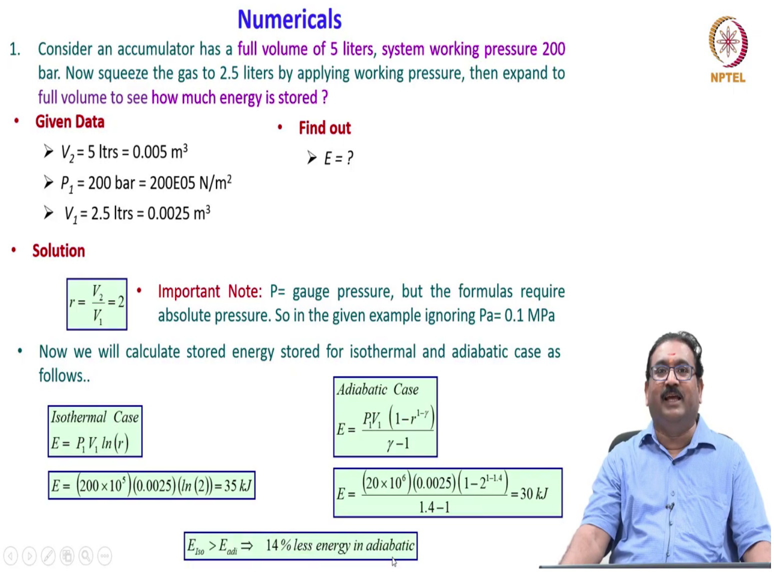
Oil Hydraulics and Pneumatics
Prof. Somashekhar S
Department of Mechanical Engineering
Indian Institute of Technology, Madras

Subsystems: Hydraulic accumulators, Classifications, Applications, Accumulator physics, Maintenance, Numericals
Lecture - 66
Part 3: Numericals – How much energy is stored, amount of oil that can be stored in the accumulator, Maintenance, Repair, Reconditioning and Troubleshooting

(Refer Slide Time: 00:23)



My name is Somashekhar, course faculty for this course. Now quickly we will see some Numericals on accumulator. Consider an accumulator has a full volume of 5 liters the full capacity of the accumulator is 5 liters, system working pressure 200 bar. Now, squeeze the gas to 2.5 liters meaning exactly half I am squeezing by applying the working pressure, then expanded to full volume to see how much energy stored? w we have to calculate.

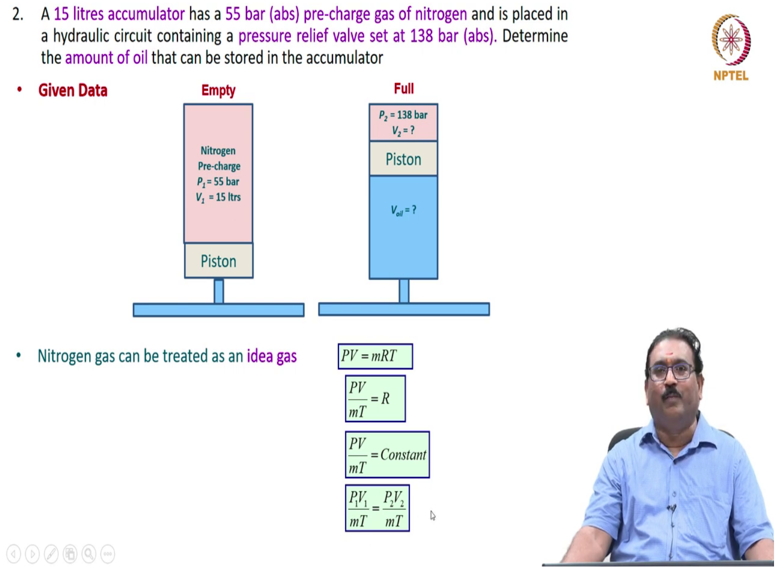
For this what are the given data? The full volume V 2 is how much it is? 5 liters, I am converted into m cube same unit. P 1 is 200 bar you know already know it Pascal how to convert multiplied by 10 to the power of 5, the V 1 is you know compressing to 2.5 liters same m cube what to do? You have to calculate the energy stored. Already we know that the r equal to V 2 by V 1 you substitute the V 2 by V 1 you will get the 2.

Please note friends here, very very important it is also question for you people, the P is a gauge pressure what they are given, but all formulas what we have calculated previously they requires the absolute pressure meaning you have to add the atmospheric pressure or you will write the note in the given example, I am ignoring the atmospheric pressure which should be the 0.1 MPa or 1 bar.

Now, we will calculate the stored energy for isothermal as well as adiabatic case as follows. Isothermal case already we know that E equal to P 1 V 1 ln r already we know all the values P 1 is known, V 1 is known and r is also known calculate 35 kilo joule.

Similarly, adiabatic gamma is coming P 1 V 1 into bracket 1 minus r to the power of 1 minus gamma-gamma minus 1. Substitute all the values, I will get the 30 kilo joule for adiabatic for isothermal 35 kilo joule. How much it is less? Approximately, the 14 percent less energy in adiabatic.

