

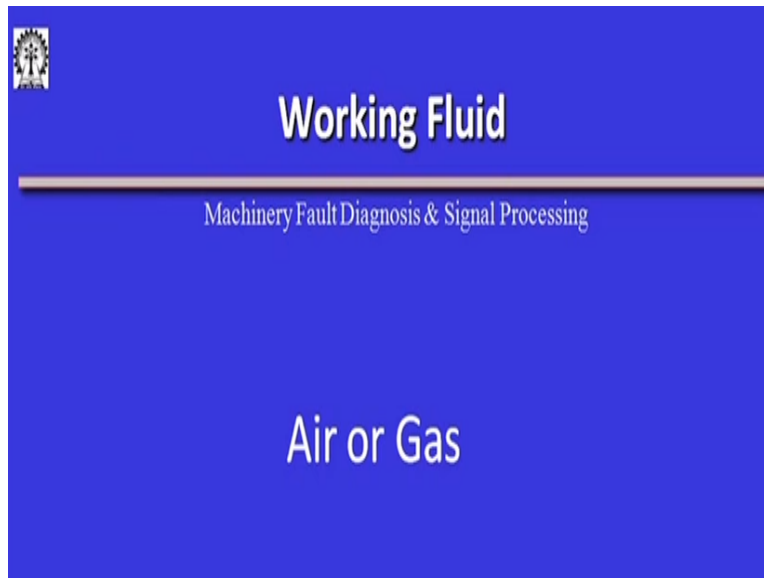
Machinery fault diagnosis and signal processing
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Module No # 06
Lecture No # 30
Fans, Blowers and Compressors

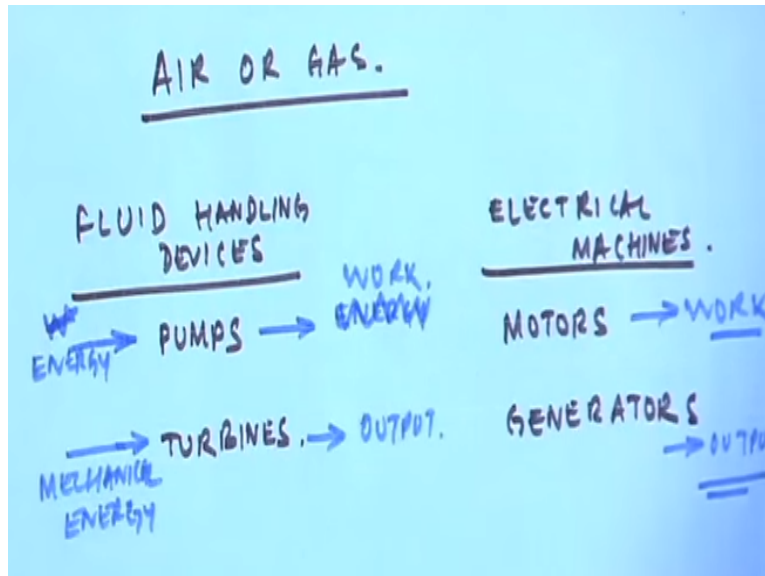
In this lecture today we will be discussing about fans, blowers and compressors actually fans, blowers and compressors these are actually air handling devices or machinery which one will come across in many plants and industries. So it is imperative that we understand this special characteristic of this machineries and how we can detect fault in them and what are the most common faults in them.

I before I get into the details of fault diagnosis in fans, blowers and compressors let me just briefly give you some examples as to how different they are from other machineries fluid handling machinery like say pumps and turbines. Basically pumps and turbines handle fluid it could be liquid of the sense of the like water other chemicals. But mostly when we talk about air handling devices we talk about fans, blowers and compressors.

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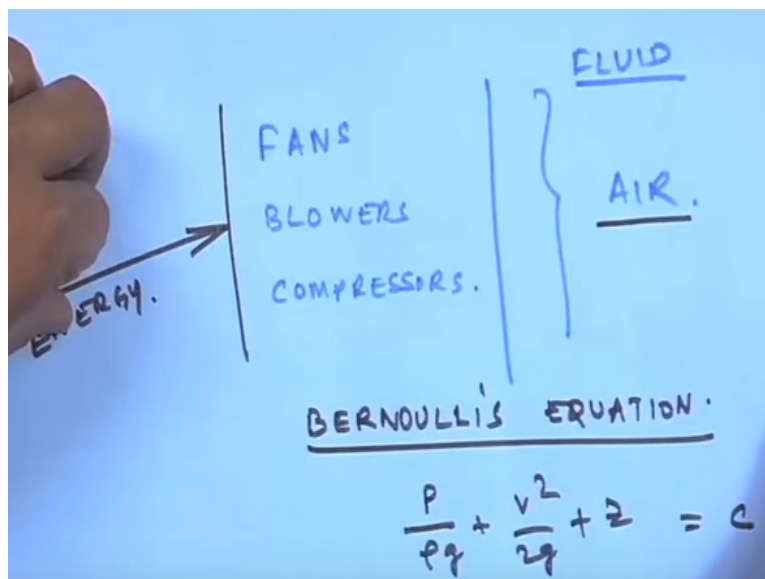
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So the working fluid in fans, blowers and compressors is air or gas see this fluid handling devices are very similar in they are out say principle or in philosophy in comparison with electrical machines. So the most type of electrical machines are the motors and the generators and the fluid handling devices are actually pumps and turbines okay.

In one case we give in work to get some increase in energy in other case it is that we give in some energy to get some work and here we give come mechanical energy to get an output okay. So in pumps or in motors we give some energy to get a work output and the reverse is to in case of turbine we give some work to get an output okay.

