**Oil Hydraulics and Pneumatics**
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**Electro-Hydraulic Actuator (EHA)**
**Lecture - 92**
**Part 1: Introduction, Power conversion in different actuations, Comparison of three actuation technology, Remarks on actuation Technology**

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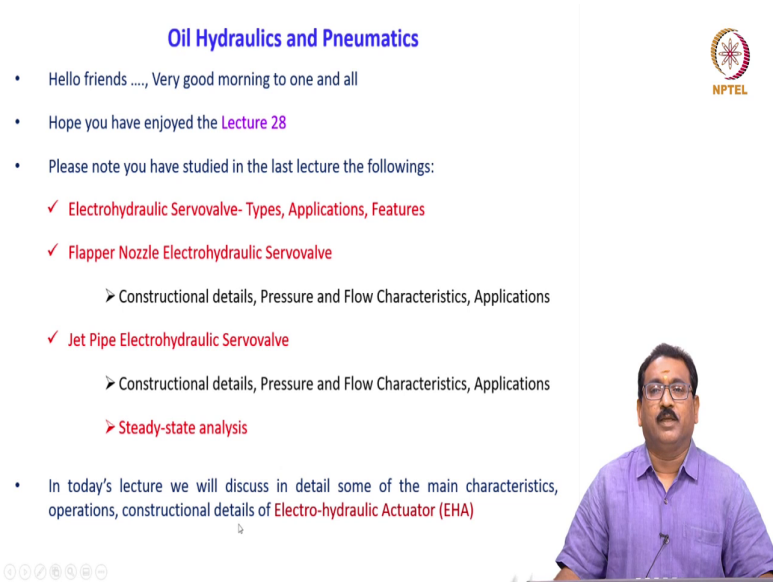


My name is Somashekhar, course faculty for this course. Hello friends, very good morning to one and all hope you have enjoyed the lecture 28th. Please note you have studied in the last lecture the followings, electrohydraulic servovalve, history different types applications, and some of the important features. Flapper nozzle electrohydraulic servovalve here, we have discussed constructional details, pressure and flow characteristics, applications.

Next we have discussed jet pipe electrohydraulic servovalve, in which we have studied the constructional details the different affecting parameter for the pressure recovery and pressure and flow characteristics. Also we have seen the applications of jet pipes servovalves.

Steady state analysis how the torque balance is achieved in the jet pipe. In today's lecture we will discuss in detail some of the main characteristics, operations, constructional features of electro hydraulic actuator, briefly known as EHA.

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Move on to organization of presentation, we will begin with introduction power conversion in different actuations. Comparison of three actuation technology, remarks on actuation technology, electro hydraulic actuator system three different possible configurations of EHA, realization of EHA, conceptual design starting with identification of the substances and, then

the cad model, and then experimental set up and experimentation. Experimental set up, control strategy, responses concluding remarks.

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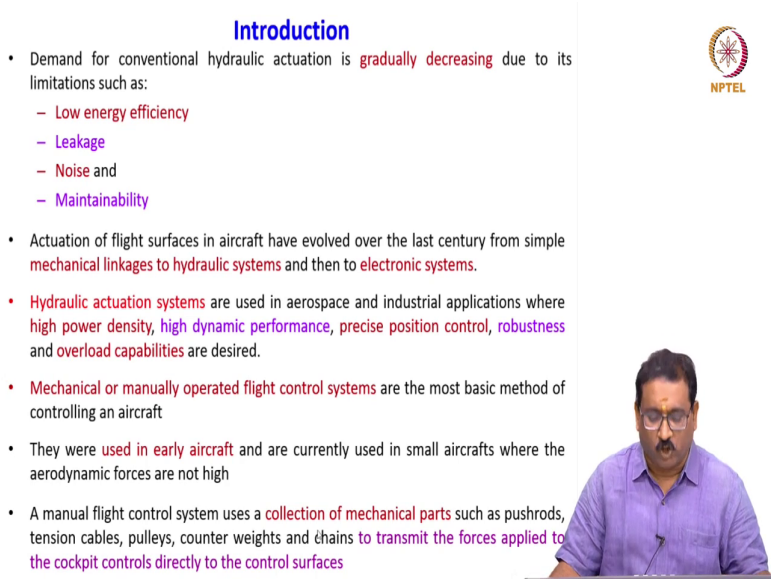


Yes we will begin here with today's introduction. Demands for conventional hydraulic actuation is gradually decreasing, due to its limitations such as low energy efficiency, leakage, noise and maintainability, actuation of flight surfaces in aircraft have evolved over the last century from simple mechanical linkages to hydraulic systems and then to electronic systems.