(Refer Slide Time: 03:14)

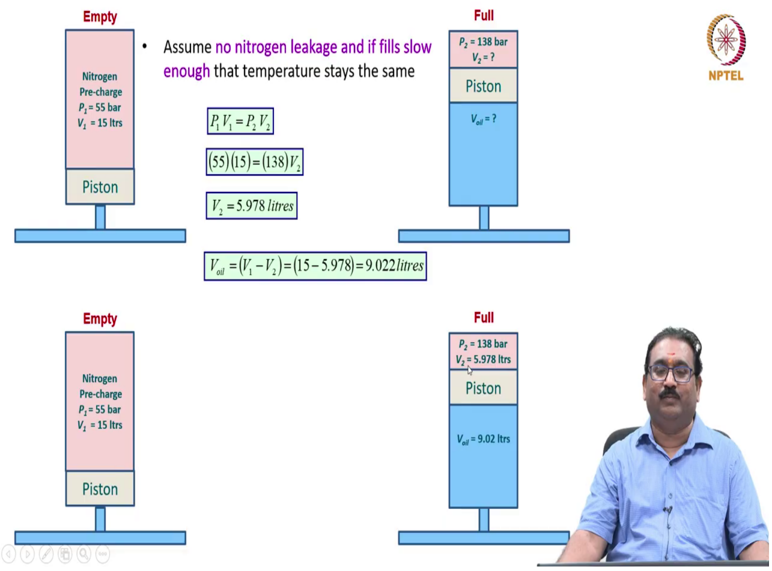


Now, we will move on to one more problem. A 15 liters accumulator has a 55 bar absolute very very important if they are given absolute automatically you will use same value. If they are given the gauge pressure be careful you have to add 1 bar to get the absolute value. Pre-charge gas of nitrogen and is placed in a hydraulic circuit containing a pressure relief valve at 138 bar absolute determine the amount of oil that can be stored in the accumulator.

For this what are the given data? I will first we will start with the empty cylinder, here the nitrogen pre charge they are given the P 1 equal to 55 bar absolute it is V 1 is given as a 15 liters full accumulator when it is compressed due to the oil entry through the pump what happens? P 2 is given as a piston pressure 138 bar. Now, our objective is to find out the how much oil will be stored here.

For this what is required? We have to use ideal gas loss, but V 2 is also I do not know how much it is; how much it is. For that what we will do? Assuming that the nitrogen gas can be treated as an ideal gas PV equal to mRT is an equation then PV by mT equal to R then what? PV equal to mT is constant R is the gas constant when you will use one state to another state P 1 V 1 by mT equal to P 2 V 2 by mT. Later these two terms will get cancel I will get P 1, V 1 equal to P 2, V 2.

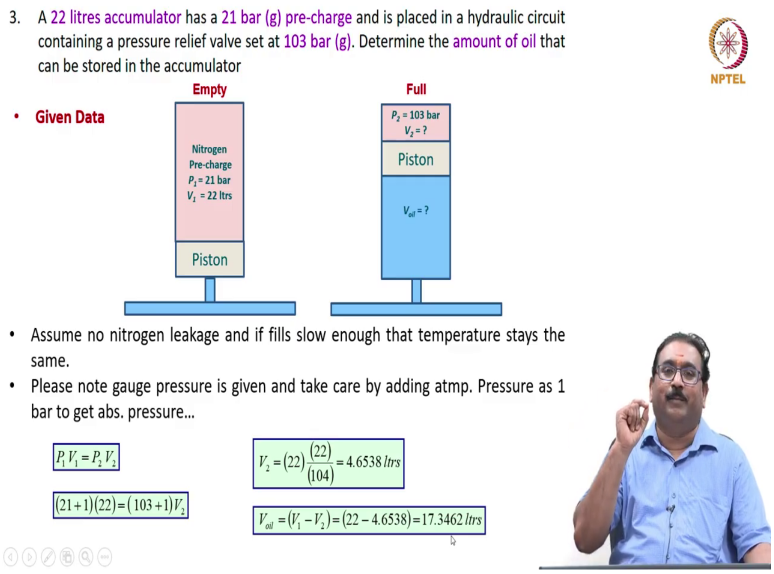
(Refer Slide Time: 05:06)



Assuming in no nitrogen leakage and if fills slow enough that temperature stays the same then P 1, V 1 equal to P 2, V 2 as I have told you then substitute all the values given values the V 2 is unknown you will calculate V 2 equal to 5.978 liters. You do not bother here friends, directly I am putting in the bar 55 bar, 138 bar and in liters.

No need to worry here because in this equation units will match all then V 2 equal to 5.978. If I know the 5.978 here I know the V 1 15 bar take the minus to get the V oil, V oil equal to V 1 minus V 2 here 15 liters minus 5.978 liters I will get here the oil volume is 9.022 liters meaning finally, I will get it all the parameter like this V oil and V 2.

(Refer Slide Time: 06:12)



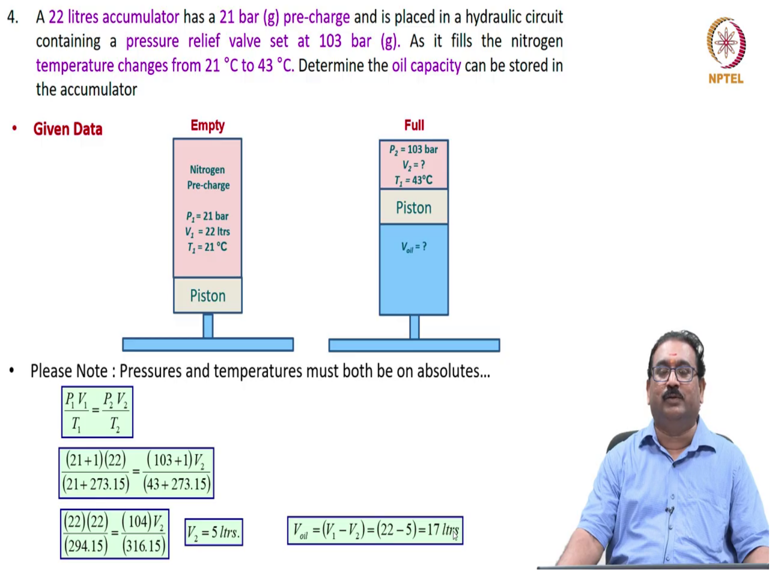
Quickly we will see one more problem. A 22 liters accumulator has a 21 bar gauge when they will give like this be careful, formulas are derived with absolute pressure from the 0 level. This is gauge pressure, gauge pressure means above the atmospheric level you have to add the one bar pressure you will see now it is placed in the hydraulic circuit containing the pressure relief valve at 103 bar gauge determine the amount of oil.