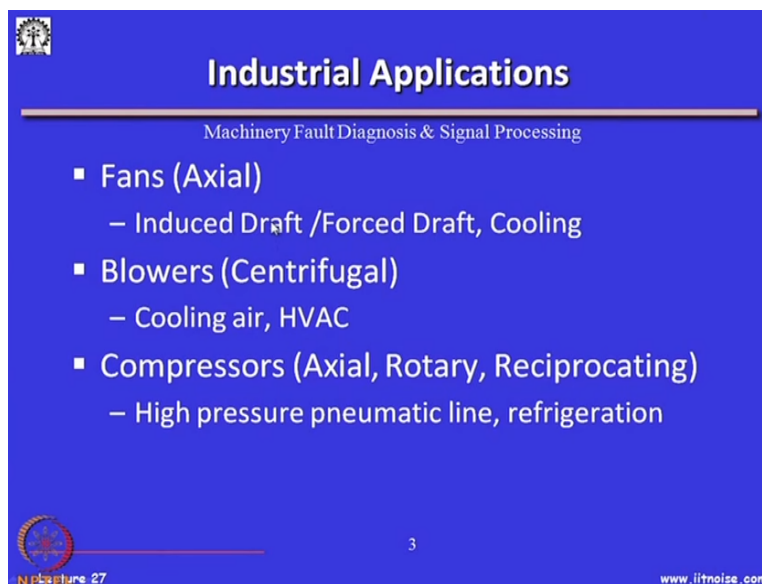
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Now coming back to this air handling devices to talk about fans, blowers and compressors. This fans, blowers and compressors are different in their sense that they are work in the fluid which is air in all the cases and we give in some extra energy from the outside okay to get some output of the systems. Now what is the output we are talking about basically if you all know the BERNOULLIS equation or so energy is constantly play around with the pressure head constant okay.

And we have to play around with the pressure head and the velocity head so basically fans, blowers and compressors we try to increase the pressure at the output by giving in more energy pressure by mean pressure of the fluid or air in this case.

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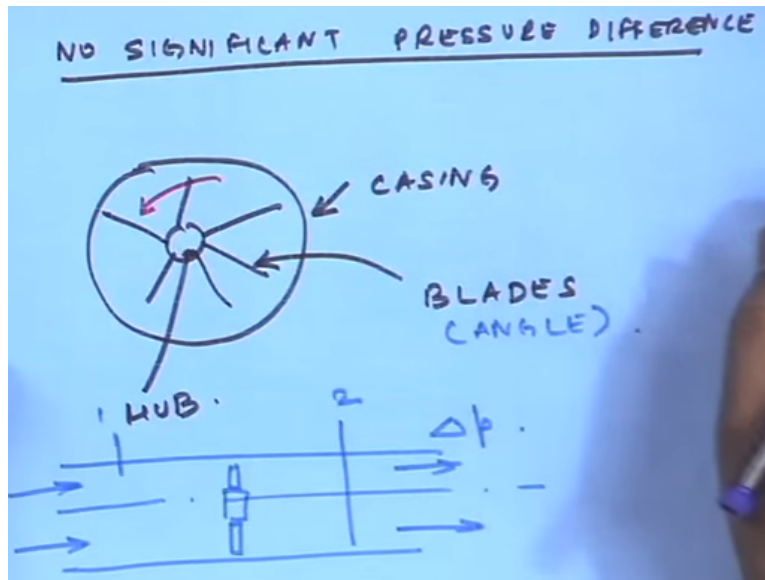
The slide is titled "Industrial Applications" and is part of a presentation on "Machinery Fault Diagnosis & Signal Processing". It lists three categories of machinery with their typical applications:

- Fans (Axial)
 - Induced Draft /Forced Draft, Cooling
- Blowers (Centrifugal)
 - Cooling air, HVAC
- Compressors (Axial, Rotary, Reciprocating)
 - High pressure pneumatic line, refrigeration

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Now in many industrial applications what are the probable industrial applications so we will see the industrial applications say fans though I have written them as mostly actual blowers as centrifugal and compressors as axial, rotary or a reciprocating. They can all be of both all the three types but usually fans are considered to be axial where there is no much pressure variations between the input and the output It can be take as a fan.

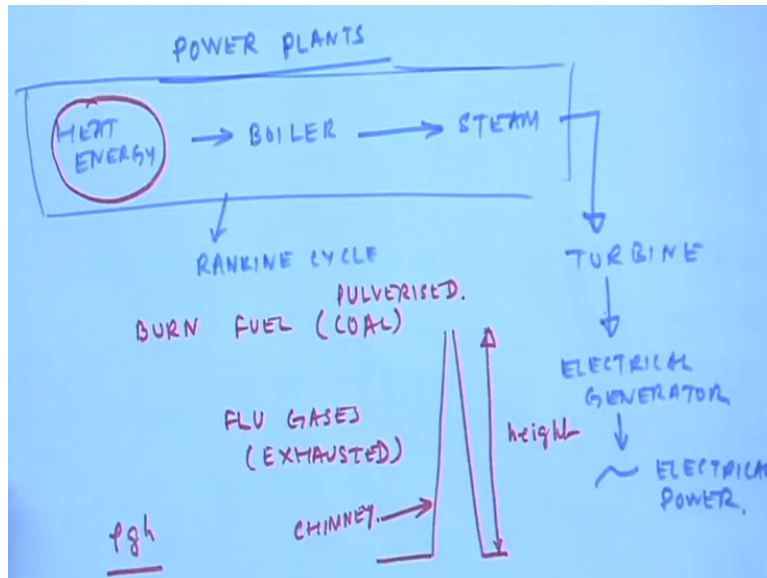
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No significant pressure difference so how that is done basically we have in a casing a set of blades this is a casing these are the blades fan blades and this is the hub which is made to rotate by an power and then because of this either and they are in casing so this could be axial. So where in I have a hubs okay and these blades are usually at an angle and so I will slightly increase the pressure between station 1 and station 2 there will be increase in pressure and essentially a fan.

Now the industrial applications the reason I am explain is the industrial application is we will see what are the ways these equipment or this fluid handling machineries can have a defect and how we can identify them.

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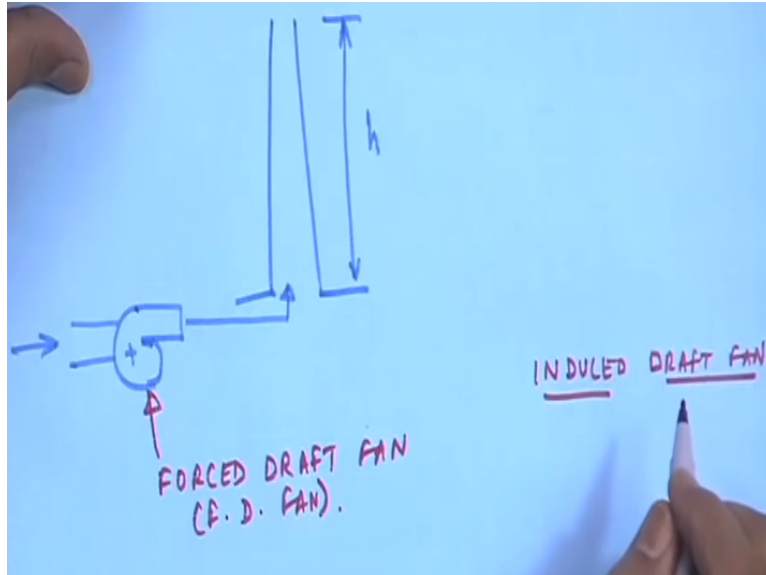


So there is a very important application this fan particularly in power plants see what happen in power plants to generate the steam the boilers are given heat energy we get steam and which drives a turbine which drives an electrical generator and we have an electrical power. And this is the steam cycle their Rankine cycle now the whole problem is to give this give this heat energy I have to burn well and this case it is pulverized coal okay.

