Vibration Control
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Module - 4
Vibration Generation Mechanism
Lecture - 1
Source Classification

Hi, this is Dr. S. P. Harsha from mechanical and industrial department, IIT Roorkee. In the course of vibration control, we discussed about how we can control the vibration. And in that you see here, what exactly the general methodology is there, when we are striking on the source or on the receiver. And also you see here, we can straightaway deviate or dammed out the excitation frequencies or the amplitude in the transmission feature.

So, in the, in the previous class we discussed about the vibration isolator, in which you see here, when we have the rigid foundation then what kind of you see, the methodology should be adopted. If we have the flexible foundation, then what kind of methodology should be adopted and in that you see here, when the exciting frequencies are absolutely tuned with the, whatever you know like, these mounting frequencies you know like, when we are simply putting you know like, the foundation or any kind of mountings are there.

Then, we are absolutely you know like, getting the huge we can say, the resonant feature or the insertion losses are of significant part. So, when we are designing at the lower frequency or when we are designing at the higher frequency or at the mounting resonances. Then we know that, what kind of you see, you know like, the insertion losses are there, how we can compute that. And even when we are trying to evaluate the insertion losses, we need to check it out the impedance and the mobility of the entire foundation.

And there also we discussed about, that when we are you know like, going for the flexible foundation and then even we have you see, you know like, the machine is mounted on the, that particular flexible foundation then how we can evaluate the insertion losses. And also we discussed about that, if we have the rigid foundation, but the flexible you see, you know like, the object is. Means you see here, when we are considering the flexibility within the object itself or the machine or any you know like, the vibration source then you see here, how the insertion losses can be evaluated.

We also discussed about that, how we can design the isolator means, what are the steps involved in that. We also discussed in the end you see here, that when we are designing the isolator then what kind of you see, you know like, the type of inputs are there and the outputs are there. Means the, you know like, it is you know like, the continuous like, in the simple harmonic motion or a kind of impact loading is there, the shock loading is there. Or else even you see here, when we are trying to see that the forcing frequencies are of you know like, of higher order then how we can design the isolator based on the minimum insertion losses. So, these things you see here specially related to the passive isolator, the vibration isolators or the passive controllers. We discussed about all the aspects, but still you see here, you know like, we can further discuss, if we can understand or if we can categories rather the vibration generation mechanism.

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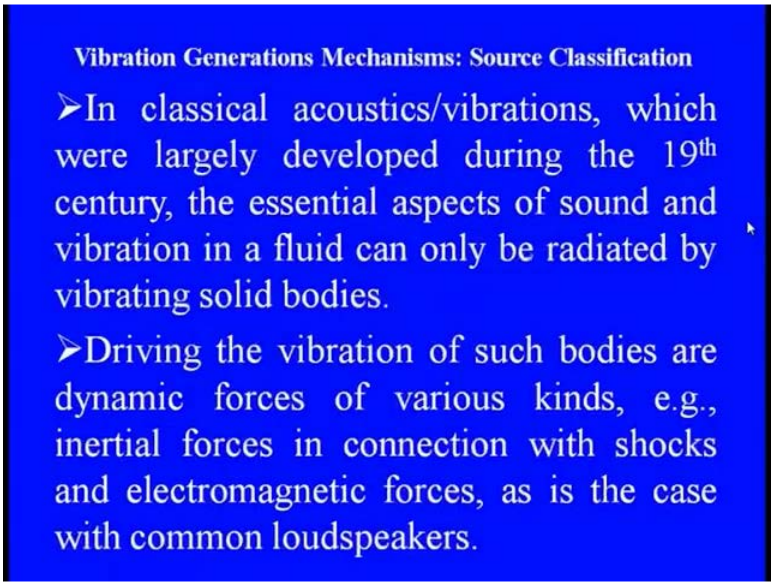

So, in this part we are going to discuss about the generation mechanism and the first thing is coming, the source classification. Because, this is one of the important feature, when we are saying that, the vibration is there, the first thing is coming. Even from the physical sense also that, what is the source, what type of source is there, what is the nature of the excitation of sources? And then when you can characterize that part, then how the transmission is being happening in that. So, you see here when we are talking about the source classification, under the category of vibration isolation.

Then we know that in any kind of you see, you know like, the acoustic or the vibration which you know like, almost started in the classical way in then 19th century. The essential aspects of this sound and vibration in either the solid or fluid can be immediately radiated and these you see, you know like, transmitted in at a very fast rate, when you have the solid media.

As we discussed already because you see the, vibration is the molecular phenomena in which the transmission is quite rapid, if we have the solid domain. And even you see, the sound waves are straightaway radiated when we have the fluid in that. So, driving the vibrations of such solids are simply the dynamic forces and these dynamic forces, which are occurred in the solid media of various kinds.

The first and the significant part is inertia force and we know that, when a heavy mass of any plate rotor or any kind of you see, the surface when they are under the rotating operation. Or any you see, the sliding operation means, the movement is there the dynamic feature is there, the inertia forces are predominating. And the same time with the inertia forces, we have the, another kind of force which also predominate in this, is the electromagnetic force. So, like you see in case of loudspeakers and all other things, these electromagnetic forces are really dominating in that. And you see accordingly, the sound propagations are there.

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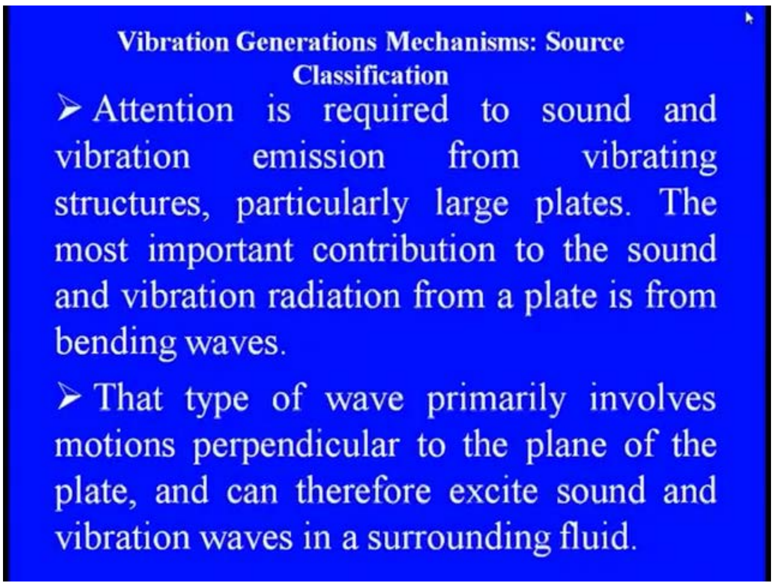

So, in this propagation or the generation, much of the attention is absolutely required to just check it out, the sound and vibration emission from the structures especially, when we are talking about the large plates, because the balancing of these plates are one of the essential feature specially, in the engineering design. So, the most important contribution to the sound and vibration, which are being radiated from the plate, is bending waves. Because, when they are oscillating, the different vibration mode shapes are absolutely you know like, showing that a different depths in the entire structure of the, in the plate. And these are forming the bending waves, which are being you know like, transmitting all across the plate, as the plate is a solid media.

And the type of wave which primarily involves in the perpendicular motion to the plane, of the plate can therefore, be you know like, we can say excite because you see here, we know that they are absolutely perpendicular. So, we have a perpendicular excitation towards the amplitude of the vibration and because of that, there is the clear exciting frequencies are there and these are being you know like, affected towards the surrounding part. So, we need to first characterize these exciting frequencies which are being coming out from the plate in form of bending waves. And we need to see that, how much transmission is there? How much energy is being involved in that? And then you see here, what is the significant effect in the surrounding parts are.

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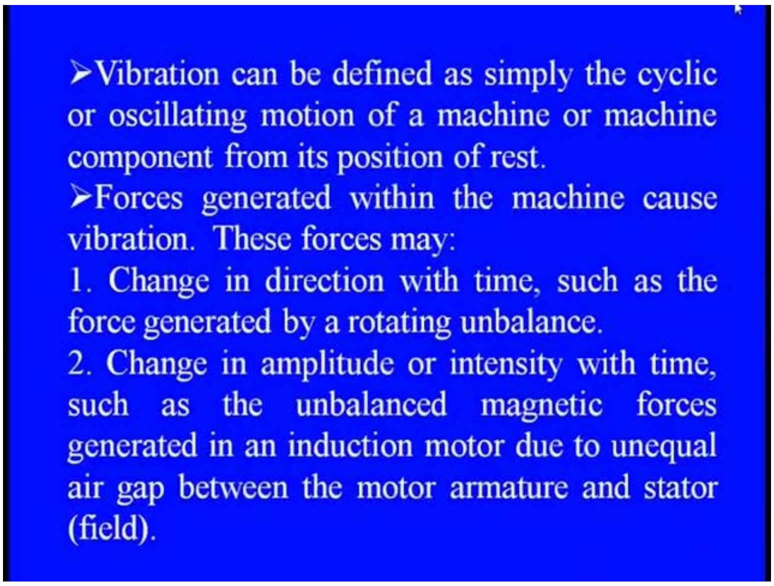

So, we can say that when the things are being you know like, exciting as per the definition of vibration we can say, it is simply the cyclic or the oscillating feature of the machine or any component from its main position. So, whatever the forces, which are being generated during this oscillatory or the cyclic motion, can cause the huge amount of vibration in the machine itself. So, these forces can be of any nature, but you see here some of the forces characterizations are like the, the change in direction of the force with respect to time, is one of the important feature when there is an, a rotating unbalance is there.

Say you see, the shaft is having some kind of unbalance so we can simply see the forces which are being generated due to that is having the change of direction with respect to time. Because you see here, what are the forces which are being transmitting, when you see it is in the load zone or on the upper side or any side you see here, it is continuously in the sense, it is in the dynamic feature, so it is continuously changing its direction.

The change in the amplitude or we can say in other word the intensity of these forces with time. So, we can dig the example of the magnetic forces, the unbalanced magnetic forces which are being generated in various induction motors. And this, these you know like we can say, the unbalanced magnetic forces which are being there in induction motor due to unequal air gap, between the armature and the static field.