Similar to previous but why I am taking this is you which pressure is given you have to be careful. The given data as usual P 1 is given V 1 is given nitrogen pre-charge it is and P 2 is given system pressure, V 2 I do not know and V oil is very important. Same thing similarly assuming the no nitrogen leakage and if fills slowly enough the temperature stays the same.

This is an assumption meaning isothermal process please note the gauge pressure is given and take care by adding the atmospheric pressure as one bar to get the absolute pressure. P1 V 1 equal to P 2 V 2 substitute all the value you will see I am adding now, 21 plus 1 here also 103 bar plus 1 then only it is absolute pressure.

Then we will get V 2 is equal to 4.6538 litre V 2 I am getting once I know the V 2 V 1 minus V 2 is nothing but the V oil 17.3462 liters very very simple problem simple see similar to previous one, only to show you the how to concentrate more on the pressure terms.

(Refer Slide Time: 08:03)

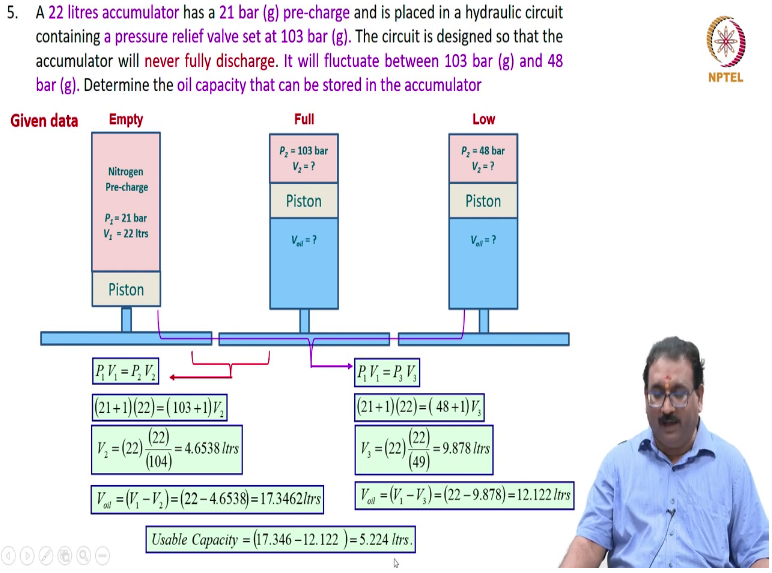


A 22 liter accumulator has a 21 bar gauge no need to worry or what we have to add it 1 bar pre-charge and is placed in a hydraulic circuit containing the pressure relief valve set at 103 bar. As it fills the nitrogen temperature changes from 21 degree centigrade to 43 degrees centigrade when it will fills temperature changes adiabatic.

Determine the oil capacity can be stored in the accumulator. So, the given parameter P 1 V 1 T 1 is given when it is storing what happens? P 2 is 103 bar, T 1 is 43 degree centigrade then we have to determine the V oil and V 2. Same thing here friends, but only thing precaution is please note pressures and temperatures must both be in absolute values.

What to do for that? Same equation P 1 V 1 by T 1 equal to P 2 V 2 by T 2 substitute the values in the absolute values meaning P 1 is 21 plus 1 temperature also to convert the degree centigrade to absolute values we have to add 273.15, then afterwards we will calculate V 2 equal to 5 liters then the V oil equal to V 1 minus V 2 it is a 17 liters, the objective of this problem is all the pressure terms and a temperature terms must be put in the absolute values not the gauge.

(Refer Slide Time: 09:58)



Now, let us we will see one more problem on accumulator, a 22 liters accumulator has a 21 bar gauge pre-charge and is placed in a hydraulic circuit containing a pressure relief valve set at 103 bar again gauge pressure it is, the circuit is designed so, that the accumulator will never fully discharge. It will fluctuate between 103 bar gauge and a minimum pressure 48 bar gauge. Determine the oil capacity that can store in the accumulator.

Friends, you will see all these parameter I am keeping same because to understand the, where the changes are taking place in the problem only that reason that is why I am keeping these 22 liters, 21 bar, 103 bar I am keeping same, but in examination they may change any value. Now, we will see here the given data for empty accumulator the nitrogen P charge P 1 is 21 bar V 1 is 22 liters.

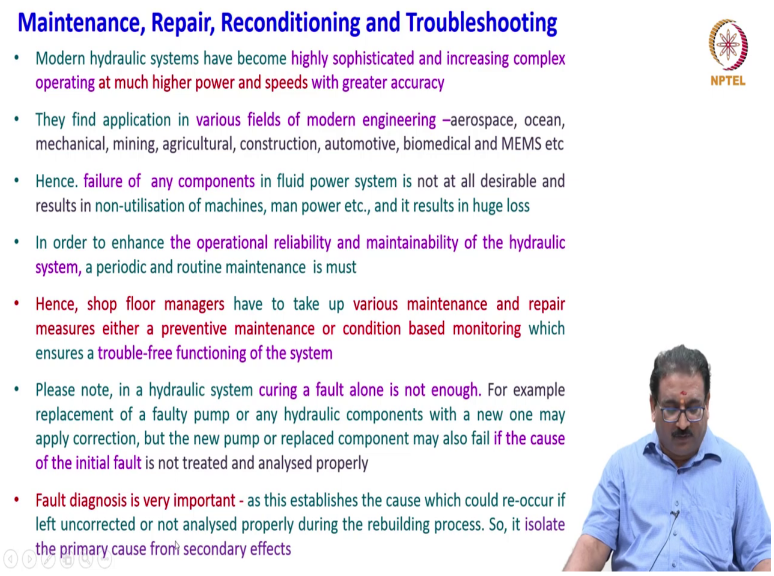
When it is fully charged P 2 is 103 bar our objective is to find out the V oil how much it is for that before we have to find out the V 2 you know already P 1 V 1 equal to P 2 V 2 from that we have to determine V 2 then you have to calculate V oil. Then given the accumulator will fluctuate between the pressure that is a low pressure is P 2 equal to 48 bar and what is my V 2 and what is my V oil we have to find out.