As, I have told you now we are moving from conventional hydraulics to electro hydraulics, where electronics are used more and more in the actuation system, characterization, acquiring the data from the responses. Hydraulic actuation systems are used in aerospace and industrial applications, where high power density, high dynamic response, precise position control, robustness and overload capabilities are desired.

Mechanical or manually operated flight control systems are the most basic method of controlling an aircraft. They were used in early aircraft and are currently used in small aircrafts, where the aerodynamic forces are not high. A manual flight control system uses a collection of mechanical parts, such as pushrods tension cables pulleys, counter weights and chains to transmit the forces applied to the cockpit controls, directly to the control surfaces.

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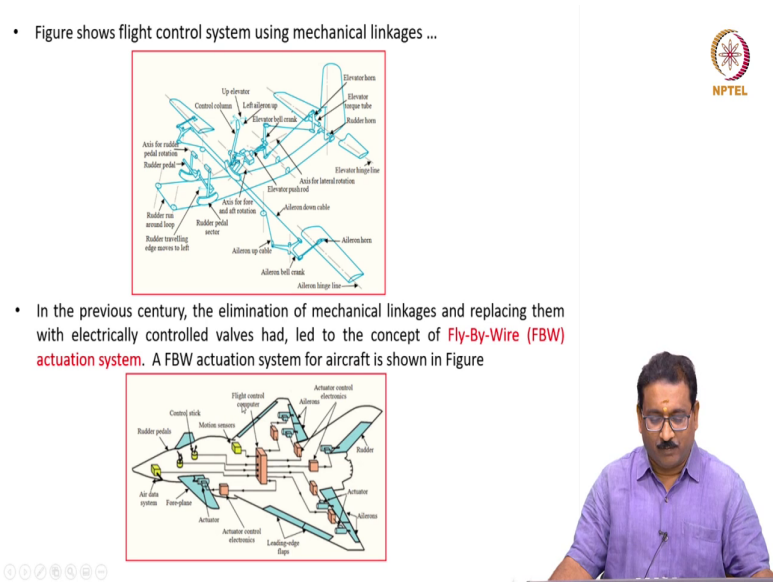


Figure shows the flight control system using a mechanical linkages. There are various parts are there here where the mechanical linkages are used for transmit the power from the source to the usable area. In the previous century the elimination of mechanical linkages, and replace them with electrically controlled valves had led to the concept of fly by wire FBW actuation system or FBW technology.

A FBW actuation system for aircraft is as shown in figure, please see here the mechanical linkage are used next version is fly by wire technology. See here the various parts are there here. I have shown you the control stick the motion sensors, rudder pedals, flight control computers, motion sensors, various places, ailerons, rudder so, many actuator are inbuilt here. But, all are drive through the fly by wire technology, instead of the mechanical linkages in the old aircraft.

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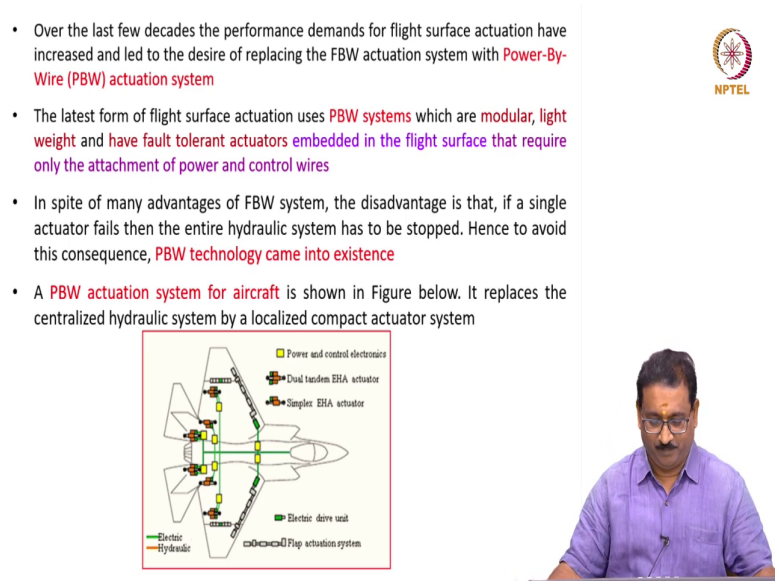


Over the last few decades the performance demands for flight surface actuation have increased and led to the desire of replacing the FBW actuation system with power by wire actuation system, it is also known as PBW technology. The latest form of flight surface actuations uses PBW systems, which are modular lightweight and have fault tolerant actuator embedded in the flight surface that require only the attachment of power and control wires.