Now this is burn I will not go into details of how these are burned okay fluid as bed combustion systems are their. But what happens because of this burning of the coal lot of flue gases evolve and they have to expelled or exhausted and they maybe containing certain poisonous gases. So they are actually and they may be containing lot of particles so they are actually made to go out of a very high chimney height and this is the chimney okay.

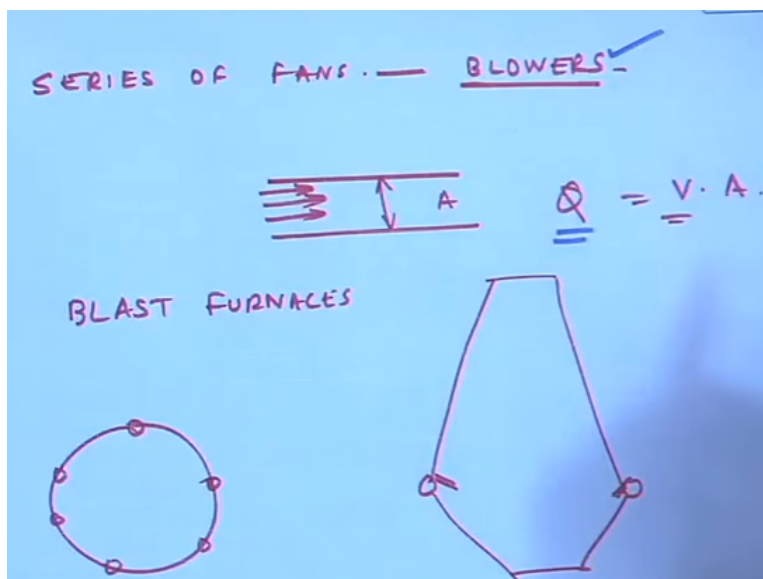
And the ρgh is the pressure so obviously for this height as to be maintained because we would not want this gases to be coming out of places where they could be harmful to people.

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So they have to be given certain energy so that they can all go out that draft item the chimney it may so happen this exhaust gases which come we have to give some extra energy and that is what is known as a forced draught fan or in shot it is FD fan okay. Now this is one application of industrial fans same is to when we want air to come into air pressure for some combustion and that is known as the induced draft fan okay.

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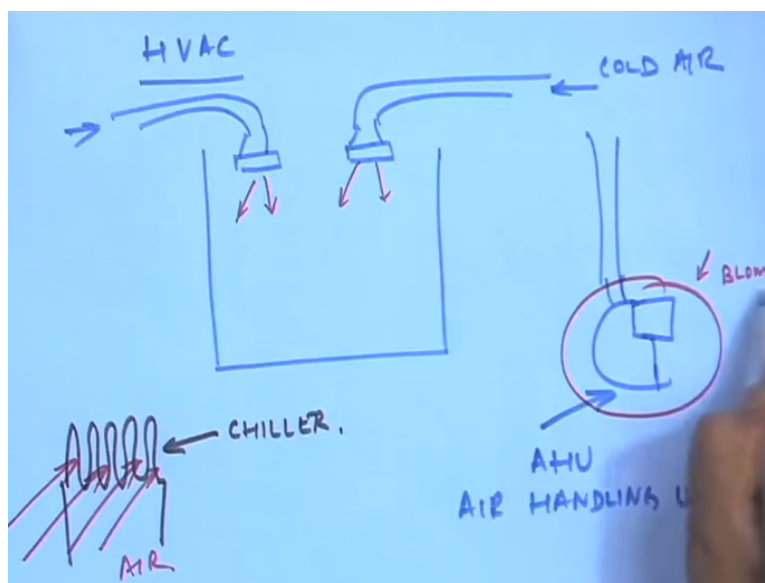
Now similar to the fan the fans can be centrifugal also but I can have series of such fans in one unit and they are usually known as blowers the idea is to give out of the system is a fluid at high pressure okay to a system where the fluid is required at a high flow rates and high pressure and

so on. So external mechanical energy is given to fans and blowers and this energy is converted to the pressure head of the fan okay or velocity depending on the application.

Suppose I want to have more flow rate more velocity I can for the same area okay this is the area so the flow V times A . So if want more flow rate I have to give an air at an high velocity okay. Many applications require a certain volume flow rate of air in the process particularly in blast furnaces okay. Blast there are rings of tubes okay and air is fed in to the blast furnace around this ring okay.

At high flow how can that happen if I have a series of blowers in the plant okay they can be all giving energy to the air and then this air is fled to the blast furnace at high flow rate and this is what is done by the applications of blowers.

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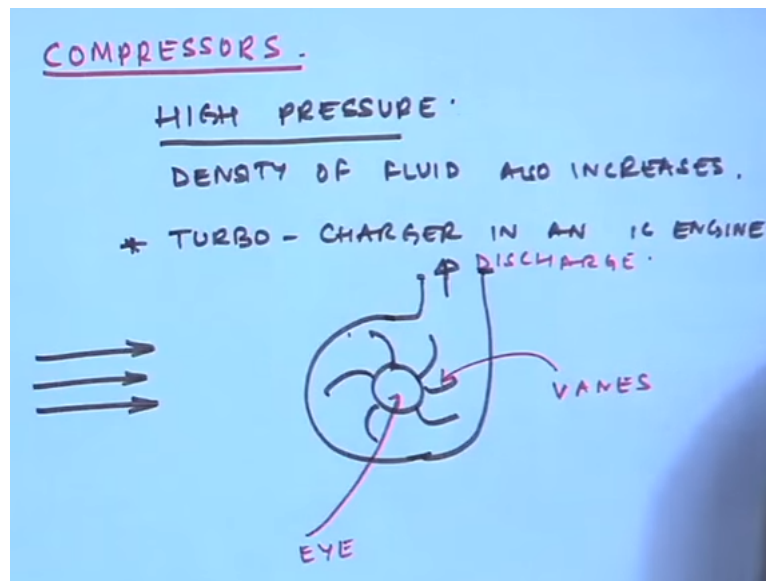
In many times in the air conditions systems heating ventilation air condition system the reason I am telling you this I just wanted to give a flavor of what are the industrial applications of fans, blowers and compressors. So we will our self realize what are the ways this things can go around. So I would like to first introduce to the fan, blowers and compressors and then we will come to what are the effects and how defects are created and then how they are diagnose noise.