So, for that first what I will do? I will apply the equations for the empty and full that time P 1 V 1 equal to P 2 V 2 then substitute all the values, but please take care friend all the values are in the absolute terms that is why I am adding the one bar here then we have to determine the V 2, V 2 here what I am getting is 4.6538 liters.

Then V oil is the V 1 minus V 2 will give you the V oil it is a 17.3462 liters. Now, we will apply the same equations for the empty and the low loaded accumulators as P 1 V 1 equal to P 3 V 3 now substitute all the values in the absolute term we will get V 3 equal to now this time I am getting V 3 equal to 9.878 liters.

Then V oil is now I am getting the 12.122 liters. Previously, I am getting 17.3462 liters when the pressure is 103 bar. Now, when it is very low fluctuates very low 48 bar I am getting 12.122 then what is the difference here this is the usable capacity is this minus this will give you the usable capacity, that is a 5.224 liters.

(Refer Slide Time: 13:20)



After knowing the some of the simple numericals on the accumulators, now let us we will quickly we will see the maintenance, repair, reconditioning and a trouble shooting steps in the fluid power system. These steps are mainly meant for the oil hydraulics and the same thing can be used for the pneumatics also.

But, only thing as we have seen only the working media will matters in the hydraulics we are using the oil incompressible fluids and the pneumatics we are using the compressible fluids only this is a change. But, all the maintenance, repair and reconditioning, trouble shooting steps are very very important in both the oil hydraulics and pneumatic system.

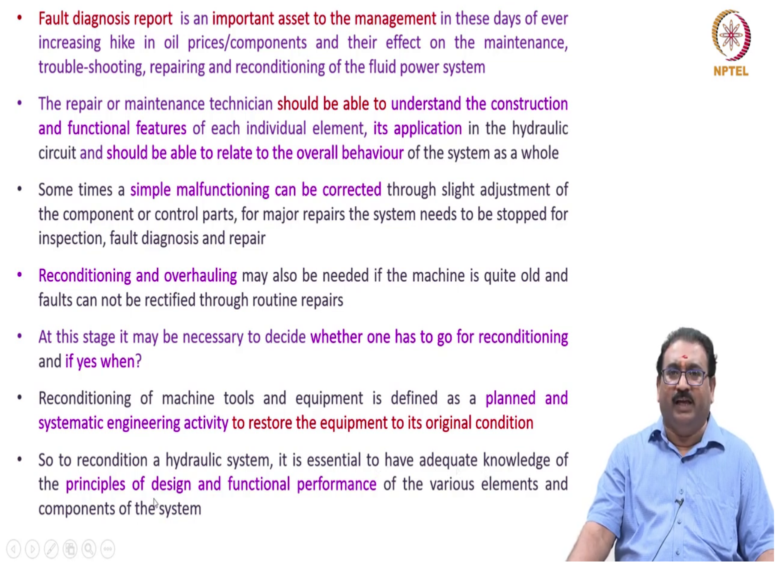
The modern hydraulic systems have become highly sophisticated and increasing complex operating at much higher power and speeds with a greater accuracy. They find a wide applications in various fields of modern engineering - aerospace, ocean, mechanical, mining, agricultural, construction, automotive, biomedical and MEMS devices.

Hence, failure of any components in a fluid power system is not at all desirable and results in a non utilization of machines, manpower etcetera and it results in a huge loss. In order to enhance the operational reliability and a maintainability of the hydraulic system, a periodic and a routine maintenance is must.

Hence, shop floor managers have to take up various maintenance and repair measures either a preventive maintenance or a condition based monitoring which ensures a trouble free functioning of the system. Please note, in a hydraulic system curing a fault alone is not enough.

For example, replacement of a faulty pump or any other components with a new one may apply a corrections, but the new pump or a replaced the component may also fail if the cause of the initial fault is not treated and analyzed properly. Fault diagnoses is very important as this is establishes the cause which could re-occur if left uncorrected or not analyzed properly during the rebuilding process. So, it isolates the primary cause from secondary effects.

(Refer Slide Time: 16:17)



Fault diagnoses report is an important asset to the management, in these days of ever increasing hike in oil prices and a components and that the effects on the maintenance, trouble-shooting repairing and reconditioning of the fluid power system. The repair or a maintenance technician should be able to understand the construction and a functional features of each individual element, its application in the hydraulic circuit and should be able to relate to the overall behavior of the system as a whole.