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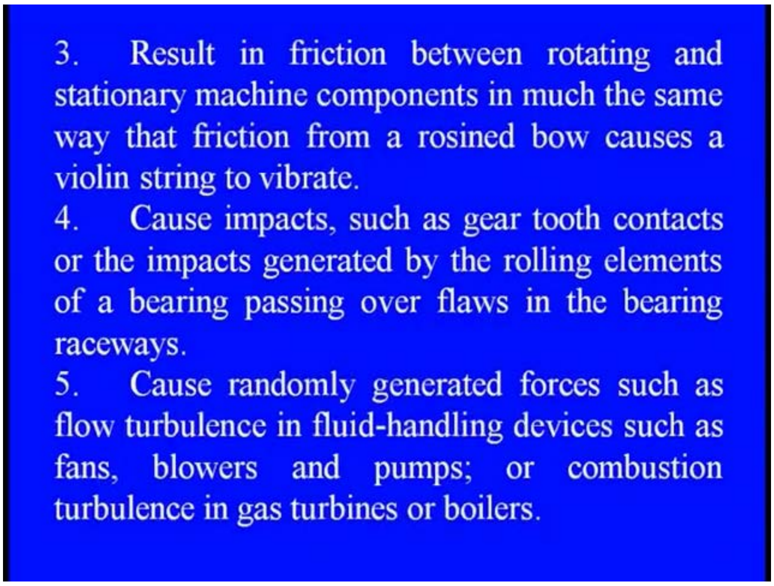

And because of you see, you know like, this unbalanced or unequal air gap, the unbalanced is being created or the, the unbalanced is induced in these rotating elements and they are creating you see, the unbalanced magnetic forces. Even, the forces may be due to the result in the friction between the rotating and stationary machine components. And also we know that, when such things are happening due to the friction, the bow or we can say, the some kind of deviation is being there in the string or in rotor, through which the vibration is being excited.

Even, when the impact loadings are there such like, you see, we know that when the gear tooth's are being matching, at that time you see sudden impact forces are being generated. Or even, when the rolling elements are being you know like, under the rotation and any sudden change due to the rotor and when they are just you know like, passing through these bearings or through the races or the rolling elements.

There is a sudden cause of impact forces are or even these forces may be you know like, we can say generated due to the, randomly generated feature of the entire object. Such as, the flow turbulence in any kind of you see, the fluid flow problem or even you see here, when the air, which is being you know like, passing through the duct, in any sudden changes there due to the turbulence or the vertex motion like, in the phase or the blower or any pumps or in you know like, the turbulence combustion, they are creating a randomly generated forces.

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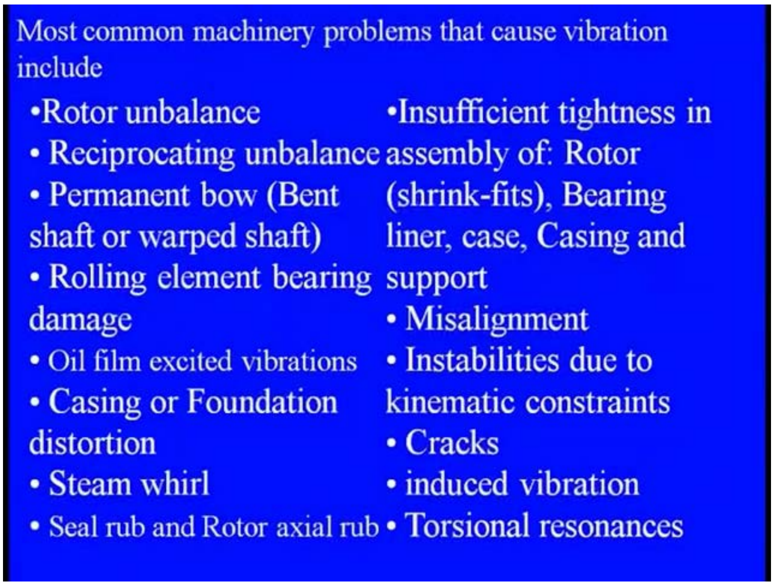

So, these are you see the variety of forces and these forces, which are being generated due to the applications, they are the main responsible factors for inducing a variety of vibrations in the machines. So, we can say you see, there are various common problems in the basic machine, which are, these machines are, the, we can see the, essential machines without which, either the manufacturing precession maintenance cannot be done in those industries. And these common machineries having the problem, because of the vibration generations like, various kinds are there few of them, we can you know like, discussed here, rotor unbalance.

The rotor unbalance is one of the basic cause for having you know like, the vibrations in any kind of machine irrespective of, the lathe machine to power generation machine, even for low or heavy duty machines, light or heavy duty machines, anything. Second is the reciprocating unbalance because either the motion of the rotating elements are, you know like, we can say in the rotating feature or reciprocating feature. Then we have, the bent shaft or the, you know like, we can say the warped shaft in which you see, you know like, we have the permanent bow. So, the total you see, the center line of the entire shaft cannot be the straight one, we have the bending feature within that and when these shafts, even of the micros level of this bow is, they can induce a significant amount of excitations in the machine.

One of the even common cause for having vibration in machine, is the bearing damage even, when you have say the ball or rolling element bearing damage, the race which damage the inner and outer race. Even, we can say the case damage is there or even the shaft which is there, any microns level of the surface discontinuity is clearly causing the machine vibrations. Then even we can go with the oil film excited vibrations, like in the zonal bearings, hydrostatic or hydrodynamic zonal bearings. This fluid film, though you see it is being there for elastohydrodynamic lubrication, but because of these also, there are you see, the self-excited vibrations in that.

The foundation distortion or even the casing distortion, can also cause the vibrations, the misalignment, the instability or even the cracks can also induce the vibration. The torsional vibrations, because you see the torsional resonances, within the shaft movement and the couples or anything kind of torsion is, you know like, being apply, if these being acted on that, can cause the clear vibration excitation.

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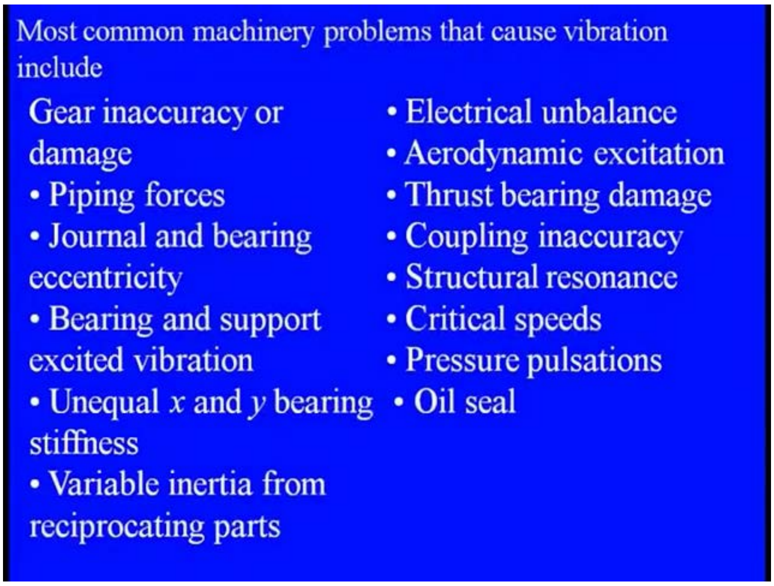

Another rotating element is gear so if any inaccuracy or the surface deviation or surface irregularities or even any damage, the crack is there on the surface of the gear, is clearly causing a different kind of excitation in the machine. If we are talking about the fluid, then the piping forces, when the fluid is passing through the pipes and even you see here, any kind of turbulence, the aerodynamic excitations, they can also cause the vibrations in that. Even if there is no damage, but also you see the vibrations are coming due to the stiffness, due to the inertia force, due to you see the self excited vibrations and even we can say sometimes, even the structural resonances can also create the vibration.

We can say even, the bearing support, bearing and whatever you see you know like the outside bearing support is, the crashing of that can also excite and creates the vibrations, electrical unbalance, the, thrust bearing damage or even you see the, pressure pulsation. These are you see, the various types and when you know like, when we are just trying to see the machine vibration, these are you see, one of the few causes, which are being always there for the vibration generation. So, if you are talking in general we know that, the unbalance cannot be avoided when the shaft speed or the, you know like, we can say it is at the higher level, some of you see, the unbalances are always being there due to the dynamic force transformation.

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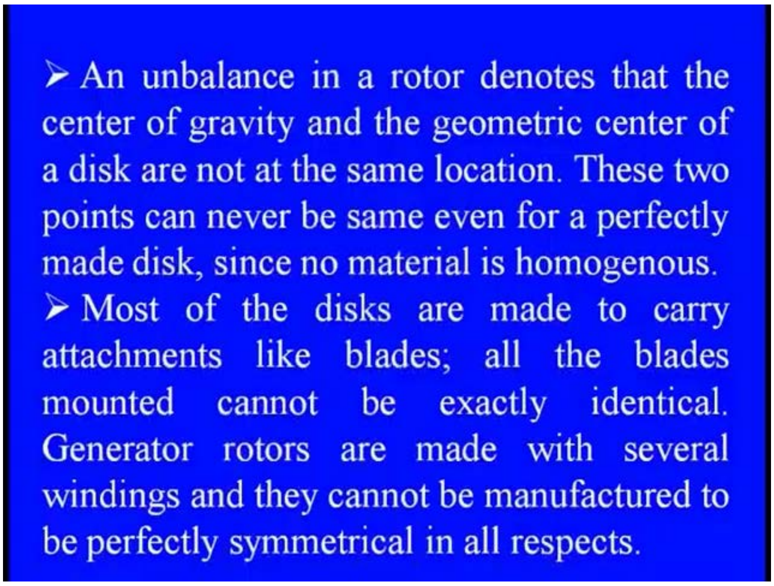

And this denotes that, the center of gravity and the geometric center of the disk, is not exactly in the same location and that is why you see, you know like, due to this unbalance, a misalignment is created. And these two points, what points? The center of gravity c j, and the geometric center of the disk. These two points, can never the same even we are making perfect shafts.

Why? Even we are going with the sophisticated machining operations and various things because we know that the material cannot remain the homogeneous properties, when it is just moving under the dynamic forces. And most of the disk which are being you know like, manufactured is always you know like, made to carry that attachment like the blades. And all blades cannot be mounted exactly into the identical features and that is why you see here, we know that some kind of unbalance is always there, when they are in the rotating feature. And these generator rotors, which are made with the various windings, they even cannot be manufactured perfectly symmetrical from all the aspects.

So, when you see, when we know that there are limitation in the manufacturing of these rotating features or the parts, that is not a practical solution through which we can get a perfect balancing or even we cannot say that, if even, if it is a robust machine it can provide the free, vibration free machine operation. So, you see these are the inherent features according to you see, the size shape or whatever you see the construction, constructional features, the machining features the vibrations are always been there within that.