So HVAC systems many place in a time in rooms we have defuses on the ceiling and which are connected to ducts okay. Which brings in cold air in an AC system and these are actually felt fed

by blower okay and these are known as the AHU air handling unit basically the way the air handling unit works is on the refrigeration system I have a chiller okay. On which through which air is blown and by heat transfer air gets cool by this cool air is given into the room.

So there this calls for a blower and again the pressure differences are not much beat the fans and the blowers okay.

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However the most important high pressure device is a compressor okay in compressor what happen is objective is to have high pressure and as a effect the density of which also increases a good example is the turbo charger in an IC engine driven by the exhaust gases which I used to compress and the inlet air so that the density of inlet increase so that the same given volume I can have more mass of air coming to my system where combustion okay.

So high pressure now this compressors is basically can be of axial flow compressors they can be rotary the sense what is known as the centrifugal compressor. They will look something like this the centrifugal compressor set of vanes okay and then the discharge and this known as the eye and these are the compressor vanes and this is the discharge okay. And of course we have the reciprocating compressors I will hand them few of other positive displacement compressor I will go to the details of compressor classification.

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Classification of Compressors

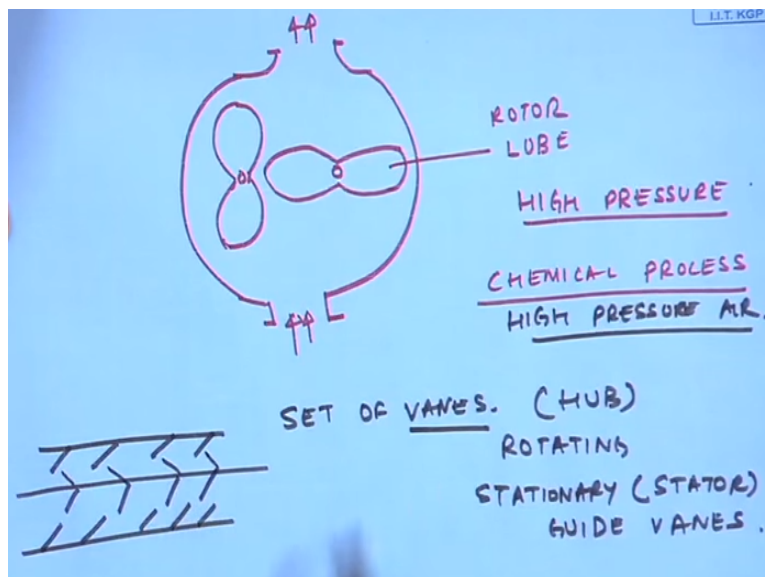
Machinery Fault Diagnosis & Signal Processing

- Positive Displacement
 - Rotary
 - One rotor
 - Sliding vane, liquid ring, single screw
 - Two rotor
 - Lobe (roots), Screw
 - Reciprocating
- Dynamic (Turbo)
 - Axial Flow
 - Centrifugal


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May be in the next slide so this is how the compressors are classified they can be positive as suppose dynamic or turbo compressors. Positive displacements can be rotary one rotor or sliding vanes or liquid vane as single screw.

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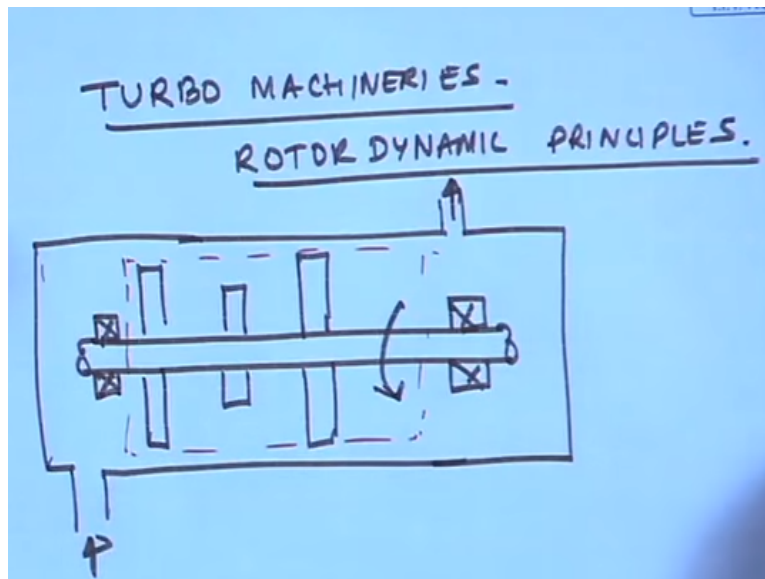


And in positive displacement basically there are lobes which look like number 8 okay. These are put in a casing okay and this is a lob rotor lob and they move in a particular direction and then this air gets compressed these are positive displacement rotary compressor and they are they get generate which are known as very high pressures. The advantage of such positive displacement compressor is in small space can very easily generate a high compressed line.

In chemical operations chemical process applications high pressure air is required high pressure air. And this will call for such compressors of course I just told you about axial flow compressor and this centrifugal flow compressors and many times this compressors have set of vanes which are mounted on a hub either actually radially and they are set as on angle and many times in compressors we have veins which are rotating and veins which are stationary what are in the casing or the stator and they can work as guide veins.

That is some sets of veins are fixed and then you have another rotor with maybe have a set of veins. So I can have multi stage veins and so on.