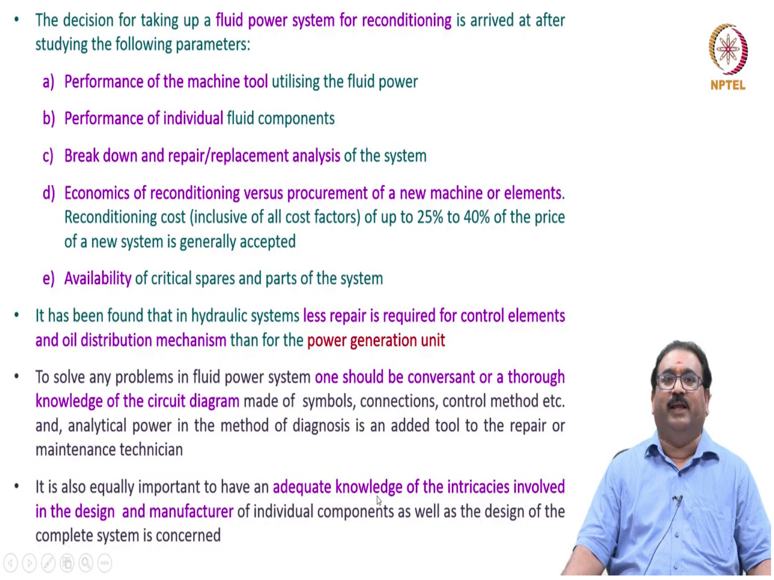
Sometimes, a simple malfunctioning can be corrected through slight adjustment of the component or control parts, for major repair the system needs to be stopped for inspection fault diagnoses and a repair. Reconditioning and overhauling may also be needed if the machine is quite old and faults cannot be rectified through the routine repairs.

At this stage it may be necessary to decide whether one has to go for reconditioning and if yes when? Reconditioning of machine tools and equipments is defined as a planned and systematic engineering activity to restore the equipment to its original condition [FL].

Student: [FL]

Reconditioning of machine tools and equipment is defined as a planned and a systematic engineering activity to restore the equipment to its original condition. So, to recondition a hydraulic system it is essential to have a adequate knowledge of the principles of design and functional performance of various elements and a components of the system.

(Refer Slide Time: 18:29)



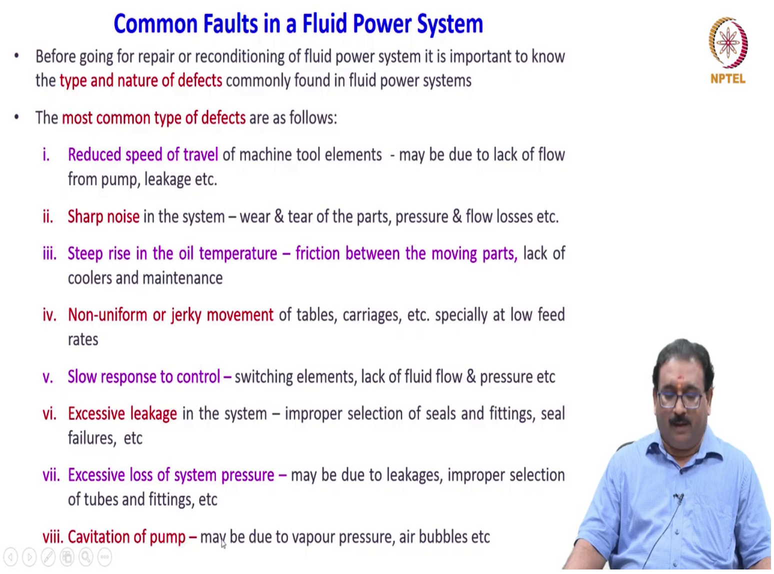
The decision for taking up a fluid power system for reconditioning is arrived at after studying the following parameters, performance of the machine tool, utilizing the fluid power, performance of individual fluid components, break down and repair or a replacement analysis of the system.

Economics of reconditioning versus procurement of new machine or elements: Reconditioning cost of up to 25 percent to 40 percent of the price of a new system is generally accepted. Availability of critical spares and parts of the system. It has been found that in a hydraulic system less repair is required for control elements and oil distribution mechanism than for the power generation unit.

To solve any problems in fluid power system one should be conversant or a thorough knowledge of the circuit diagram made of symbols, connections, control method etcetera and also analytical power in the method of diagnoses is an added tool to the repair or a maintenance mechanic.

It is also equally important to have an adequate knowledge of the intricacies involved in design and manufacturing of the individual components as well as the design of the entire system is concerned.

(Refer Slide Time: 20:21)

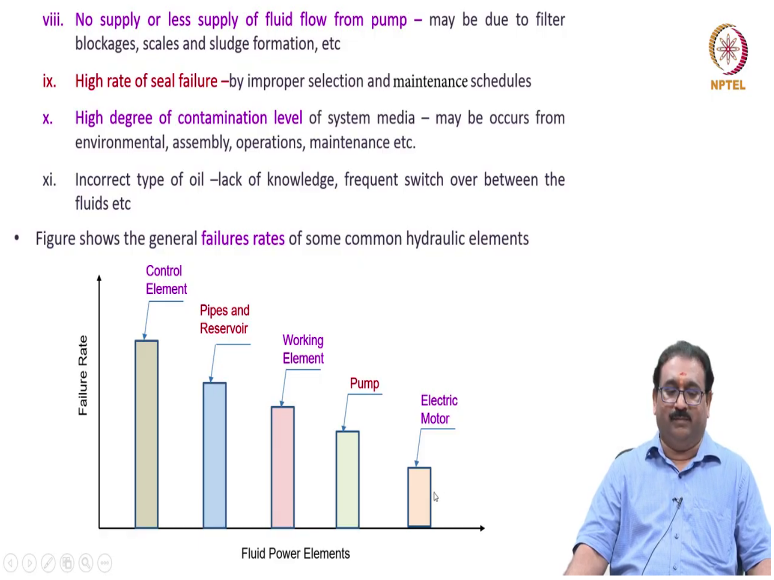


Now, let us we will see common faults in a fluid power system. Before going for repair or reconditioning of fluid power system it is important to know the type and the nature of defects commonly found in the fluid power systems. The most common defects you come across are as follows. Reduced speed of travel of the machine tool elements, this may be due to lack of flow from the pump or a leakage in the hydraulics line.