In spite of many advantages of FBW system the disadvantage is that if the single actuator fails, then the entire hydraulics system has to be stopped. Hence to avoid this consequences PBW technology came into existence. A PBW actuation system for aircraft as shown in figure below objective is it replaces the centralized hydraulic system by a localized compact actuator system.

You will see here there are various actuators are there here, all are having the self contained power pack, these are also known as the pipe less technology.

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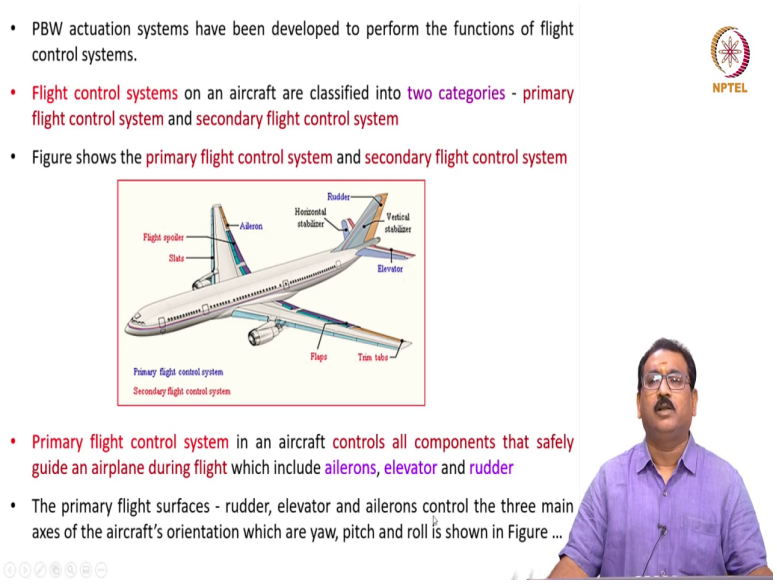


PBW actuation systems have been developed to perform the functions of flight control systems. Flight control systems on an aircraft are classified into two categories primary flight

control system, and a secondary flight control system. Figure shows the primary flight control system and a secondary flight control system.

See here I have shown the many elements here, the blue color is primary flight control system, mainly the ailerons, rudders, elevators. Secondary flight control systems are shown red color, flight spoiler, slats, flaps, trim tabs and many more. What are these? Primary flight control system in an aircraft controls all the components that safely guide an airplane during flight, which includes ailerons, elevators, rudders.

The primary flight surfaces rudder elevator aileron control the three main axis of the aircraft orientation, which are yaw pitch roll as shown in the figure here.

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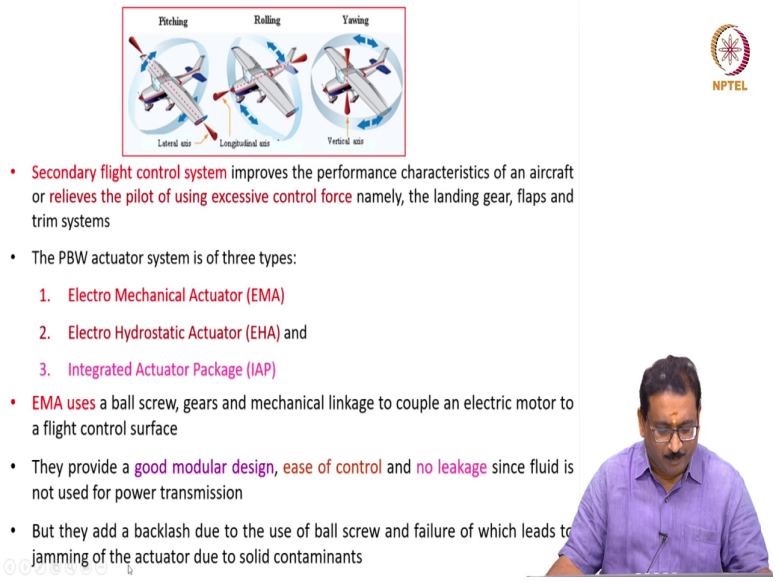