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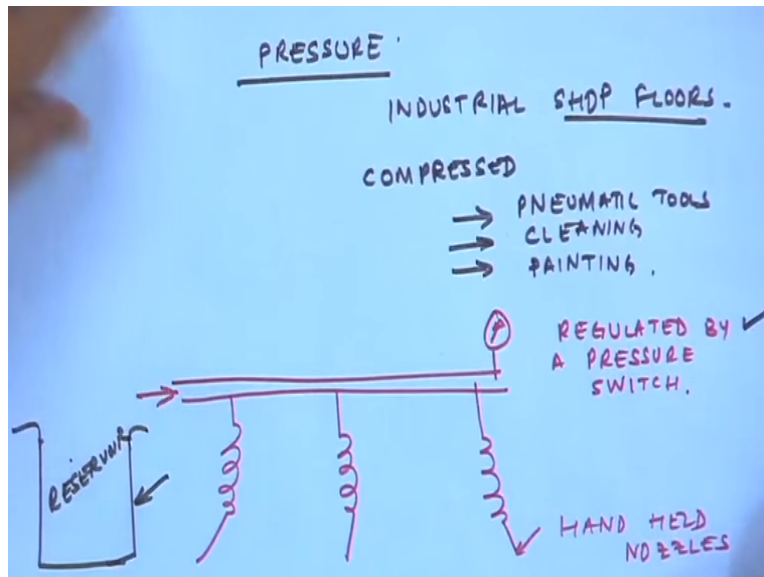


And all of these compressors are basically again if you are talking about dynamics compressors they are turbo machineries. So all the rotor dynamics principles which we have studied earlier apply to such fluid handling devices. So essentially these shafts they could be long which contain maybe a single set of veins or multiple set of veins they have to be supported on bearings and then they can be long they can be flexible depending flexible depending principles or rotor dynamics.

And we and they are of course mounted in a casing maybe with an appropriate inlet and discharge depending on the configuration okay. So because they are supported on bearings you know this could be internal the defaults could be many and they way to identify this faults is what I will discuss next. So in such fans blowers and compressors for its fault diagnosis.

What are the parameters on needs to monitor flow rate is very essential because of the fact my primary objective was to get a high flow rate okay.

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In case of the blowers or in compressors to get high pressure so the flow rate measuring devices could be a mass flow meter okay. And many times because this compressors increase the pressure there is also the increase in the temperature okay. And you know particularly bearing because see some effect of this compressors operations is going to effect the auxiliary devices particularly if the compressor is defective the bearings go bad how does the bearings go bad because of the fact of high temperature.

You know some of this rotors of the compressors are supported at the end by anti-friction bearing and these anti-friction bearings have layer of a lubricant okay. Now because of high temperature the lubricant can get baked by baked I mean they will burn and they will become hard deposits hard deposits and then they will form as an imperfect impurities in the races and give rise to this vibration.

So we have to monitor and compressors and always the temperature and temperatures are monitored by detectors or even we have thermocouples permanently mounted. So in the machinery maintenance we need usually they monitored the temperature of these bearings of the compressors. And if there is bearing defect in terms of the because somebody would not like the

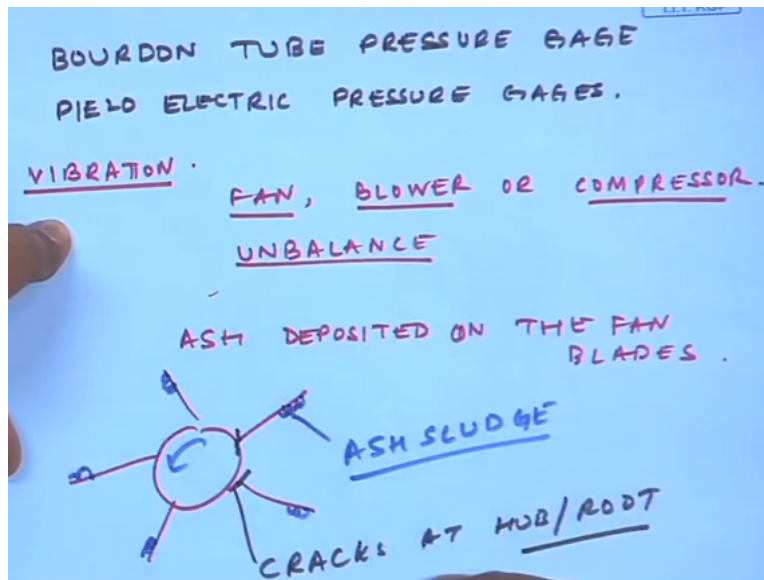
temperature is really it is avoided it should be the temperature of the bearings should be less than 75 degree Celsius.

And that is the recommended principle in the industry to have the temperature of the bearings less than 75 degree Celsius that has to maintain to such a temperature it of course has to be monitored always and RTDS and thermocouples are installed around the bearings of the fans compressors and the blowers. And another really important parameter which has to be always measured is also the rotational speed which I will come later on when I talk about the vibration but then another most important is the pressure.

If there is a pressure loss in the line okay we have to look into why the loss in the pressure loss and many times you have would have seen in the industries shaft floors compressed air use for all pneumatic tools expand screwdrivers etc driven pneumatic tools then we have a cleaning for painting etc. So many auxiliary plant operations are using compressed air and they usually compressed air line okay. And out of which this coil kind of things are coming and they are handled puzzles there will be handheld nozzles okay.

And whenever there is fall in pressure beyond a certain line and these compressors are actually regulated by a pressure switch. So when the drops below certain level the circuit will enable the compressor to start operating again and then store in compressed usually in a large reservoir. And of course this is a design for a particular pressure so as a precaution this compressed air cylinders or a reservoir should not be able to should not store pressures higher than they are designed for and that is why this pressure regulator switch is very important.

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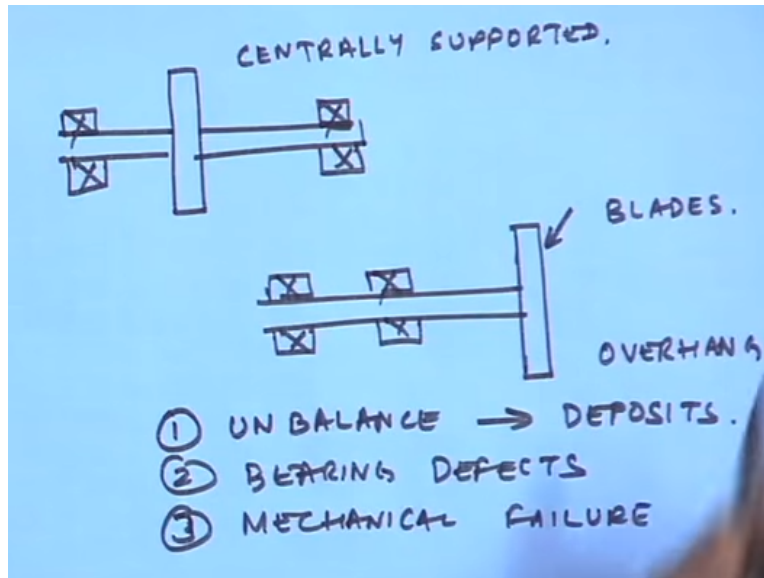


So this pressure sensors are basically if they are static we can have the BOURDON tube pressure gauge for real time pressure monitoring use is known as the use of electric pressure gauges okay. Now another very important parameter is this vibration so what are the sources of vibration in a fan, blower or compressor because some of them are high speed rotor dynamics devices and because of any amount of unbalance will give rise to vibrations.