Sharp noise in the system this may be due to the wear and tear of the parts, pressure and fluid losses, steep rise in the oil temperature this may be due to friction between the moving parts, lack of coolers and maintenance. Non-uniform or a jerky movements of tables, carriages, etcetera specially at low feed rates Slow response to control: meaning here due to the switching elements, lack of fluid flow and a pressures and many more.

Excessive leakage in the system-this may be due to the improper selection of seals and a fittings seal failures and many more Excessive loss of the system pressure maybe due to the leakages, improper selection of tubing and fittings, vibrations, wear and tear of the parts and many more. Cavitation of the pump: maybe due to vapour pressure, air bubbles, foam formation in the reservoir tank and many more.

(Refer Slide Time: 22:24)

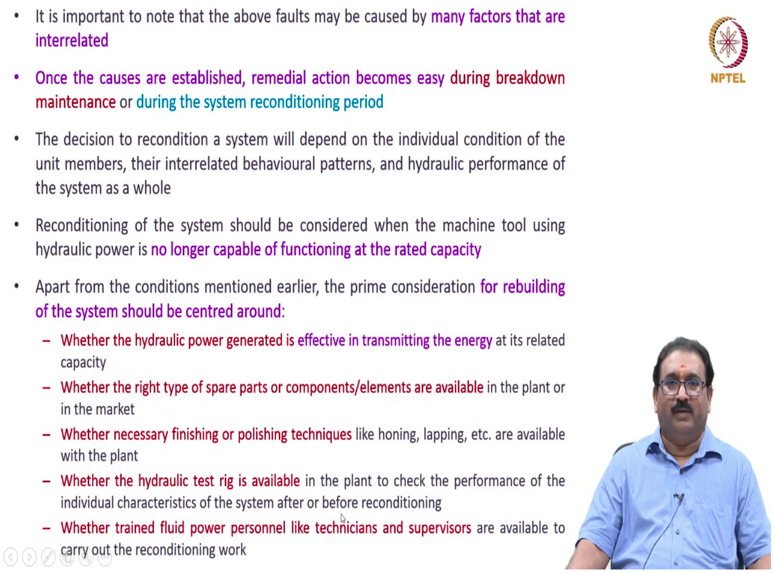


No supply or a less supply of flow from the pump what is the reason here? May be due to filter blockages, scales and sludge formation in the tank and many more. High rates of seal failure this is by improper selection and maintenance schedules. High degree of contamination level of the system media this may be occur from the environment or assembly time or operations the wear and tear will take place due to the friction between the parts.

And also during the maintenance the environmental dust particles may enter in the system this is also the main reason. Incorrect type of oil, this may be due to lack of knowledge, frequent switch over between the one fluid to another working fluid this is also affecting the performance.

Now, I am showing you the general failure rates of some common hydraulic components, you will see here friends the failure rate versus the fluid power elements the control elements failure rate is more. Next is a pipes and reservoirs working element like actuators, here it is a pump next one is a electric motor.

(Refer Slide Time: 23:58)



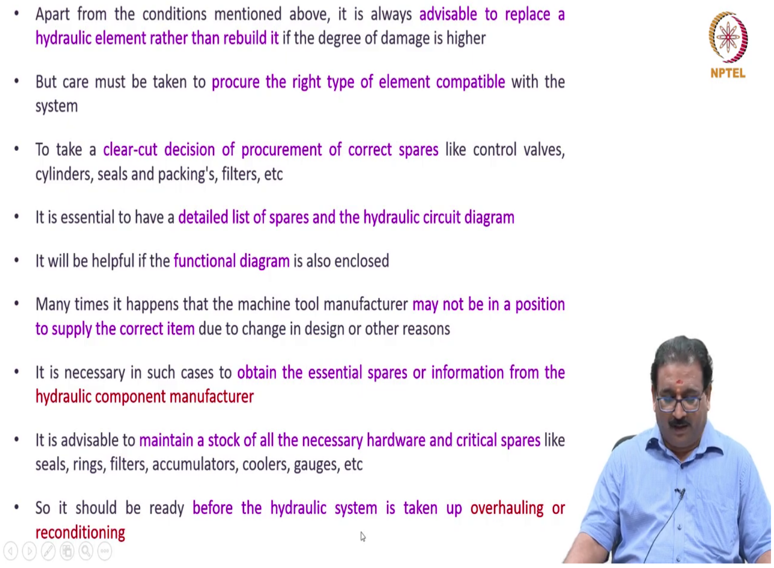
It is important to note that the above faults may be caused by many factors that are interrelated. Once the causes are established, remedial action becomes easy during the breakdown maintenance or during the system reconditioning period. The decision to recondition a system will depend on the individual condition of the unit members, their interrelated individual patterns, and hydraulic performance of the system as a whole.

Reconditioning of the system should be considered when the machine tool using the hydraulic power is no longer capable of functioning at the rated capacity. Apart from the re conditioning mentioned earlier, the prime consideration for rebuilding of the system should be centered around: - whether the power generated is effective in transmitting the energy at its related capacity.

Whether the type of spare parts or a components or elements are available in the plant or in the market; whether the necessary finishing super finishing or polishing techniques like a honing, lapping etcetera are available with the plant.

Next, whether the hydraulic test rig is available in the plant to check the performance of the individual characteristics of the system after or before reconditioning. Also you have to see whether trained fluid power personnel like a technicians and supervisors are available to carry out the reconditioning work.