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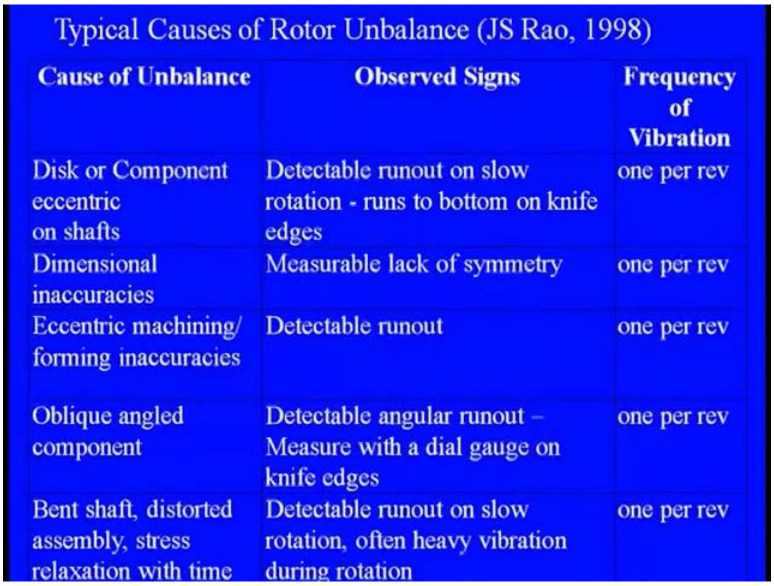

Typical Causes of Rotor Unbalance (JS Rao, 1998)

Cause of Unbalance	Observed Signs	Frequency of Vibration
Disk or Component eccentric on shafts	Detectable runout on slow rotation - runs to bottom on knife edges	one per rev
Dimensional inaccuracies	Measurable lack of symmetry	one per rev
Eccentric machining/ forming inaccuracies	Detectable runout	one per rev
Oblique angled component	Detectable angular runout – Measure with a dial gauge on knife edges	one per rev
Bent shaft, distorted assembly, stress relaxation with time	Detectable runout on slow rotation, often heavy vibration during rotation	one per rev

So, you see J S Rao who you know like, just derived various causes of unbalance, in its rotor dynamics book, we can take a few of the examples out of it, you see here that, what are the common causes of unbalance? What are the sign, when we are just looking the signature of vibration? And then what could be the possible exciting frequencies in the spectrum, when these unbalance feature is there, these unbalance features are there in that? First, when we are saying that the disk or component eccentricity on the shaft, when we are putting any rotor disk or any component of the shaft and you see, they are having some kind of eccentricity.

It can be immediately detectable because you see it is just running out on the slow rotation and runs to the bottom on the knife edges and in every, you know like, individual revolution per minute you see here, this specific kind of exciting frequencies are been there in the spectrum of vibration. Or even if we have any dimensional inaccuracy, even if we have any oblique coupled component or if any you know like, the bent is there the shaft or the distorted assembly or the stresses, which are being you know like, we can see the relaxed within the time.

These are all detectable you see here, with their run out, angular run out or any you see, you know like, we can say the kind of different vibration in every revolution, with the, you know like, the time. So, what does it means that you see these are the common features like eccentricity, like, you know like, the inaccuracy of the forming process all these are you see, you know like, the common cause for unbalance.

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Cause of Unbalance	Observed Signs	Frequency of Vibration
Section of blade or vane broken off	Observable Bearing vibration during operation	one per rev, Possible process pulsations
Eccentric accumulation of process dirt on blade	Bearing vibration	one per rev
Differential thermal expansion	Shaft bends throws c.g. out Source of heavy vibration	one per rev
Trapped fluid inside rotor Possible condensing/vaporizing with process cycle	Vibration reappears after balancing, Apparent c.g. angular movement Occurs	one per rev Possible

Even if you are going towards the blade side, then the section of blade if you look at you see, the cross sectional feature of that or any vane broken off is there, we can clearly see the vibration, when you see we are just looking the signature of the bearing. And it is straightaway you see here, the process with the pulsation can create the exciting frequency or any eccentricity, which has been you know like, accumulated of the dirt process in the blade or even you see, we can say that, if any you know like the fluid is trapped inside the rotor may be you know like, we can say due to the condensation or any vaporization.

Then we can have clear vibration responses, even after balancing of all these masses with the center of gravity. So, what I mean to say that, there are lots of causes of the rotor unbalancing. So, it is not that you see, when we are seeing that, rotor unbalance is there and we are simply getting the vibration response, that is the sufficient thing, no. We need to check it out that, what is the basic cause for having this rotor unbalance. So, professor Rao explain in a very significant way you see here, that what are the common causes and how do we get a clear online fall diagnosis of this kind especially, just by observing the vibration response in one cycle.

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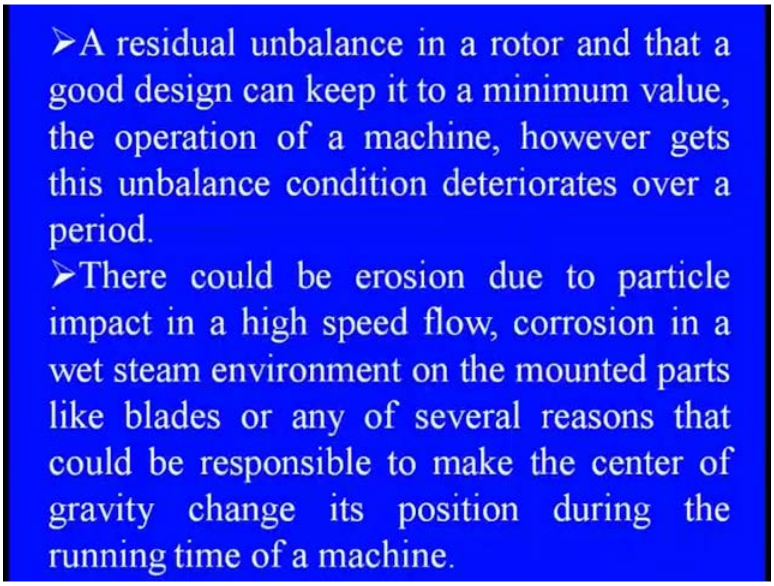

So, these residual unbalance in the rotor and you see a good design can keep up to the minimum value, when the operation of machine is there. And this unbalance condition can be you know like, immediately deteriorate the entire other parts, which are closely coupled to the shafts. And there could be erosion, due to particle impact of high speed flow and corrosion in the wet steam also because it is the entire environment is having the wet steam.

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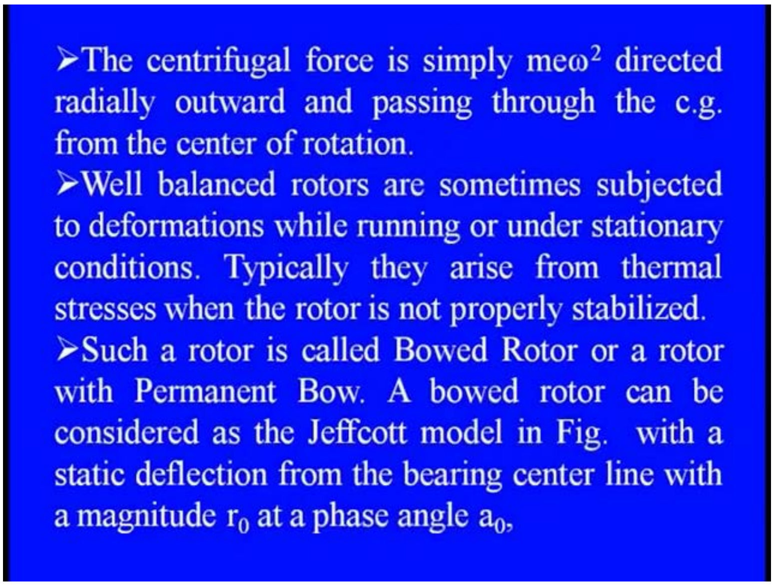

So, certainly you see here, this has a clear effect on all the rotating elements like you see, the blades or any you know like, the rotor itself. And because of these things you see, you know like, we have a clear deviation in this entire shaft or unbalance is there, from the mean position. And we have you see, the huge amount of vibrations are and even the centrifugal forces which we are saying you see, the any omega square the mass, which is being there is the eccentricity omega is the rotational speed. They are creating the huge amount of, as the speed increases the huge amount of these forces are generated and they can create the exciting frequencies.

So, well balanced rotors are sometimes we can say that, they are simply subjected to the deformation and these as deformations are just showing the periodic excitations. And even you see here, the thermal stresses which are being there due to, you know like, the variation can also induce some kind of material you know like, the disorderness. And then you see here, when we have the material disorderness there is a different kind of exciting frequencies there. And this bowed rotor, which the bent rotor is always creating the huge amount of vibrations.

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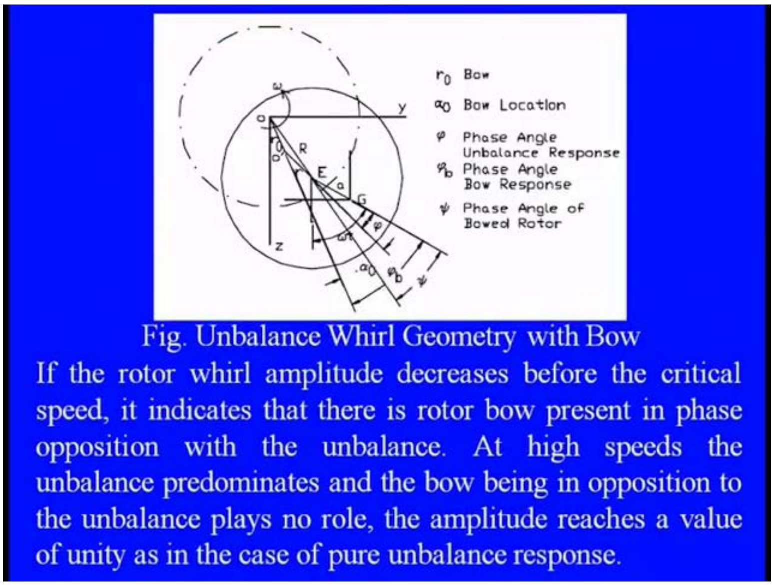

Fig. Unbalance Whirl Geometry with Bow

As you can see on your screen, we have the bowed row you see here bowed rotor. And in this one you see, we have a clear deviation, you can see on that screen, it is a clear deviation is there, with the, we can say that the r 0 is the bow and alpha 0 is the bow location. And if the rotor is having the whirl amplitude and which is decreases before the critical speed that simply means that, again please remember, when the rotor whirl amplitude is decreasing just before the critical speed, which is not a common sign. That means you see here, we have a rotor bow means, the bent rotor is there and this is absolutely in phase opposition with the unbalance.

And if you are going towards the higher side, means high speed of the unbalanced, high speed of the rotor then unbalance, whatever the unbalance is there. Because of this predominates and both being in the opposite to the unbalance which is you know like, sometimes it is not playing a critical role. And the amplitude will certainly reaches towards its maximum, when you have a pure unbalance case.

So, it is simply shows that when you have the bent or the bowed in the rotor the unbalance is simply a cause and then you see here, the different kind of exciting frequencies can be there. So, when we are talking about the unbalance part in the rotor, the unbalance phenomena says that, when you have a different we can say, you know like, the balances, the balancing feature or when you do not have you see, your center line of the shaft, which is absolutely line to the plane, the unbalance can be happened.