Now how does unbalance occur in the first place if a plant is new you saw this case of this idea or FD fan which are exposed to the flue gases so many times what happen the ash gets deposited in on the blades fan blades and mind you over the years this over the years because there is a ash there could be sometimes you know with the moisture they could be wet and they will form like a sludge this is the ash sludge which gets deposited and then it creates an unbalance in the fan.

And I have seen many times and he power plants particular because of these getting neglected in the very first day because they thing new plant you know what would go wrong with the fan is okay behavior okay. But what happens is the fans because of such unbalance such an uneven distribution of the masses first of all this stresses become high okay. Many times failure crack occurs at hub roots okay and then unbalance this leads to a vibration.

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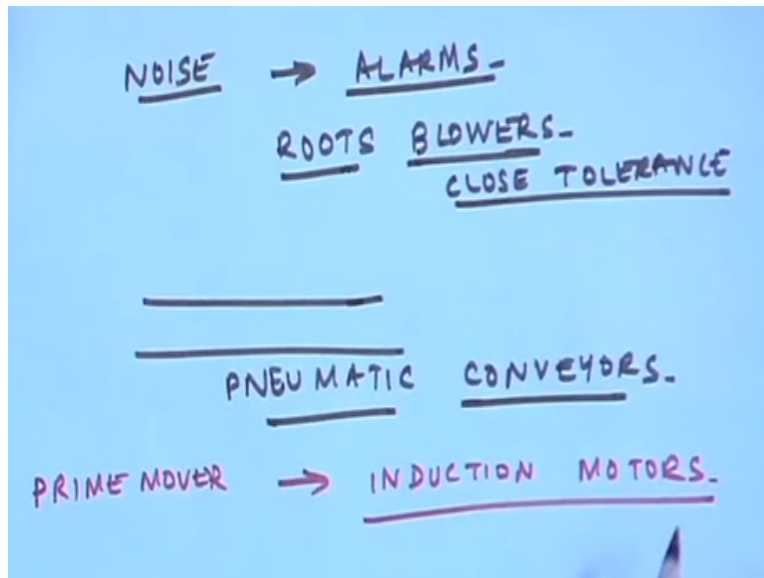


And might be all of these goes unnoticed they will eventually effect a bearings because this sets of impellers can be either overhang or they could be supported in the center scan of a scenario or many time they are overhead okay. Now this could be your blades and this is the origin of vibration one is unbalanced because of deposits unbalanced because of manufacturing defects can happen and of course we use to bearing defect and this will leave to mechanical failure.

Usually the problem with such idea of defects because they are outside the plant machinery unit were outside the sloppy shop area there is some where very close to the chimney base of the chimney and nobody actually periodically monitors them and I have seen in many thermal power plants suddenly in an FD fan bearing broke excessive vibrations from the FFT fan the blade of the FFT fan is missing and these are scenarios which one has come across in the industry and why this happened was nobody really noticed it.

But now a days with the advanced instrumentation online automated instrumentation where in we have permanently monitored vibration sensors on these compressors on fans or blowers both for temperature and vibration these levels can be monitored and of course algorithms are there which will take corrective measures in terms of shutting down the machinery or giving you the enough alarm as to something wrong with this system and they need to taken care of.

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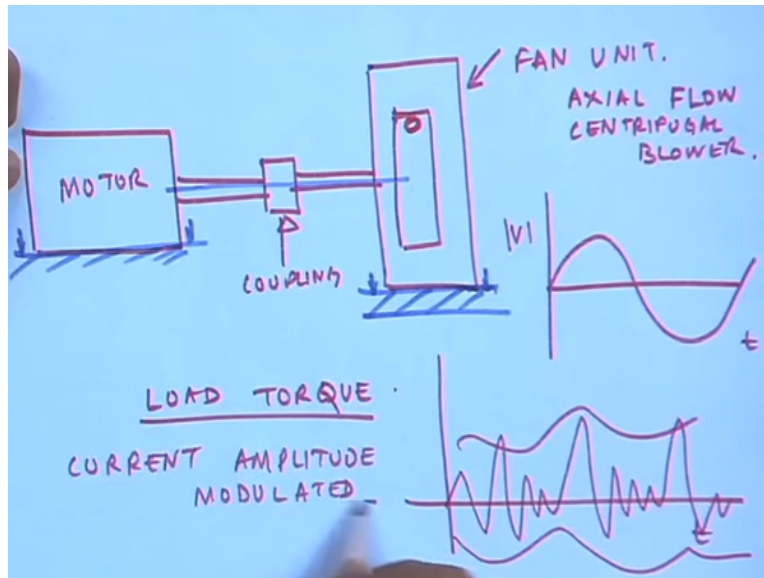


Now associated with vibration is obviously noise but nobody uses noise as a condition monitoring tool for fans, blowers and compressors but they definitely at high speeds these axial flow compressors and particular they routes blowers are very noise because of positive displacement nature and opening and closing of the falls and at very high speed this create problem and they rotate this lobes are very close tolerance okay.

So it is not to alarm that because of high noise that is something wrong with the system but these routes blowers positive displacement compressors they are very noisy okay. Many of the material handling equipment in plant they also rely on compressor and to transport soft items conveyors pneumatic conveyors. In many plants this pneumatic conveyors or compressors lines are used for conveying things okay.

And another very important parameter you know all this compressors are the fans, blowers whose driving them the prime mover in all the cases is usually an induction motor. Usually in such systems we do not have a gear box.