(Refer Slide Time: 25:59)

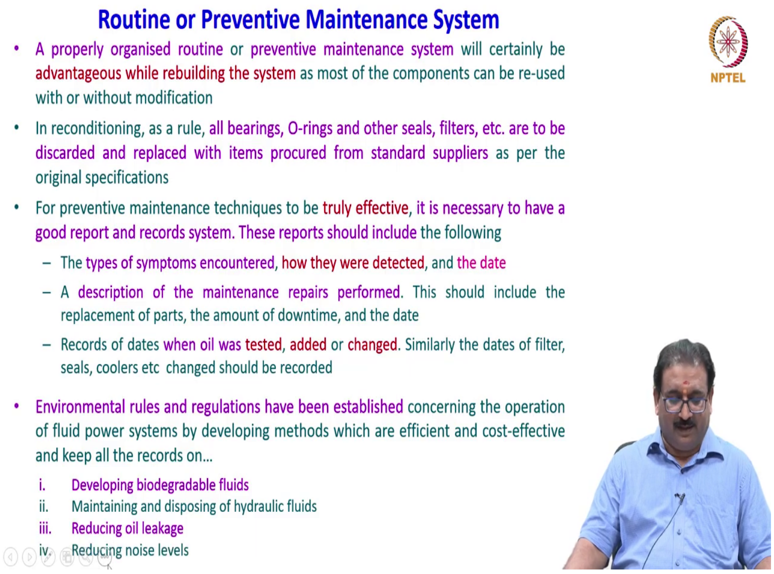


Apart from the conditions mentioned above, it is always advisable to replace a hydraulic element rather than rebuild it if the degree of damage is higher. But care must be taken to procure the right kind of elements compatible with the system is very important. To take care a clear-cut decision of the procurement of correct spares like a control valves, cylinders, seals and packings, filters etcetera.

So, it is essential to have a detailed list of spares and hydraulic circuit diagrams in hand. It will be helpful if the functional diagram is also enclosed. Many times it happens that the machine tool manufacturer may not be in a position to supply the correct item due to change in design or other reasons.

So, it is necessary in such cases to obtain the essential spare parts or information from the hydraulic component manufacturer. It is advisable to maintain a stock of all the necessary hardware and a critical spares like a seals, rings, filters, accumulators, coolers, gauges etcetera in the hands. So, it should be ready before the hydraulic system is taken of over hauling or a reconditioning.

(Refer Slide Time: 27:48)



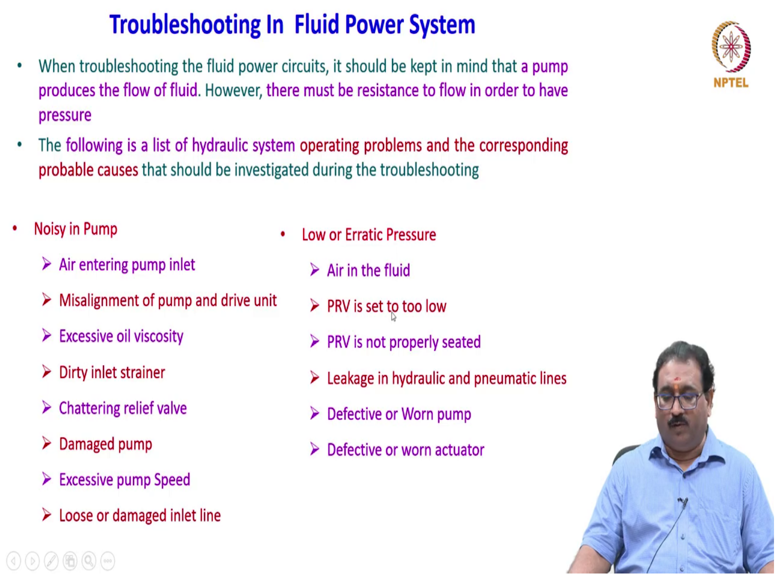
Now, quickly we will see the routine or a preventive maintenance system. A properly organized routine or a preventive maintenance system will definitely be advantages while rebuilding the system as most of the components can be re-used with or without modification.

In reconditioning as a rule of thumb all bearings, O-rings and other seals, filters etcetera are to be discarded and replaced with items procured from the standard suppliers as per the original specification. For a preventive maintenance techniques to be truly effective, it is necessary to have a good report and records the system. These reports should include the followings the types of symptoms encountered how they were detected and the date.

A description of the maintenance repairs performed: This should include the replacement of parts, the amount of down time and the date. Records of the date when oil was tested added or changed. Similarly the dates of filters, seals coolers and many other auxiliary component changed and should be recorded.

Last, but not the least environmental rules and regulation have been established concerning the operation of fluid power systems by developing the methods which are efficient and a cost effective and keep all the records on the developing biodegradable fluids, maintaining and disposing hydraulic fluids, reducing oil leakages, reducing noise levels.

(Refer Slide Time: 30:08)



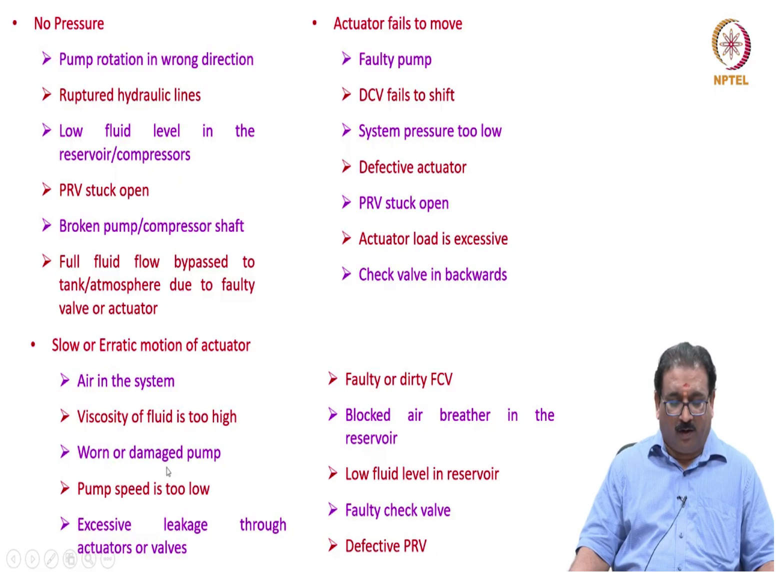
Now, quickly I will give you some glimpse on the trouble shooting on the various hydraulic components, why they will occur and where we will concentrate during the maintenance.