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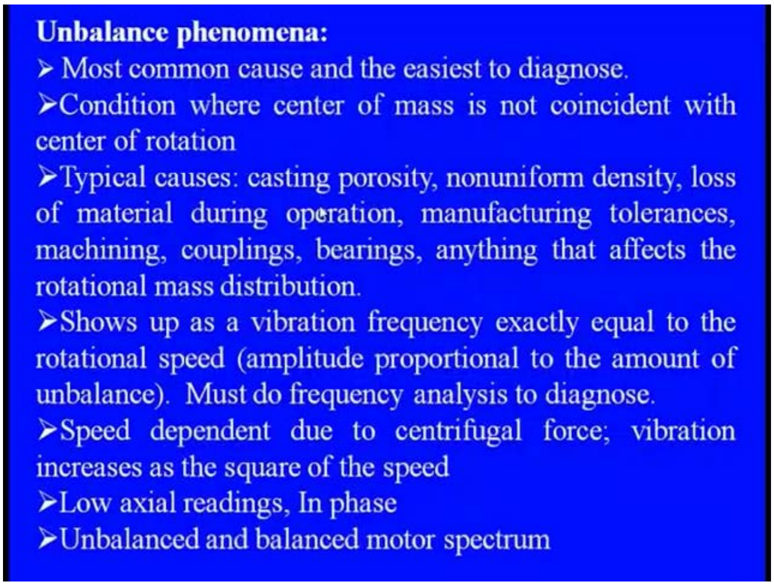

This is one of the most common cause and it can be easily diagnosed. So, the condition where you see the center of mass is not coinciding with the center of rotation in the same plan, we have clear unbalance phenomena. And there are various causes in that like, even from the manufacturing side, if any porosity is there during the casting operations. And certainly we have the non-uniform density variation, because of some where you see, the material is loosed, some where the material is significant.

So, there is a dip because of the stiffness and the damping variation and even when you, when we do not have a perfect manufacturing tolerances. Even the machining whatever, machining couplings are there, they are not perfect or even the bearing, the robust bearing is being there, due to the self-excitation. And you see here because of you know like, we can say, the load zone there is, you see, the eccentricity is being there.

And because of that, we have the unbalance phenomena and this unbalance phenomena can be straightaway show up in any vibratory signature. And they are absolutely coming at the rotational speed, rotational speed is nothing but the you know like, it is the amplitude which is proportional to the amount of unbalance. Generally we are, you know like, putting 1 x, 2 x, 3 x and all that part. And we can straightaway find out, when this x type of frequencies 1, 2 multiple you know like, this thing that means, there is a unbalance in the rotating element.

And this is you see here, the unbalance phenomena is speed dependent due to centrifugal forces, we know that m e omega square. And the vibration excitation is increases, as the speed is increases because of the omega square. So, we have you see, the low axial readings as you know like, the different phases are being there or we have a different kind of you know like, the motor spectrum with the balance and unbalance rotor.

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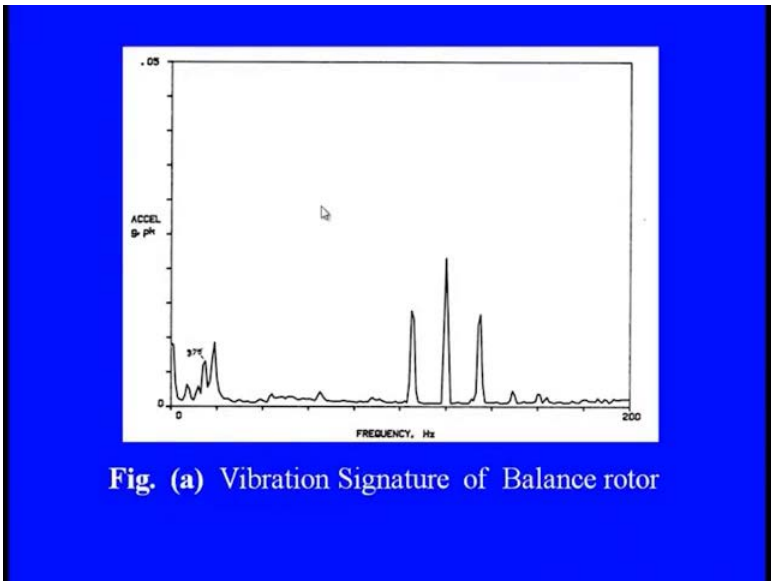

Fig. (a) Vibration Signature of Balance rotor

So, if you are looking towards say, the balance rotor vibration signature, this signature is just showing the variation of the acceleration level on vertical side, with the frequency level on the horizontal side. So, you can see that there is no rotational frequency axis being present in that, because of the well balanced feature, these excitations, the three peaks which you can see on the screen is mainly due to the other reason or the self-excited vibration. Because, as these you know like, the rotor is moving the bearing as, bearings are coming under the load zone and these excitations are there, which are dedicated to the specific feature of the bearings itself.

But if we have say the unbalance and when the unbalance is there you can see that, we have the rotational frequency excitation and which is dominating in the entire spectrum as compared to the other excitation frequencies. So, you can see the peak amplitude of vibration, which is very significant even at the beginning of that, due to the unbalance, the rotational frequency. Then the, another cause is the misalignment phenomena, the misalignment can be there absolutely at the coupling part.

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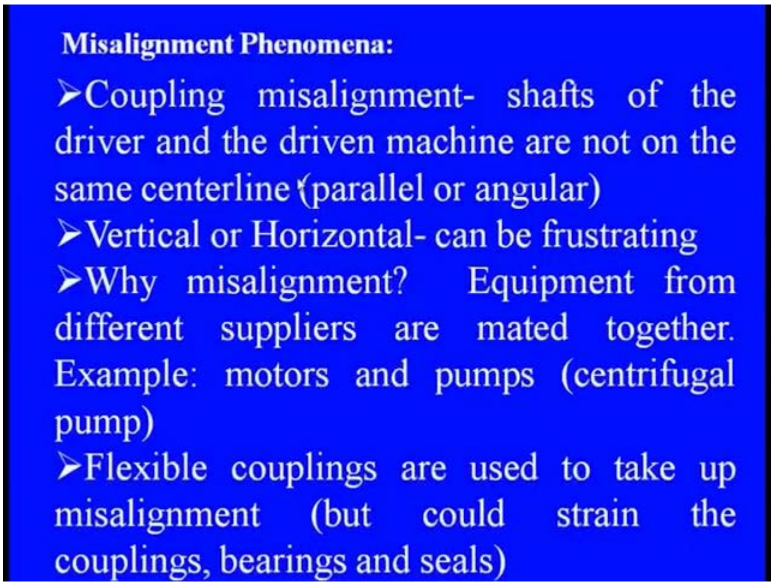

So, coupling misalignment, the shaft of either the driver or the driven machine is very common because we know that this, the centerline is not absolutely coinciding with the shaft. And that is why you see here, you know like, when you know that the coupled feature is not you know like, either the parallel or the angular, we have both kind of eccentricity. And these are causes the misalignment, it can be either vertical or horizontal.

And when the equipment, when we they are coming you see here, towards you know like, the operation side, they are absolutely matching together like you see, the motor or pump any centrifugal or any kind. When they are closely coupled, with the flexible coupling and the shaft whatever the misalignment is there, they are always coming inbuilt with the, from the manufactures. Sometimes you see here, we are using the flexible coupling just to absorb the kind of variation, during the transformation or transmission of the motion. But again you see here in that, the strain at the coupling or the bearing or the shields can always being raised and due to that, the severe vibrations are there.

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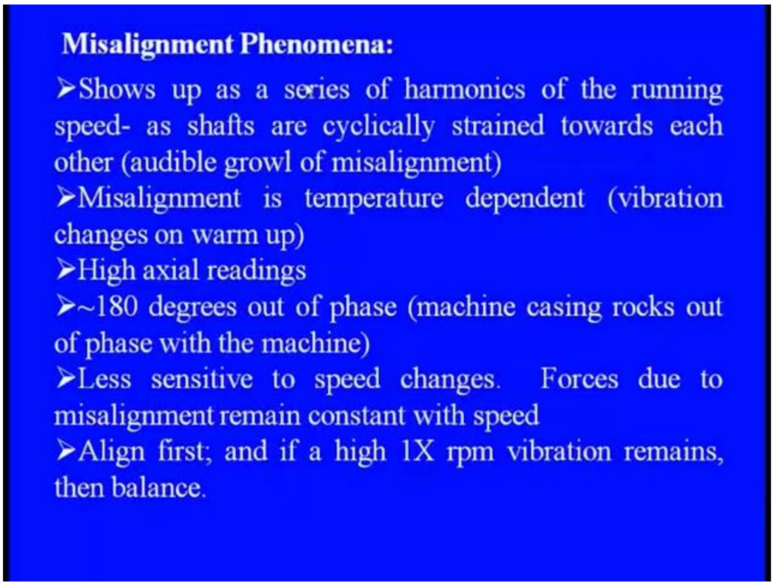

Or else we can say that, these micro, this misalignment phenomena can be show up as a series of harmonics of the running speeds like, we now that the shafts, when they are you see, you know like, the cyclically, cyclically strained. Then they are straight way causing the misalignment in the machine, but again this misalignment is not a permanent phenomena, it is temporary feature when you see the machines are there.

And it is also very sensitive towards the temperature because we know that when it is vibrating at such a significant way, at the contacting surfaces, the huge amount of temperature is being generated. And you see here, they are absolutely less sensitive to the speed changes, the forces due to the misalignment is almost remain constant with the speed. So, first of all we need to align the forces so that, the vibration can be controlled up to 1 x or anything. So, this was a second, third generally we are saying that there resonances.

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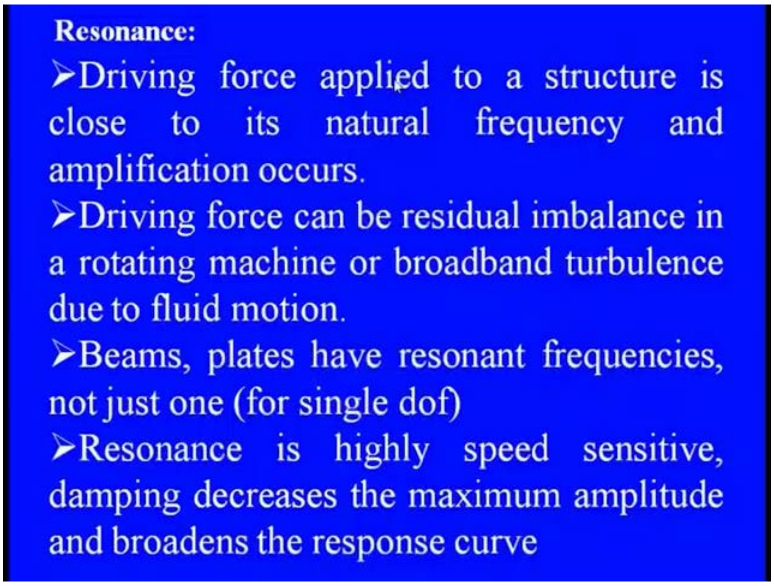

We know that, when the driving forces which are being applied to the structure and when they are going close to the natural frequency, the huge amount of amplitude occurs. And these driving forces can be of residual imbalance or any kind you see here, in the rotating machine or broadband turbulence, due to the fluid motion. When you know like, these forces, the driving forces are being there and they are dominating certainly you see here, when they are coming close to the natural frequency, the resonance occurs.