You will see her aircraft is a pitching action, you will see the pitching action. Along the lateral axis, along the longitudinal axis, rolling actions it will roll and in vertical axis the yawing actions. Secondary flight control system improves the performance characteristics of an aircraft or relieves the pilot of using excessive control forces namely the landing gear, flaps and trim systems.

The PBW actuation system is of three types, 1st one is Electro Mechanical Actuator briefly known as EMA. 2nd one is electro hydrostatic actuator which is a today's class discussion on it and Integrated Actuator Package also known as IAP. What is this EMA? EMA uses a ball screw gears and mechanical linkages to couple an electric motor to a flight control surface.

They provide a good modular design ease of control and no leakage. Since the fluid is not used for power transmission in EMA, but they add a backlash due to the use of ball screw and a failure of which leads to jamming of the actuator due to solid contaminants.

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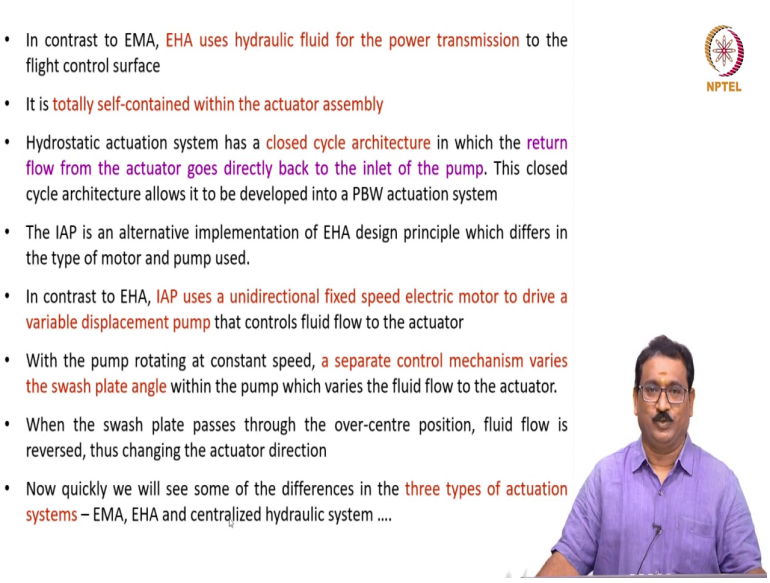


In contrast to EMA, EHA uses hydraulic fluid for the power transmission to the flight control surface. It is totally self-contained within the actuator assembly. Hydro static actuation system has a closed cycle architecture please remember closed cycle it is, meaning which in which the return flow from the actuator after doing the work goes directly back to the inlet of the pump. This is closed cycle architecture allows it to be developed into a PBW actuation system.

The IAP is an alternative implementation of EHA design principle, which differs in the type of motor and pump used in contrast to EHA, IAP users a unidirectional fixed speed electric motor to drive a variable displacement pump. That controls fluid flow to the actuator with a pump rotating at constant speed; a separate control mechanism varies the swash plate angle of the piston pump which varies the fluid flow to the actuator.

When the swash plate passes through the over center position, the fluid flow is reversed thus changing the actuator direction. Now, quickly we will see some of the differences in the three types of actuation namely here EMA, EHA and a centralized hydraulic system which is in olden aircraft is more frequently used.