When troubleshooting the fluid power circuit, it should be kept in mind that a pump produces the flow of fluid.

However, there must be a resistance to flow in order to have a pressure. The following is a list of the hydraulic system operating problems and the corresponding probable causes that should be investigated during the trouble shooting. The noisy in pump maybe due to air entering pump inlet, misalignment of pump and drive unit, excessive oil viscosity, dirty inlet strainer, chattering relief valve, damaged pump, excessive pump speed loose or damaged inlet line.

Another problem may be a low or erratic pressure in the system, this may be due to the air in the fluid pressure relief valve is set to too low, PRV is not properly seated, leakage in hydraulic and a pneumatic lines, defective or worn pump, defective or worn actuator.

(Refer Slide Time: 31:49)



No pressure; this may be due to the pump rotation in wrong directions. Ruptured hydraulic lines, low fluid level in the reservoir or a compressors, PRV stuck open, broken pump or a compressor shaft, full fluid flow bypass to the tank or atmosphere due to faulty valve or actuator.

If actuator fails to move then what are the reason here? Faulty pump, DCV fails to shift, system pressure too low, defective actuator PRV stuck open, actuator load is excessive, check valve in backwards. Sometimes, we will come across slow or erratic motion of actuator.

This may be due to many reasons like a air in the system, viscosity of fluid is too high, worn or a damaged pump, pump speed is too low, excessive leakage to the actuator or valves faulty or a dirty flow control valves, blocked air breathers in the reservoir, low fluid level in the reservoir, faulty check valve, defective pressure relief valves.

(Refer Slide Time: 33:22)

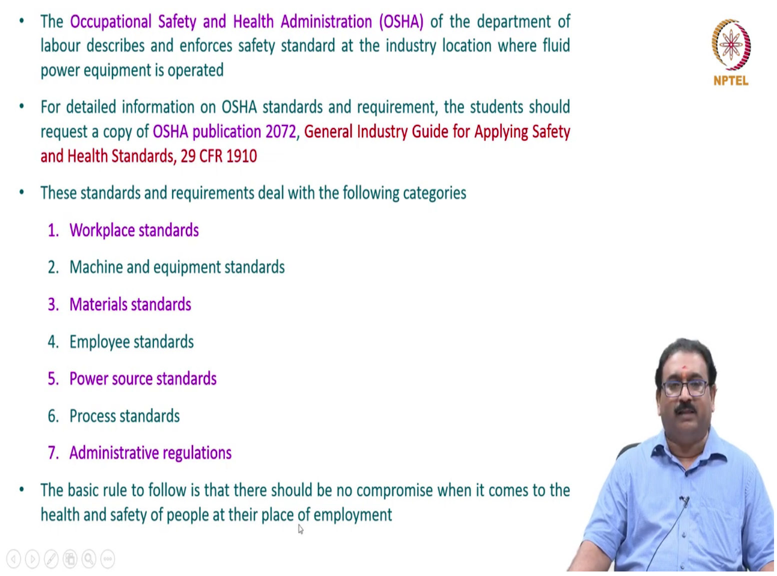
If we are come across over heating of the hydraulic fluid what are the reasons? Heat exchanger turned off or a faulty, undersized components or a piping's, incorrect fluid continuous operation of pressure relief valve, over loaded system, dirty fluid, reservoir too small, inadequate supply of oil in the reservoir, excessive pump speed clogged or inadequate sized air breathers.

Like this there are various parts they will give the precautions by generating the noise or sometimes you will not observe the pressure or sometimes you will not see the actuator movement or sometimes you will not get the flow at the pump outlet. Our objective is to find out what is a cost for it then we will try to rectify this using the your preventive maintenance or condition based monitoring system.

Now, quickly I will tell you friends, the safety aspects in fluid power, basically in hydraulic system is very important because we are operating at a very high pressures compared to pneumatics. There should be no compromise in the safety when fluid power circuits are designed, operated and maintained.

However, human errors are unavoidable, and accidents can occur, resulting in injury to operating and maintenance personnel. This can be greatly reduced by eliminating all unsafe conditions dealing with the operations and maintenance of the system. Many safe practices have been proven effective in preventing the safety hazards, which can be harmful to the health and safety of personnel.

(Refer Slide Time: 35:44)



The Occupational Safety and Health Administration briefly known as OSHA of the department of labour describes and enforces safety standards at the industry location where fluid power equipment is operated. For detailed information on OSHA standards and requirement the student should request a copy of OSHA publication 2072, General Industry Guide for Applying a Safety and Health Standards, 29 CFR 1910.

These standards and requirements deal with the following categories of standards. Workplace standard how it should be? Machine and equipment standards, material standards, employee standards, power source standards, process standards, administrative regulations. The basic rule to follow is that there should be no compromise when it comes to the health and safety of the personnel at their place of employment.

(Refer Slide Time: 37:12)

Ok friends, we will conclude today's lecture. So, in the today's lecture we have discussed in detail the followings hydraulic accumulators, characteristics, basic functions, desirable properties, broad classifications of the accumulators, application of accumulators in hydraulic circuit, accumulator physics here we will discuss the governing equation while designing the accumulators.

Numerical problems we have seen. Last, but not the least we have seen the maintenance, repair, reconditioning, trouble shooting and safety aspects. Ok friends, we will stop now and see you all in the next class.

(Refer Slide Time: 38:05)

Until then bye bye.

Thank you one and at all for your kind attention [FL].