The beams, the plates have the resonant frequency various kinds means, it is not you see, when we are talking about beams, plates or entire things, the main we can say the basic domain. They not have just once natural frequency, they have many natural frequencies in the higher harmonics. So, resonance is highly speed sensitive, just like in the previous case we discussed about the misalignment, the misalignment is not a speed sensitive, but the resonance absolutely you see, it is a speed sensitive. And at this point of time, when we know that the resonance is happening, the huge amount of energy, the acoustic emission or the energy is being you know like, coming at the machine surface.

So, we need to now absorb that so the damping is one of the effective criteria as we discussed already. And through that you see here, we can reduced the amount of amplitude or the energy you see here, of the exciting frequency or we can reduce the broadnance of the responses curve.

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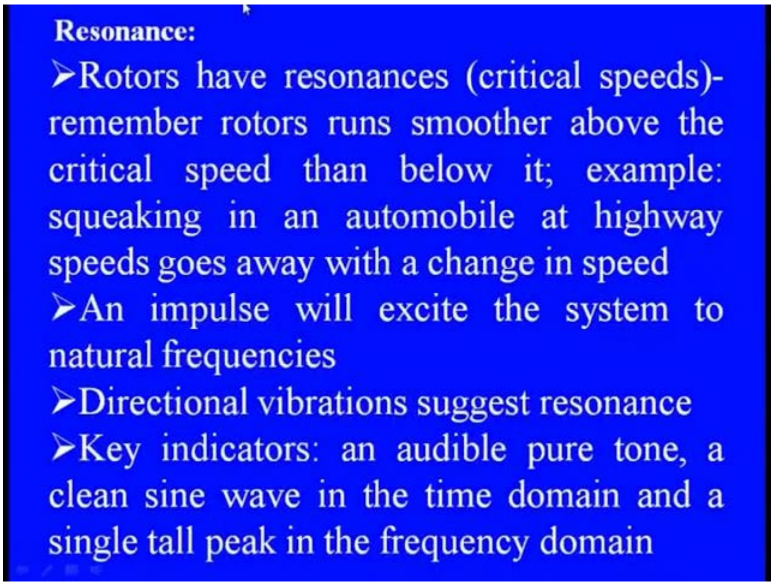

So, you see here we can say, the rotors have the resonances at the critical speeds and they are always running the smoother, if the other frequency zones. Because, we know that, when they are absolutely coming on the resonance, they have the highest amplitude in that way. And other feature when an impulse will be excited, the system to natural frequencies certainly we have, when we are just putting the impulse and the exciting frequencies are absolutely with the resonant, this natural frequency, the resonance will occur.

So, the directional vibrations always suggest that, we have the resonance generations and there are various indicators like you see, you have a pure tone. When it is coming out from the system means, resonant condition is there or else if we just, if we are looking towards the vibration response in the time domain, of clear sine wave means, no deviation no two or three features, a clear sine deviation is indicating the pure tone or the resonant condition. Or even the single you know like, tall peak in the frequency domain means, you have just, you know like, the 20 hertz and there is a peak only. And all other parts before 20 or after 20 hertz, when they are not showing any kind of exciting peak that means, you see you have a clear resonance frequency.

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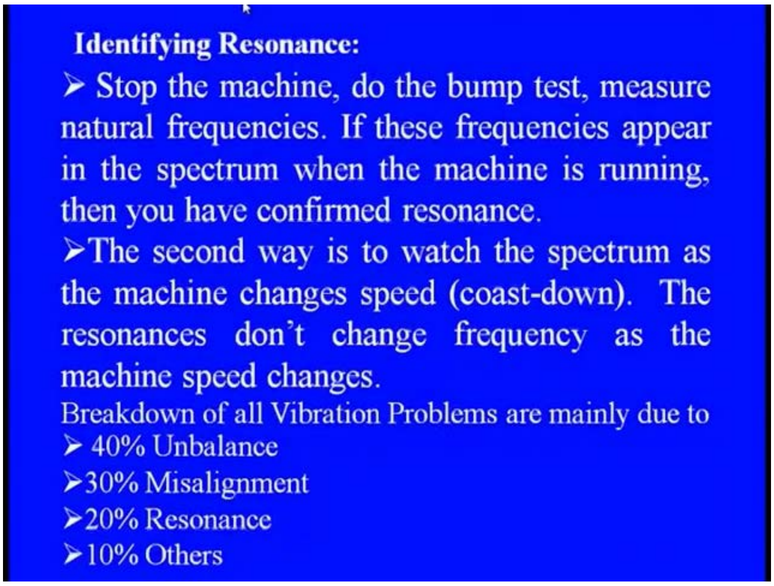

So, if you want to find out the resonance first we need stop the machine, we need to do the bump test and find out the natural frequency. And if these frequencies are you know like, appearing and the same location when you start, when you are running the machine that means, you see here it is a clear resonant condition. So, you see when we are trying to do these things, we could easily figure out that, what is the contribution of the vibration in any machine from these things.

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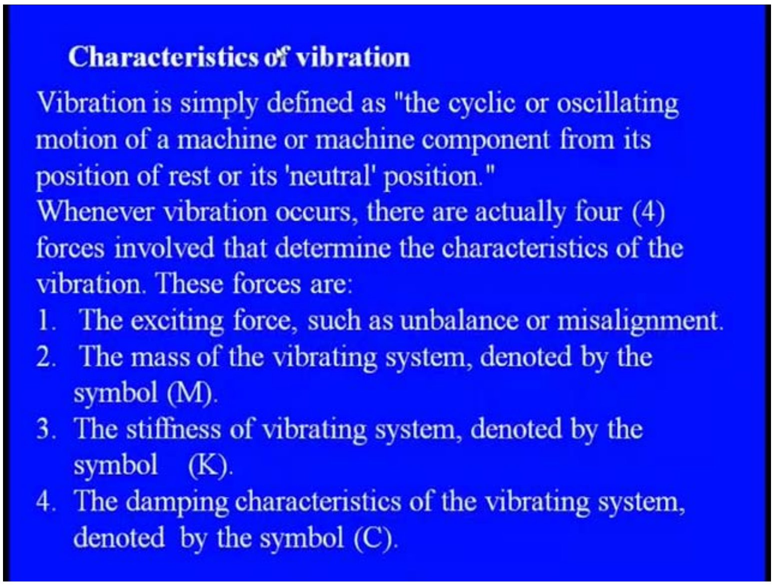

So, when we are talking about you see, the, you know like, the significant amount of vibration in these machines, the 40 percent contribution is from unbalance. The 30 percent contribution is from misalignment, 20 percent in is resonance and the remaining you see, you know like, the 10 percent are various other causes of this.

So, we can characterize this vibration with its cyclic order because we know that the vibrations are nothing but equals to the, you know like, the cyclic loading or oscillating motion of that. And when we are trying to do that, there are four forces which are being involved and if we have, if you want to characterize those things, we need to configure those forces together.

First, the exciting force, the exciting force may be of any, any, any, any we can say type may be because of unbalance, may be because of you see, the misalignment, may be because of any forcing factor, like in resonance and all other things or maybe any other damage feature like that. The second is the inertia force, when the mass is vibrating. The third is the restoring force, when the springs or you know like, the stiffness's are there at the contact point. And the damping force is due to any viscous or material damping.

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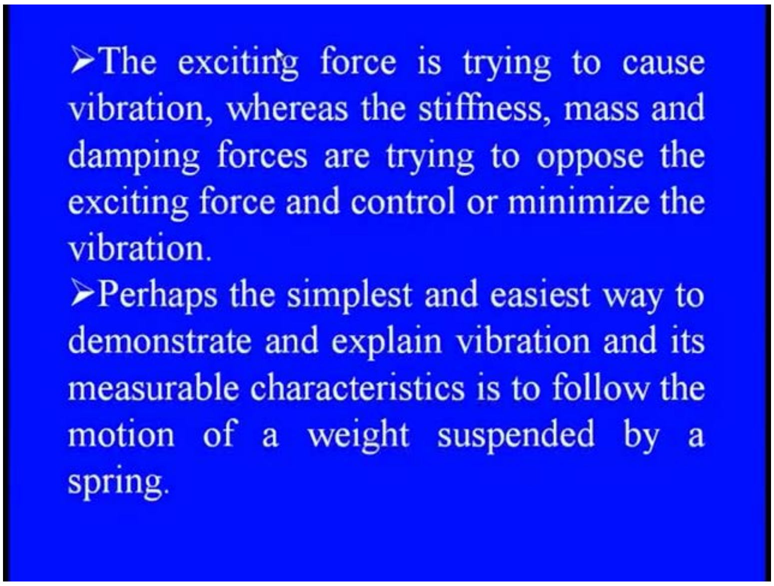

So, these exciting vibrations are always been coming due to the stiffness mass or damping force variation. And these forces are always trying to oppose the exciting forces, just to control or minimize the vibrations. But you see the simplest and the easiest way to demonstrate and understand the vibration is, just based on the frequency and the time domain. And if they can straightaway follow the motion of any weight suspended spring, as you see you know like, the sinusoidal features or anything.

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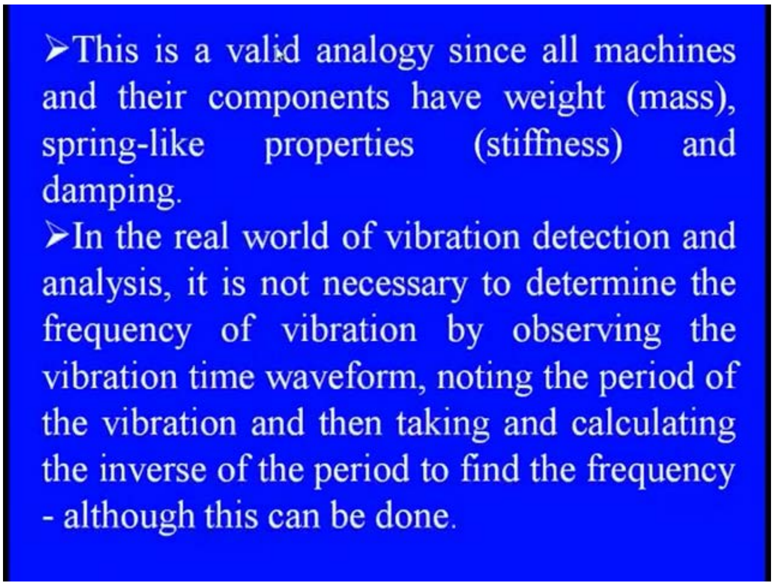

And you see we can put any kind of analogy, with the machine and their components with the mass spring and the damper. As we have done you see, in the previous cases.

So, in the real world of vibration detection analysis, it is always remember that, we need to go with the two domain, the time and the frequency domain. And we need to check it out that, what is the, you know like, the significant amount in terms of amplitude or in terms of energy is available, when such vibrations are being occurred there.