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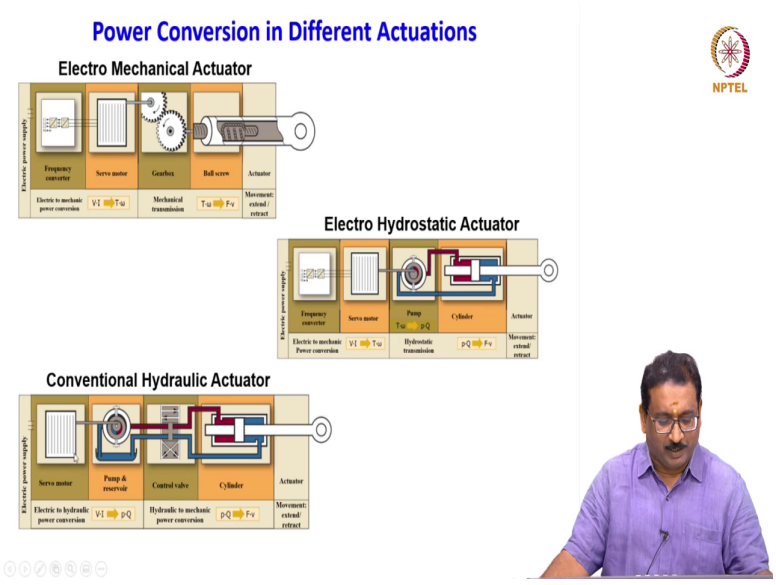


Let us we will see the first we will see the power conversion in different actuations, you will see here I am showing you electro mechanical actuator EMA actuator. Here the electric power supply first one is a frequency converter, then it will go to the servo motor from the servo through the gear box, it will reach to the actuator the ball and screw. What is a electric to mechanical power conversion here? The voltage and current input to torque and omega.

In the mechanical transmission what happens here torque and omega is an input here, and then it will gives the force and a velocity of the actuator it is an EMA. Now, we will see the

electro hydrostatic actuator friends how it is, here the frequency converter, servo motor, then a pump and then your actuator cylinder then it will go to the load. Here you will see electric to mechanic power transmission voltage and current is an input similar to here.

Then, torque and omega is an output here which he used to drive the pump here, which will give you the here hydrostatic transmission is p and Q is used by the actuator to convert into force and the velocity. Now, you will see friends hear conventional hydraulic actuator. What is this?

Here you will see the electric to hydraulic power conversion, servo motor, which rises the pump here and reservoir is there and again V and I is an input to servo motor gives you the pump output is p and Q. Which is directed to the control valves, you will see here you will not found control valves from the control valves it will go to the actuators.

What is a hydraulic to mechanic power conversion? Here p and Q is used F and v is an output similar to here. These are the power conversion in EMA, EHA and conventional hydraulic actuator.

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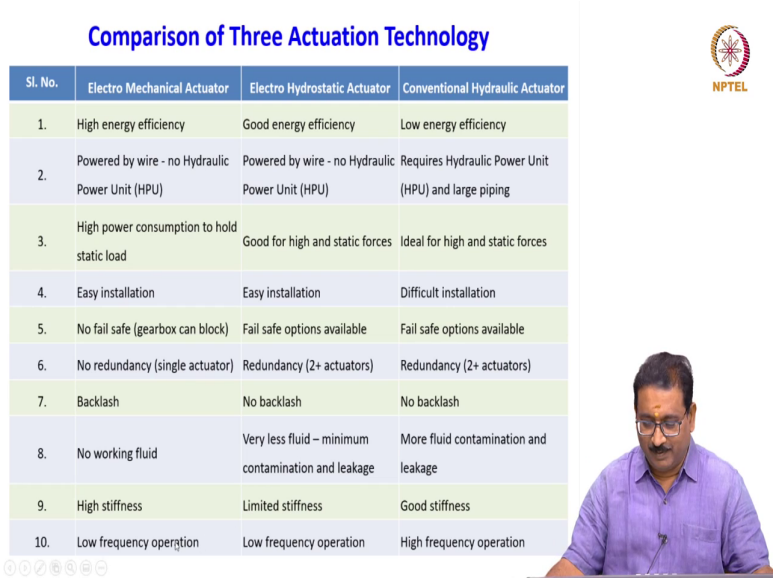


| Sl. No. | Electro Mechanical Actuator | Electro Hydrostatic Actuator | Conventional Hydraulic Actuator |
|---|---|---|---|
| 1. | High energy efficiency | Good energy efficiency | Low energy efficiency |
| 2. | Powered by wire - no Hydraulic Power Unit (HPU) | Powered by wire - no Hydraulic Power Unit (HPU) | Requires Hydraulic Power Unit (HPU) and large piping |
| 3. | High power consumption to hold static load | Good for high and static forces | Ideal for high and static forces |
| 4. | Easy installation | Easy installation | Difficult installation |
| 5. | No fail safe (gearbox can block) | Fail safe options available | Fail safe options available |
| 6. | No redundancy (single actuator) | Redundancy (2+ actuators) | Redundancy (2+ actuators) |
| 7. | Backlash | No backlash | No backlash |
| 8. | No working fluid | Very less fluid – minimum contamination and leakage | More fluid contamination and leakage |
| 9. | High stiffness | Limited stiffness | Good stiffness |
| 10. | Low frequency operation | Low frequency operation | High frequency operation |

