spool then dynamics will affect that is a very very important. Please take care for this. I will tell you what are the other parameter in the next slide. Second time we will see here friends, when the spool will starts moving what happen? The flow will takes place to the C 1 and C 2 that time second stage area modulation; area modulation you will see the ports are here.

As I have told you in the last class octagonal ports are there here, only you will see this is a 1 mm into 45 u degree, meaning it will not move 1 mm within a 0.25 mm the complete flow is

going to an actuator. Then you will see how to control this spool very very precisely. You must calculate the area modulation second stage area modulation also because the first stage area modulation. Second stage area modulations are very very important in the finite element modeling because we have to input it in the model. I will show you later, no need to worry now friends.

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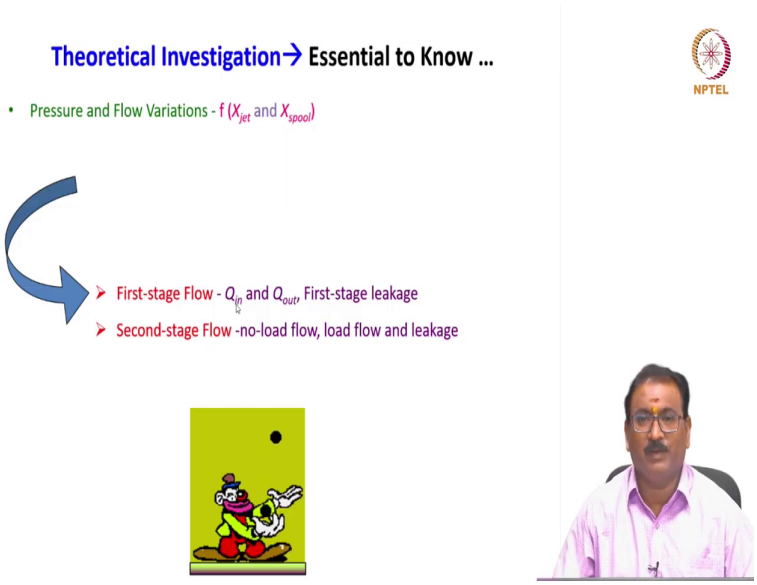

Now, we will see the theoretical investigation is essential to know the pressure and flow variation which is a function of jet and spool. When the jet pipe will starts rotating over the receiver, pressure variation takes place and flow variation takes place. Then as the spool move again the flow variation a pressure variation takes places. These are a very very important must know it this.

So, the first stage flow as I have told you Q in now how much flow is coming in whenever the jet pipe is center or it is deflected which consists of Q in 1 and Q in 2 in the left receiver and the right receiver. Similarly, Q out means after pushing this spool no passage it is, it come out you out Q out 1 and Q out 2 to the receivers 1 and 2, correct friend? Similarly, second stage, no-load flow, load flow and leakage flows are essential.