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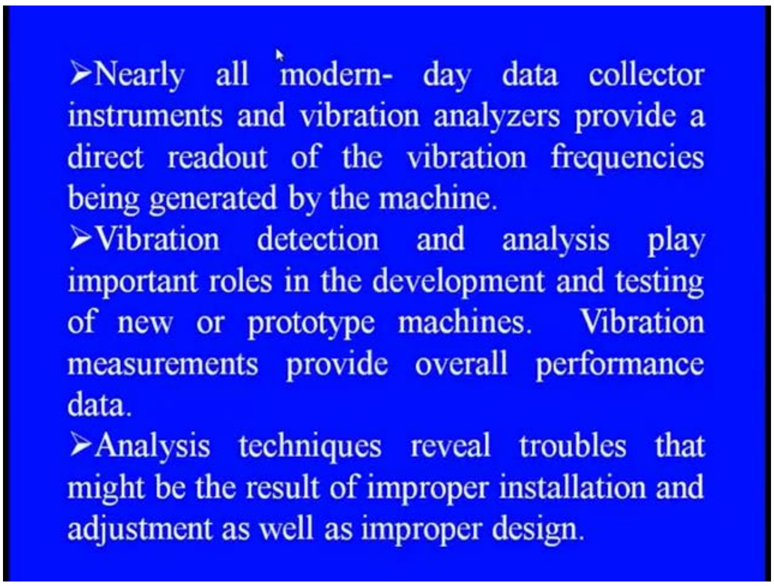

Now you see, we can straightaway, nowadays you see, lots of you see, the sophisticated equipment are available. So, we can simply collect the data, from the data acquisition system using the sensor and we can analyze the vibration online. And the vibration detection and analysis is always playing a key role in development of the new system even, with the prototype or any feature. Because you see, these vibration signature is always giving the full data analysis and we can evaluate the overall performance based on this data.

But again you see here, lots of research has been done for this digital signal processing or for this signature analysis. Because we know that, every time we are not getting the steady state response, we have the transient response. And for that you see here, there are you see, the chances of having the stationary and non-stationary data, along with this.

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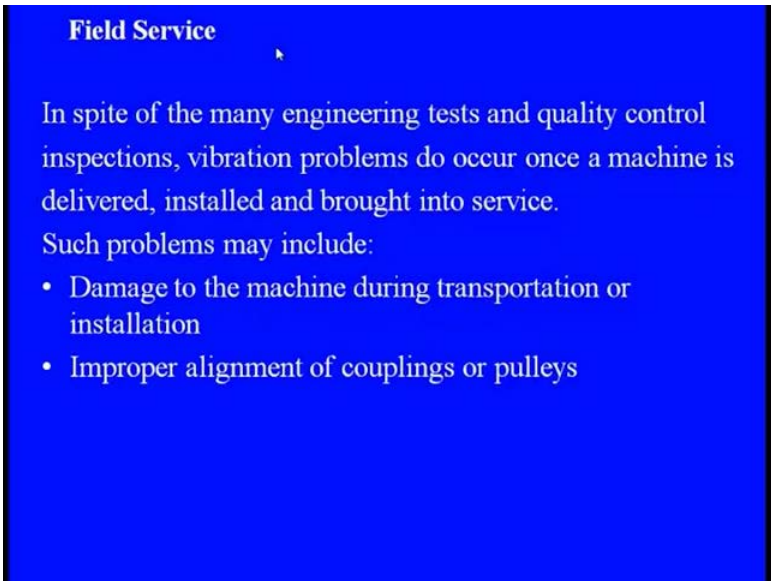

So, you see here you know like we need combine together and check it out this. And in the last category in the field service, we need to check it out that, what are the test and the quality control inspection. Especially, about these dynamic motions of the vibration problems, when the, is being installed or brought into the service. So that, we can define the characteristic frequencies of those components and also we can define that, if there is no the defect and the robust design is there, then what are the dedicated frequency or the time responses for that. So, latter on you see when the problem comes of the vibration or the damage comes to any machine part during transportation of installation, we could easily figure out or else even we can find out, the improper alignment of couplings or pulleys.

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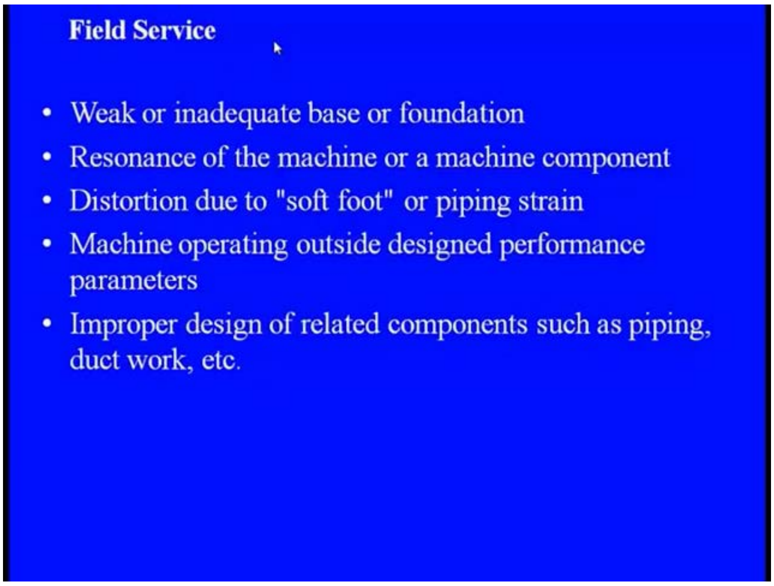

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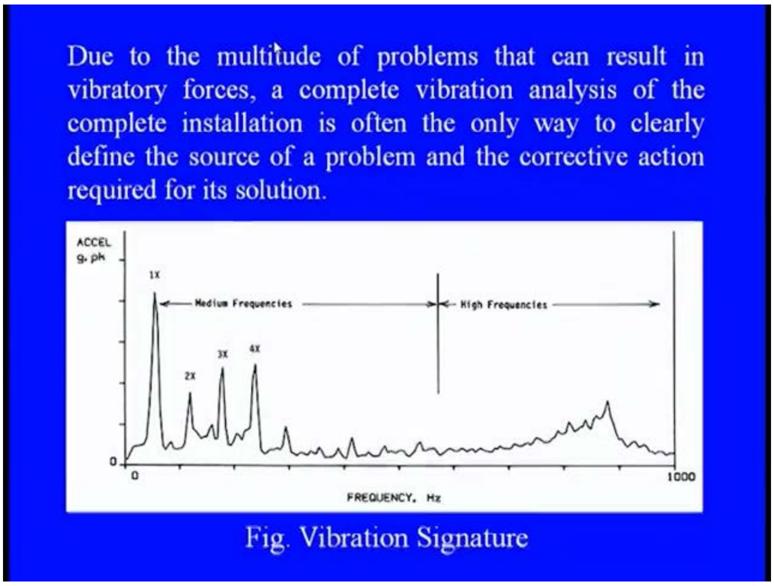

Fig. Vibration Signature

Even we can find out the, any kind of inadequate base or flexible foundation or even we can find out that, what is the resonance of the machine or any component so that, you see here we can evaluate that. The distortion can be also you see, you know like, in the field due to service conditions or anything you see, the design parameters, in the piping part and improper design for any component, can raise the vibrations in that. So, we can see that you see, you know like, there are two main categories the medium and the high frequency in that spectrum.

And due to you see, the multi attitude you know like, the problems, it can creates the various types of vibration forces. And the complete vibration analysis is just giving, a clear indication about the different level of peaks and the energy and the, or the amplitude of vibration at the low and high frequencies.

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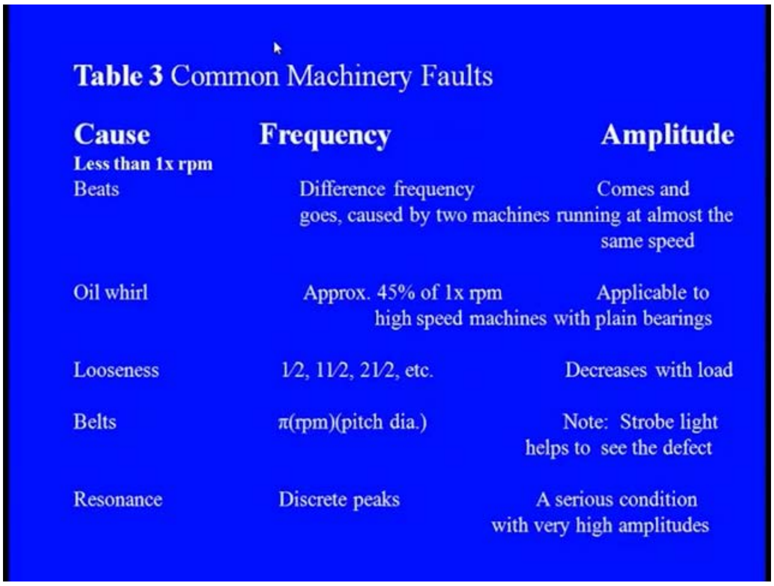

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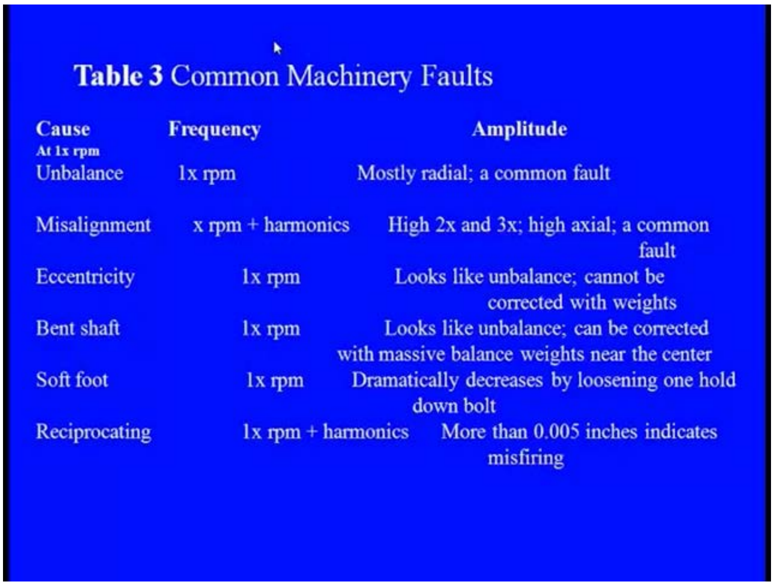

So, you see here these are the various common machinery faults are there like, we have the beats we have the oil whirl, we have you see the looseness, belts or reason. They are always showing the exciting frequency less than one rotational frequency. But when we are going to the 1 x rpm means, the rotational frequency is being there in its absolute form. Then there is a clear interaction, the clear indication of unbalance misalignment eccentricity, the shaft bow or the bend shaft, the soft wood and the reciprocating features are being there, with the exciting vibrations.