Now, we will see very quickly the comparison of three actuation technologies, you will see I have given the big list here. First one is a electro mechanical actuator, electro hydrostatic actuator and a conventional hydraulic actuator. All are relative comparisons here high energy efficiency, here good energy efficiency, conventional is low energy efficiency. Here powered by wire the no Hydraulic Power Unit HPU.

Here powered by wire here also no hydraulic power unit, in conventional requires a hydraulic power unit and a large piping's. Here high power consumption to hold a static load in the EHA good for high and a static forces, here ideal for high and static forces. Easy installation if you will see here, easy installation both here difficult installations because, we have to buy the individual component, and then assemble through the piping and hoses many things here difficult installation.

Now, we will see here no fail safe because gear box can block, here fail safe options are available here fail safe options available. No redundancy in EMA single actuator here, here redundancy is possible in EHA 2 plus actuators are there. Redundancy is their 2 plus actuators backlash here it is there, because it is electro mechanical actuator here no backlash, no backlash.

No working fluid here very less fluid, because after doing the work again it will join to the pump, it will recirculate. Here more fluid contamination and leakage, high stiffness, limited stiffness, good stiffness, low frequency operation, low frequency operation and a high frequency operation. These are some of the comparison of three actuation technologies.

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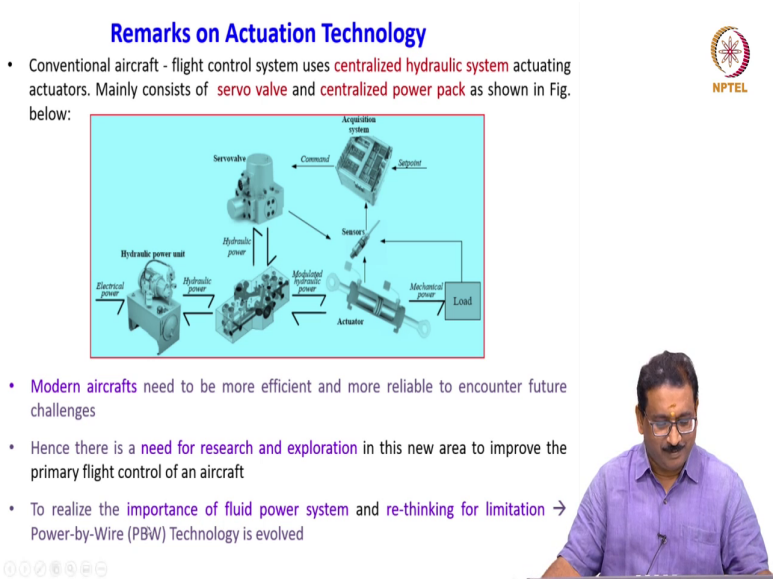


Now, quickly will see remarks on EMA, EHA and a conventional hydraulic actuations. Conventional aircraft flight control system uses a centralized hydraulic system, actuating

actuators, mainly consists of a servovalve and a centralized power pack as shown in the figure here. Here power pack is there and it will supply the energy to the various part of the actuator here, a main parts are here, this is a hydraulic power pack servovalve.

And then here it is a acquisition system data acquisition system electronic sensors are there to measure the actuator output actuator and a load. Modern aircrafts as I have told you need to be more efficient and more reliable to encounter the future challenges. Hence, there is a need for research and exploration in this new area, to improve the primary flight control of an aircraft.

To realize the importance of fluid power system and rethinking for limitation PBW technology is evolved.