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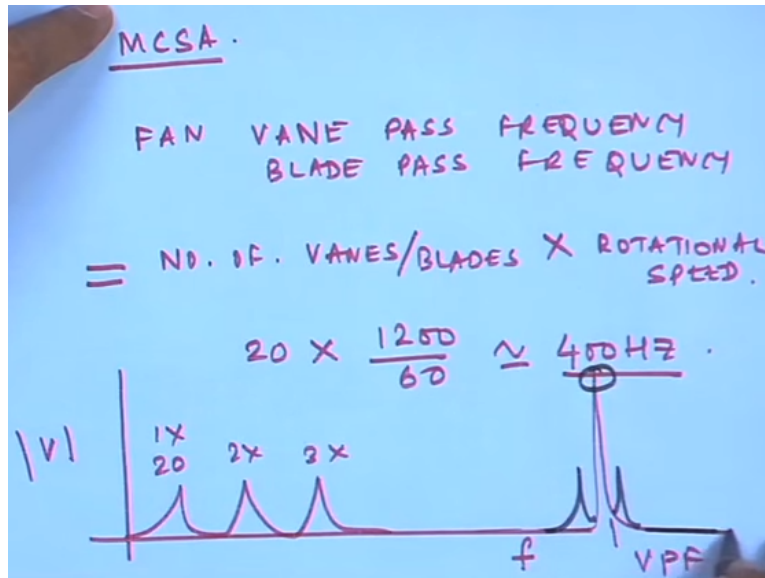


So basically these are motor and then there is a coupling and then there is a fan unit which could be a axial flow fan could be a centrifugal blower or so on. Now usually there is no gear box and this is actually a coupling and they are put on the respective foundations okay. And they are nicely anchored because some of this motors could be as high as the thousand horse power particularly in steel plants where we require such high pressure air to be fed to the blowers for combustion they have very high power motor.

And if this motors and the scientifically motors of course they are not in this in perfect alignment there will be misalignment so all the problems associated with rotating machines which we have studied so far in terms of unbalanced looseness misalignment foundation bolt lose okay. They all manifest as vibrations but apart from vibrations we can also because we what happens because if there is a defect in this vanes it is going to give a and this defect.

Say for example unbalance so this unbalance is going to create a sinusoidal variation in the force torque vibration level. So this kind of vibrations do come as a load torque on to the motor. So because of this load torque the current drawn by the motor also changes and it gets it gets current becomes amplitude modulated so I had told you about this motor current signature analysis or maybe we will study in few of the classes.

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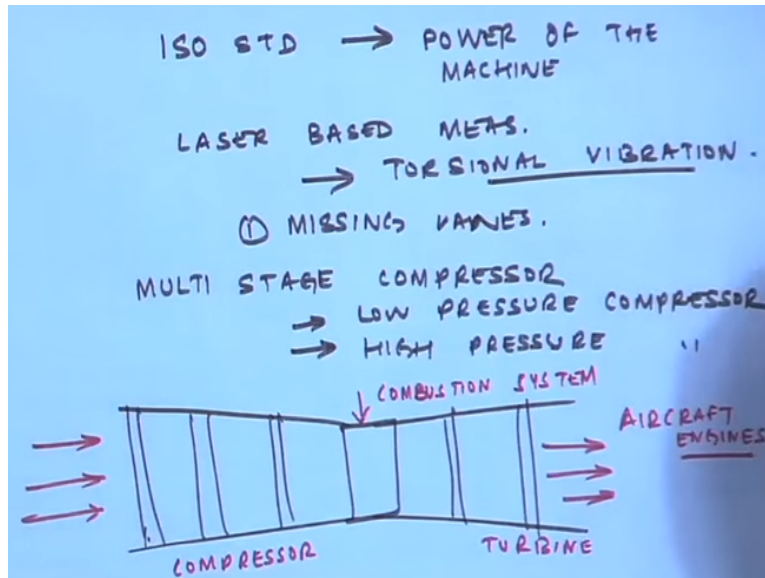


Previous lectures on motor current signature analysis so MCSA can also be used to monitor the defects in the fans, blowers and compressors but from the vibration spectrum so we can also find out the characteristics of all the fans, blowers and compressors is what is known as the fan, vane pass, frequency or what is known as the blade pass frequency which is nothing but number of vanes or blades times the rotational speed.

So for example if there are 20 vanes and the fan are running at 1200 RPM so this is $1200 / 60$ this is close to 20 hertz. So in the vibration spectrum I will definitely see peaks at a this corresponds to how much 20 hertz I will see peaks at 20 hertz, 40 hertz maybe 60 hertz and of course all the way so this is 20 or which is known as 1X, 2X, 3X and then of course 400 hertz this is the vane pass frequency some waves in amplitude okay.

So the occurrence of vane pass frequencies and sometimes side bands around this vane pass frequencies indicate the condition of the compressor.

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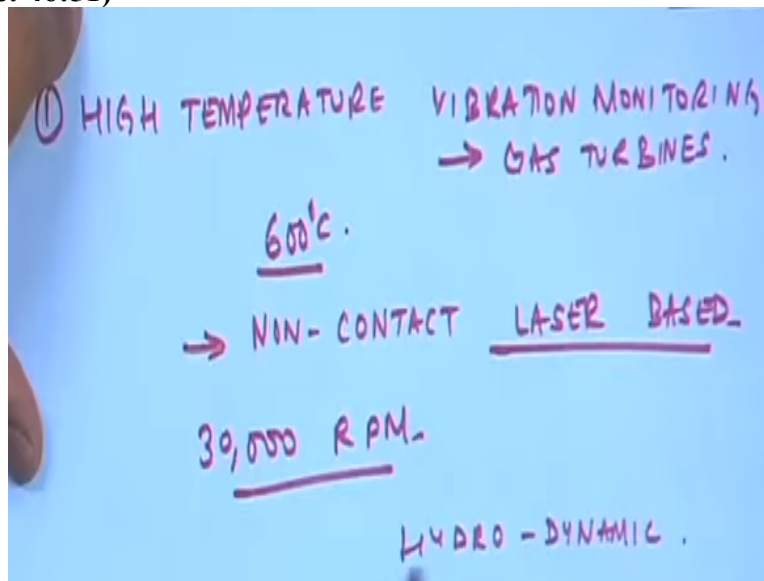
So we talked about an ISO standard depending on the power of the machine in this case the machine being a fan a blower or a compressor there are limits as to what is the maximum amount of vibration level which can be withstood by such a machinery but this does not tell us what is wrong with this rain pass frequency or what is wrong with this fan blower or compressor. So if we do a detailed diagnosis usually by vibration monitoring we will find out the vane pass frequencies and side pass around the vane pass frequencies.

And there will be change in the vane pass frequencies number of blades change and all the theory behind the vibration mounting which we have discussed earlier as to where to put the vibration success in the case of fans, blowers or compressors. We can still use the bearings housings now if I the bearings housings are not accessible we can come close to the casing or close to the foundations and many times peoples are also using lot of laser based measurements by measuring the torsional vibrations okay.