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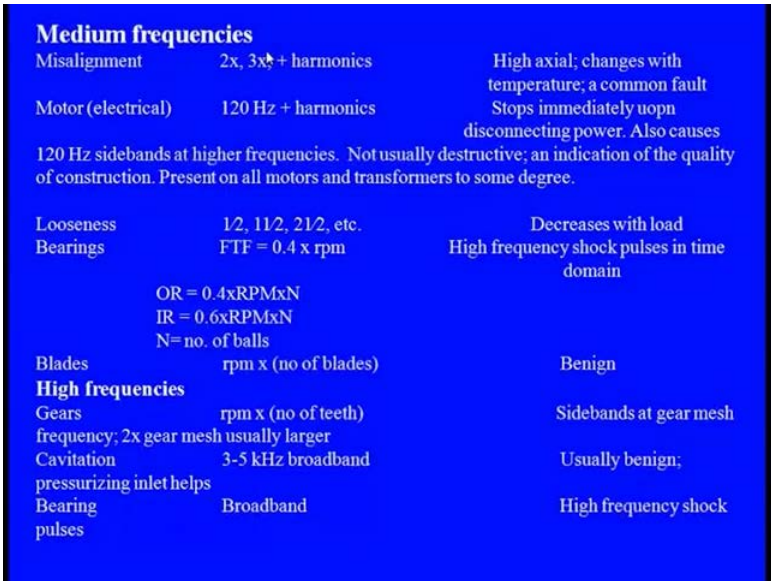

On even, or even for the medium frequencies we can simply go with the misalignment and the motor excitation, with the rigid foundation or else, even we can go with the looseness bearings or the blades at this. And if you are going towards the final feature, that is the higher frequency, the things are coming like the gears. Like you see, you know like, the two gears which are being matting at a common frequency or even with the bearing pulses, all these things can be immediately evaluated. And when we are going towards the root cause analysis, the machine vibrations have, the various category for this and these categories are may be of design defect, may be manufacturing defect. The operational stresses, when it is being operating any couple or moment is being applied to that, the operational stresses.

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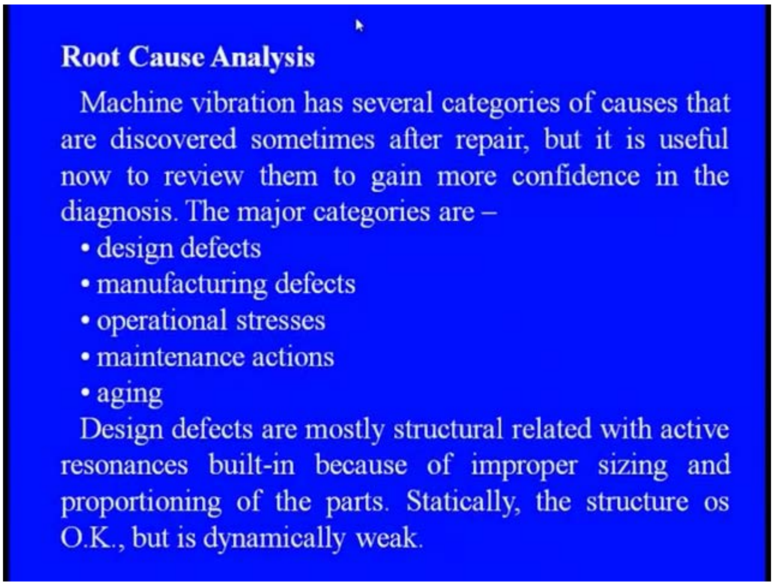

The maintenance actions, when we are doing maintenance certainly there are you see, the variety of cause through which the distortion is being there or any kind of deviation. And then that will cause the vibration or aging. The design defects are pretty common and it is related with the structural ability of the system, according to the active resonances. And also, see the improper sizing and you see, the improper proportionate of the parts is creating the huge amount of we can say, the non-linear distortion and then the corresponding vibrations are there.

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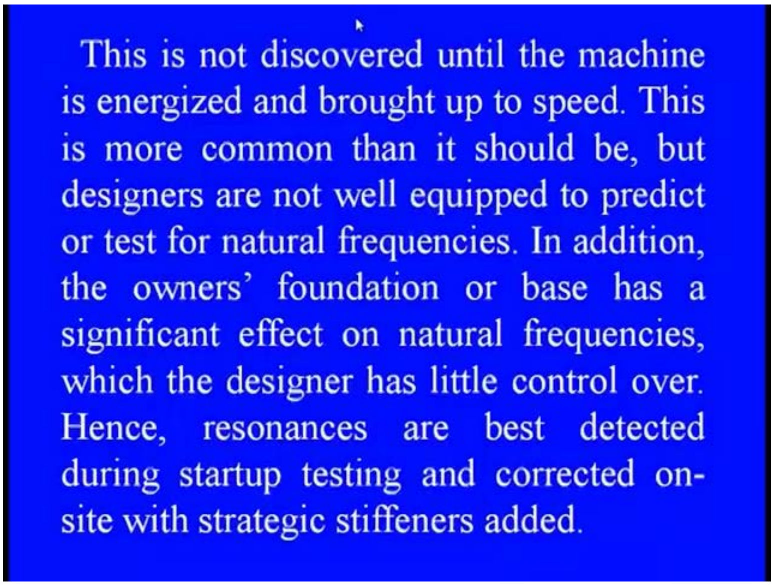

So, in these see you know like, the machine vibration we can say that, the machine is energized and brought up to certain speed limit and the, this is very common when we are applying this, to any real system. But the designers are always saying that, now the dynamic action is pretty transient or you see, pretty you know like, the straight forward we need to check it out, the a natural frequency. And in addition, the foundation of the base is always having a significant effect, irrespective whether it is a rigid or the flexible base. However you see, the resonances are best detected during the startup is the transient feature of the testing and corrected, onsite with strategic stiffness added.

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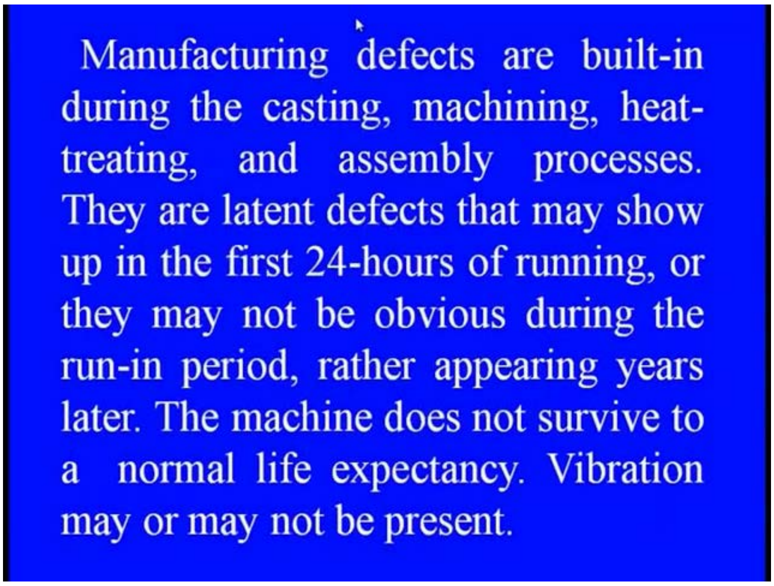

And these manufacturing defects, which are defects, which are being built in during the casting of machining or any heat treatment process or any assembly process, they are creating or very dedicative exciting frequencies, into the vibration signature and we could easily figure out. And these machines are not you see, you know like, survive to a normal acceptancy level, because of this vibration present.

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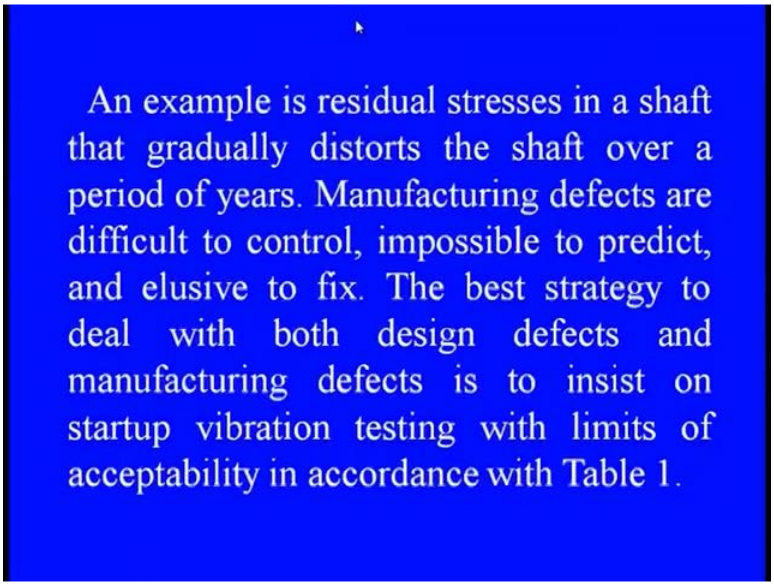

And you see, even we can go up to the residual stress in the shaft because these residual stresses are generally you know like, we can say, distort the entire shaft, for that. And in this also you see, the manufacturing defects or you know like, we can say, any imperfection is really difficult to control or even to predict about these. So, we need to apply at the design aspect that, what could be the manufacturing policy and method should be there so that you see here, these defects can be eliminated from that point.

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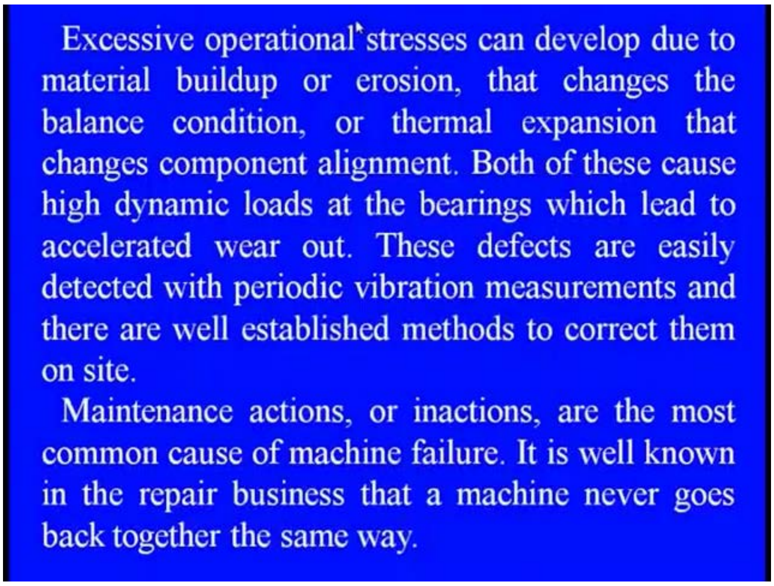

So, you know like in this particular feature we know that, there are various ways through which the defects are being coming. And these defects are you know like, somewhat easily detectable, under the vibratory signatures, even the defects which are there due to the, due to the maintenance action or the interaction, they are also causing the machine failure. So, you know like, we need to check it out that, what are the potential features through which the excitations are being happening with the system.