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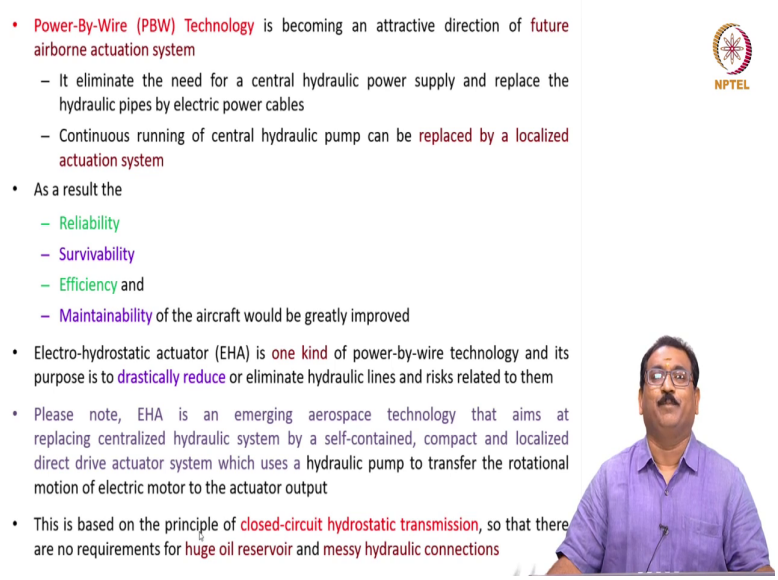

PBW technology is becoming an attractive direction of future airborne actuation system. It eliminates the need for a centralized hydraulic supply, and replaces the hydraulic pipes by electric power cables. Continuous running of central hydraulic pump can be replaced by a localized actuation system.

As a result the reliability, survivability, efficiency and maintainability of the aircraft would be greatly improved. Meaning each actuator has its own power pack oil is very very simple, other actuators as and when you use it. Electro hydrostatic actuator is a kind of power by wire technology.

And its purpose is to drastically reduce or eliminate hydraulic lines and a risk related to them like a leakage. Please note EHA is an emerging aerospace technology that aims at replacing the centralized hydraulic system by a self contained compact, and localized. Direct drive actuation system which uses a hydraulic pump to transfer the rotational motion of electric motor, to the actuator output.

This is based on the principle of closed circuit hydrostatic transmission; you have discussed these thing in the previous classes. So, that there is no requirement for huge oil reservoir and messy hydraulic connection. That is why it is a light weight compact system it is EHA.

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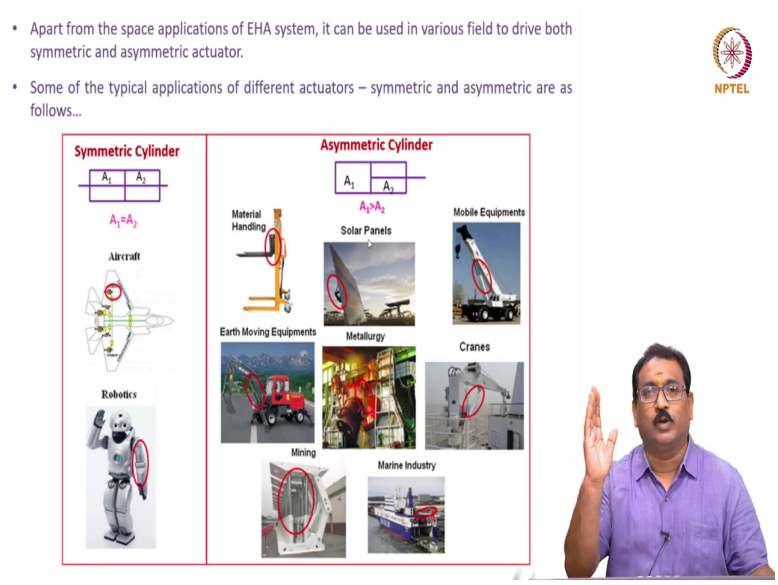


Apart from the space applications of EHA system, it can be used in various field to drive both symmetric and asymmetric actuator used in various applications not only in aerospace. Now, you will see some of the typical applications of different actuators like a symmetric and asymmetric actuator is as follows. Symmetric means already you know that the equal areas A 1 and A 2 are same, it is symmetric actuator areas are same.

Here various aircraft application are there in robotics also they are used. Asymmetric also occupy the large number of application, where the areas are different A 1 is greater than here head side and tail side area a symmetric. Here material handling earth moving equipments, heavy equipments, mining ok, marine industry, metallurgical industries, solar panels to rotate the solar panels the EHA systems are used. Also cranes mobile equipments and many many.