I can find out the missing vanes because we just mentioned about the compressor and we talk about the gas turbines I will talk about multi stage compressors okay. There is usually a low pressure compressor because as you know as soon as you compress the temperature will increase and we have to have when intercooler okay. And then intermediate or a high pressure compressor because the limits of compressional so limit you to how much compression when in given and volume or given stage.

So there are multi stage compressors particularly in the gas turbines okay this are the compressors and then of course you have the combustion systems and then we have the turbines okay. So the compressor on turbine particularly in an aircraft engine when we talk about a turbines I will talk about this aircraft engine compressors and then we have the combustion system.

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Now in such a case the temperatures are very high one has to be careful how to monitor the vibrations and so high temperature vibration monitoring is a special applications for particularly for gas turbines of course now a days accelerometers are available which can measure charge type close to about 600 degree Celsius but beyond that we cannot possibly measure vibrations contact type accelerometer but then we have to go for the non-contact type laser based systems.

Of course there are many challenges in condition monitoring of fans, blowers, compressors but particularly for high pressure and high temperature applications aircraft engines there are challenges and then whether to monitor vibrations or whether the reliability robustness of the measurement systems such high temperature and pressures also play a major role. We know a simple plant level idea fans and AHU blowers they are very standard they are very easy to monitor and diagnose.

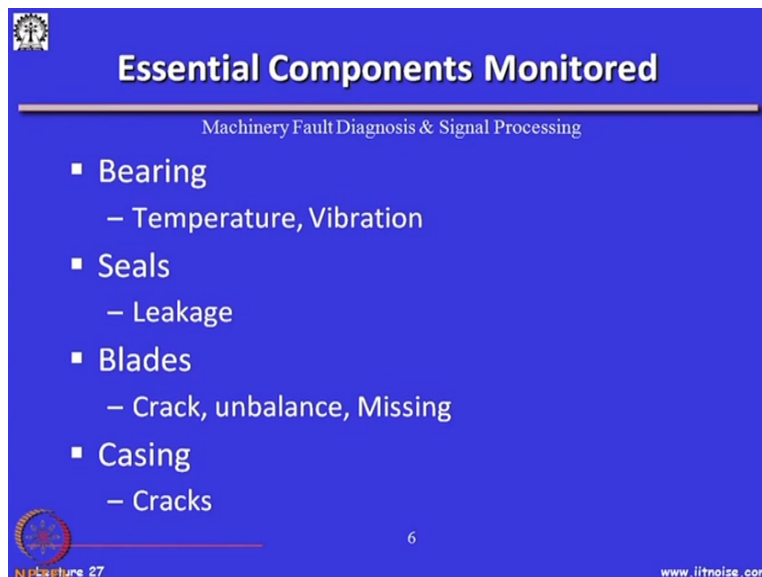
We can put an accelerometer on the bearing housings measure the vibrations level or do an FFT find out this spectrum find out the vein pass frequencies that's it pretty good but think of an aircraft engine or think of an such an gas turbine unit really used for marine propulsion systems.

When we talk about gas turbines as such high temperatures there are challenges as to can vibration monitoring be made.

What about rubs? What if the compressors vane try to touch the casing? What if they foul with the stator blade? So there are very series issues you know to detection of rubs in compressors detection of the misalignment in such stages are compressors or kind of many compressors imagine one blade is imperfectly fit or has an small amount of unbalance and we are talking about speeds of 30,000 RPM.

Such high rotational speed you will see that the unbalance forces are so high that they are determinant effect on the bearings again what type of bearings do we need particularly in land based systems you know we can have a because the rotor weights are sells so high we need to have hydrodynamics bearings okay. And what are the stability issues of hydrodynamics of hydrodynamics bearings with in terms of the temperature in terms of the oil viscosity okay.

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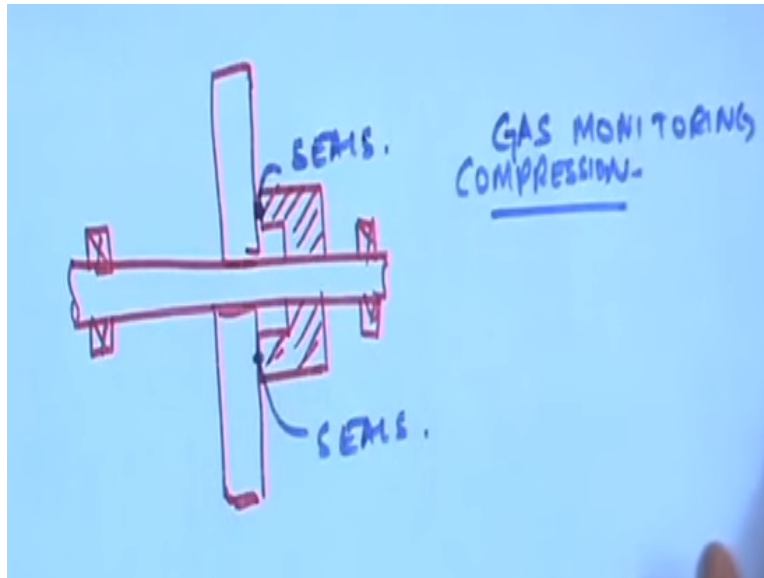
The slide is titled "Essential Components Monitored" and is part of a presentation on "Machinery Fault Diagnosis & Signal Processing". It lists four main components to be monitored, each with specific parameters:

- Bearing
 - Temperature, Vibration
- Seals
 - Leakage
- Blades
 - Crack, unbalance, Missing
- Casing
 - Cracks

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And these are series issued which need to be looked into it so what are the essential components which we can monitor in a compressor or even in a blower of course the bearing. And bearing means bearing temperature and vibration and a very essential important point in this compressors or air particularly we are handling gases which should not interfere with the system.

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We have to design of certain seals okay which are made to rotate with the shaft okay so that they do not come in contact okay. So and this actually pressed against this surface with the spring so seals are there okay to avoid a leakage so the seal leakage is a particularly when we are doing gas monitoring or sorry not gas compression. So many special features are there whether the scenes are over not rules were wear out we will have wear debris collected in the casing.

And then blades could be cracked unbalance missing casings can be cracked so then we can use entity techniques. So these are some of the techniques by which this machineries can be monitored these are the components bearings, seals, blades and casing cracks okay thank you