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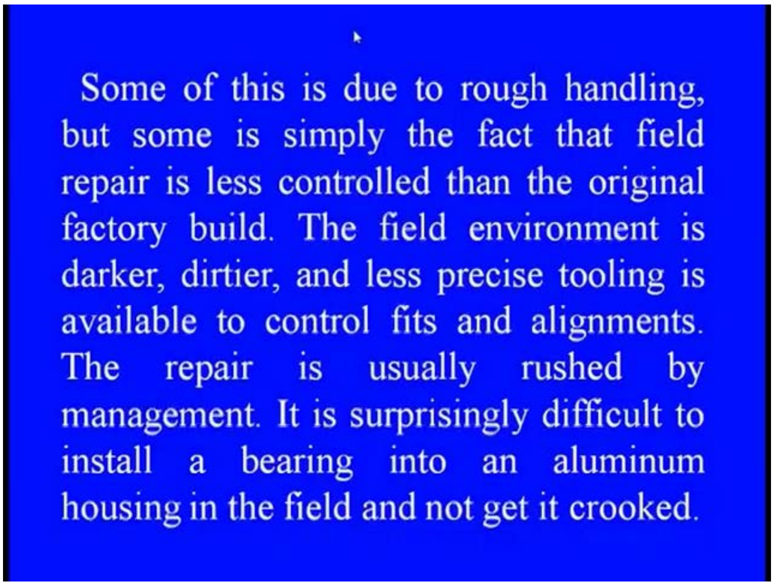

Such like you see here, the various feature of the maintenances are rough handling. Sometimes it is not easy to control that, the field environment like, you know like, the dirt is there, the darker features are there, even the less excises are being there with tool. They are always creating the huge vibration and the repair is usually rushed by the management. So, we know that it is really difficult to install a bearing into aluminum housing and then you see, we know that, there are certain used problems are there.

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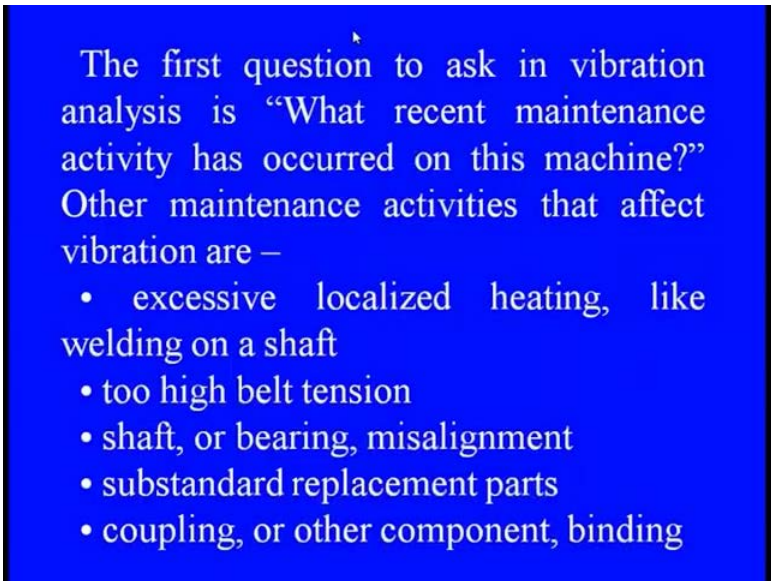

So, the things are coming that when we know that, even in the maintenance there are some problem. So, what is the strategy in that so first of all the maintenance activities which are being affected the vibrations are excessive localized heating or the welding or shaft. When we are doing these things, there is an unbalanced feature is there, too high belt tension, the shaft or bearing misalignment, the substandard replacement parts and you see the couplings, with the binding feature.

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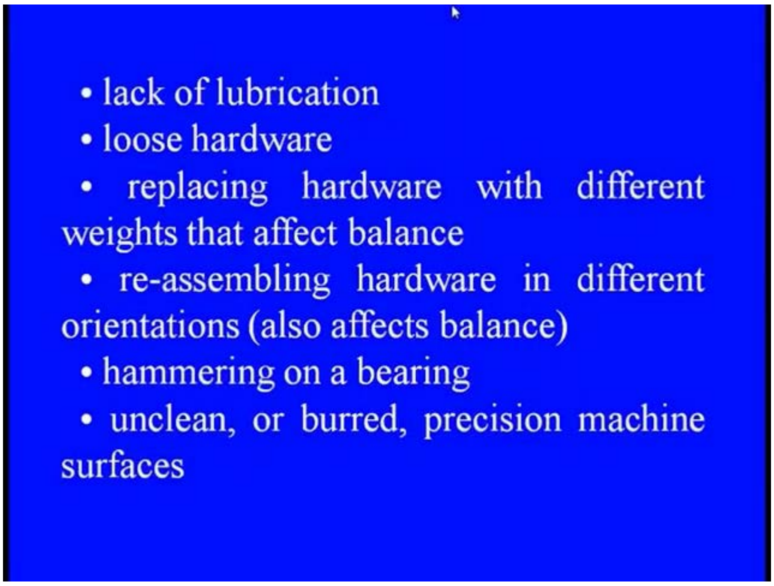

Or even the lack of lubrication or some looseness is there in the hardware. So, we can immediately correct those things and we can simply see that, even if we are going with the precised machine surfaces, we can reduce the vibration significantly.

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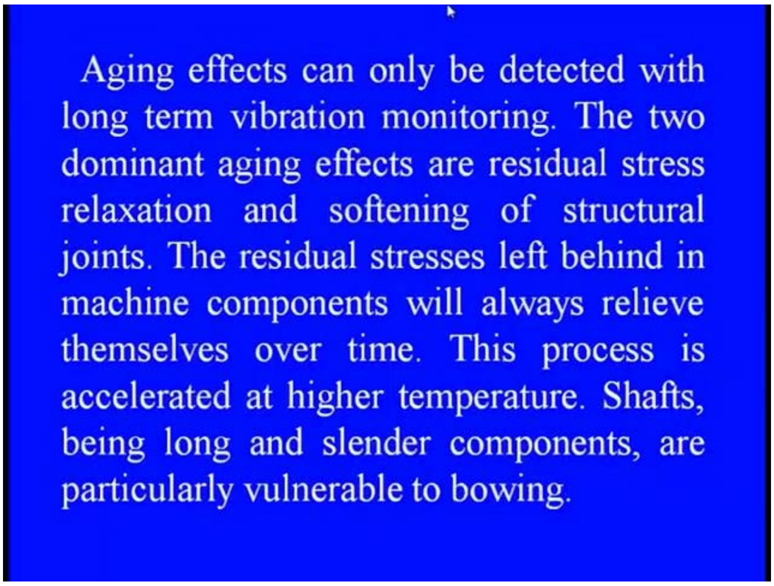

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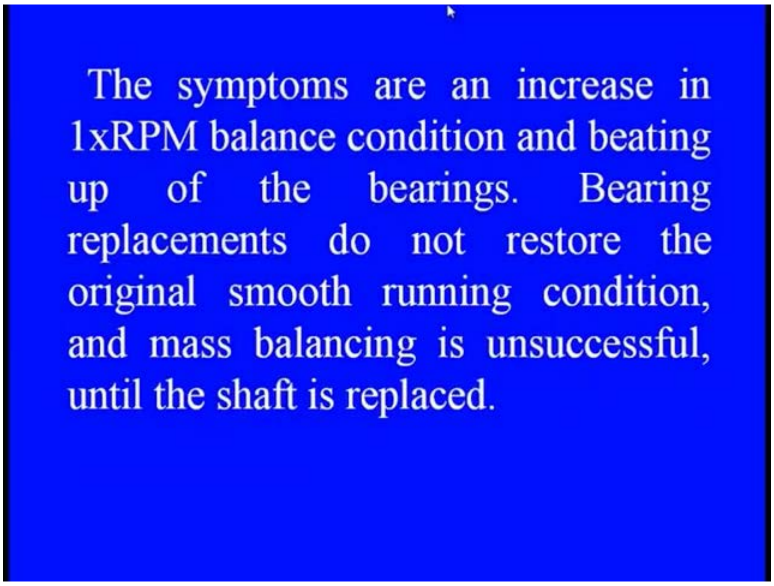

And the aging effect which is the last part, can also be detected with the long term vibration monitoring. Because, the residual the stresses, which are being there with the machine components, always you know like, excite with these things. So, the process in which the accelerations are being there at the high temperature of the shaft, you know like, the shaft being or any slender component is basically coming under the bow, bowing feature of that.

And the symptoms in which you see, there is an increase in the rotational frequency of the bearing is clear that, you see here, there is you see, you know like, the different kind of loading conditions are there and the operations are there in the bearing part, in that.

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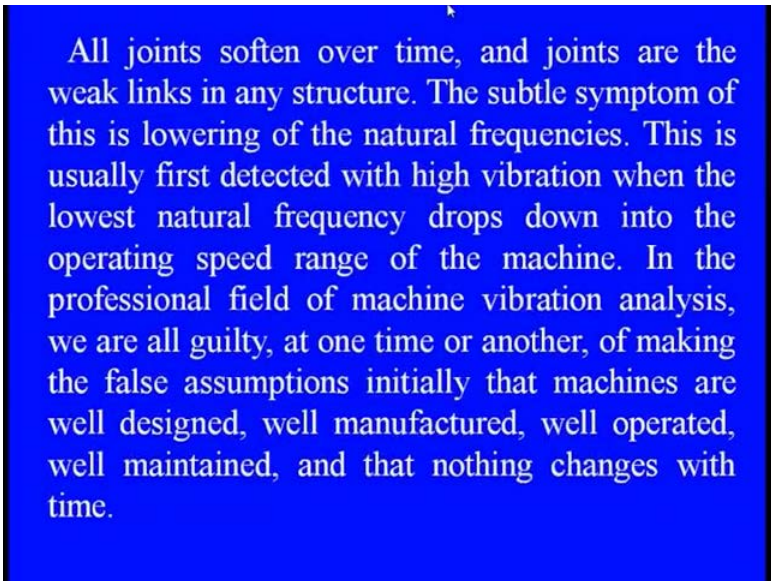

So, all joints which have soften you know like, over the time can say that, they are ultimately supporting the vibration, when the excitation is there lowering the natural frequency or higher the natural frequencies. And even in the professional field of machine vibration analysis, we know that once we are, once we have done the vibration analysis is one point of time, in the next there will be a different cause and different analysis of that.

So, in this lecture we discussed about the source classification of basic vibration generation and we could easily figure out that, there are various common causes like the rotor unbalance, like misalignment, like resonance or like various other you know like, the causes, they can contribute in a very significant way. So, we can clearly classify vibration generation mechanism, based on the frequency spectra or the time spectra and based on the behavior of the entire machine itself.

Now you see in the next lecture, we are going to discuss the similar kind of you see, the vibration generation mechanism, not the source classification, but the self-excited vibration. Because even we can say, we have seen already in that, even the machine is robust and perfect, even after that there are clear exciting peaks in the vibration signature. And when such things are there, that means you see here, they are some self-induced vibrations are there. And these self-induced vibration can also sometimes cause, the machine failure. So, how we can relate the self-excited, self-excitation vibration with the other exciting frequencies in the vibration spectrum, is one of the interesting part and also we are going to discuss about the, numerical problems of that.