Introduction to Mechanical Micro Machining
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Lecture – 37
Components of machine tool (Contd.)

Good morning everybody, and let us continue our discussion on the Guideways. In the last class, we have seen that. There are different type of guidesway are available, linear guidesway, hydrostatic guideway and aerostatic guideway and we have found that aerostatic guidesway have the very-very low friction and that is mostly useful for the micro machining of the very-very high precise motion applications.

So, in that case, let us continue further in these cards. So, this was the last slide, we have seen in the last class, and here, what are the things, which is good for the aerostatic that it avoids.

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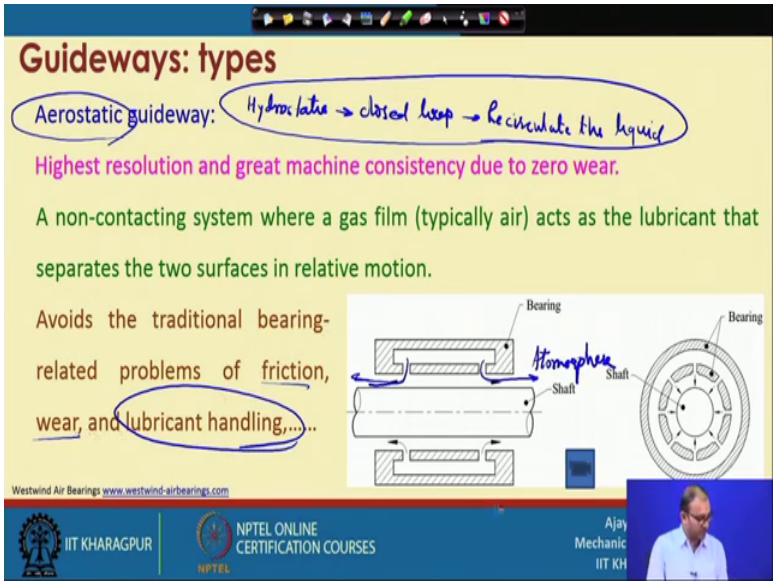

The traditional bearing related problems of the friction wear and lubrication handling, if you see that earlier case that where we are using hydrostatic part. There was one particular things, you might have noticed that it was a close loop system right. So, it is a hydrostatic, hydrostatic is a closed loop. So that means, that you have to recirculate the liquid correct; that means that here what we are doing that, we are actually not worried

about the collecting the arrogant, whatever air is coming from this particular bushing, it is going to disperse in the atmosphere right.

And that is not the case here, because here what you have to do that, you have to body lubricating handling, it should be a fully closed loop circulating system. So, once, you pass this liquid from this particular bearing that you should be collected and then again you should be recirculated. So, this is more complex system compared to the air, because in the air, you have to worried about supply only. Note that, what is going to happen after supply, but here in the aerostatic bearing, you have to actually look after the supply also and then how to collect those particular liquid, because you cannot actually spiel all the oil after it is, it uses.

So, that is the big problem or very big difference between the two things hydrostatic and the aerostatic guideway and linear and friction and the wear. Both things are more discuss about this both, the things, but still we consider the aerostatic bearing, have much less friction compared to the other cases right.

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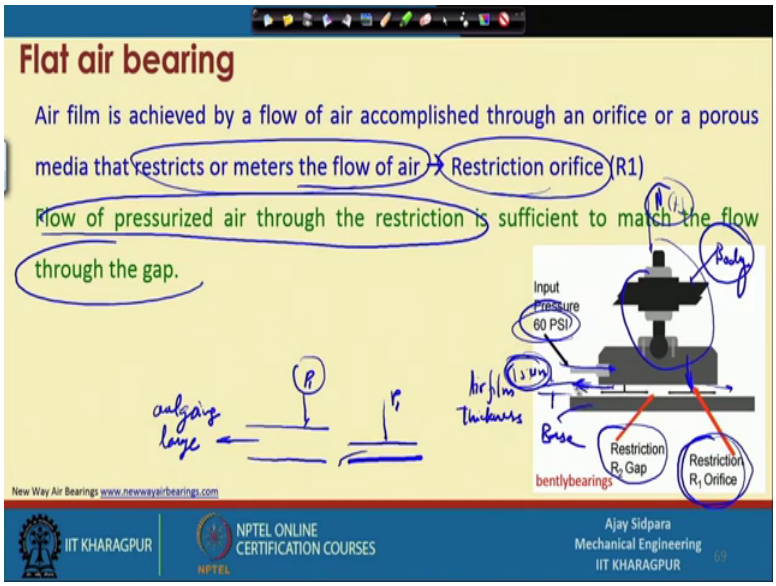

So, this is a flat air bearing type of thing. So, here what is the thing here ? So, these are the two ways. So, it is mostly done by the orifice type of or the porous media that restrict the meter or meter, the flow of the air and there is called restriction orifice. Now, what is this restriction orifice that you have? You can see here that there are two things, a restriction orifice R 1 and restriction gape that is R 2 and now, you are providing the air

supply from here and these whole body is lifted on the base surface. So, this is the base and this is the body correct.

So, now, you have to restrict or meter the flow of the air right, because now, once you provide a 60, Pascal per square is psi then what is going to happen that you do not know first that how much is the load coming from the top right. That is the force or the load, then depending on that you have to find out, how much is the thickness required, air film thickness correct. So, if you want to maintain this particular air film.

Suppose, you are considering air film thickness maintenance is considered 15 micron and your load is variable then what you have to do? You have to actually do a restriction on the supplier. You have to meter, the flow in such a way that even if there is a variation in the load. You always maintain the 50 micron by maintaining a particular pressure, because we know the, what is the area available, this location. So, by area force and the pressure calculation we know that force equal to load upon area.

So, in that particular case, you can easily calculate that how much is the pressure required to maintain, a particular film under a different loads. So, that is called the restriction orifice. So, this orifice will supply the air between the body and the base. So, that you always maintain this particular part, then it will actually go away from this particular part right.

So, flow of pressurize air, through the restriction is sufficient to match the flow, through the gape. Now, what is happening that we know that, we are actually throwing everything away from this part right, because you are not collecting anything. So, what we have to maintain you, to maintain a balance between the two things. First thing is the flow of the pressurized air through the restriction. How much is the air is coming through this and how much it is passing through this gap correct. So, if you consider, this gap is very-very large. Now, consider this are the two surfaces. This is the one location and this are the two location and you consider, you are providing the same pressure P 1, it is also P 1 correct.

So, here what is in the area is very-very large. So, what is going to happen? Your load will be very-very low. So, you have more clearly. So, whatever is coming out of this thing, it is a large, outgoing is large. So, here it is a less. So, here it is a more meter; that means, more balance the thing. So, what we have to do that we have to balance both the

thing. How much we have putting this thing and how much it is passing through this particular gape? So, that is called the restriction of the gap right. So, what is the restriction gape?

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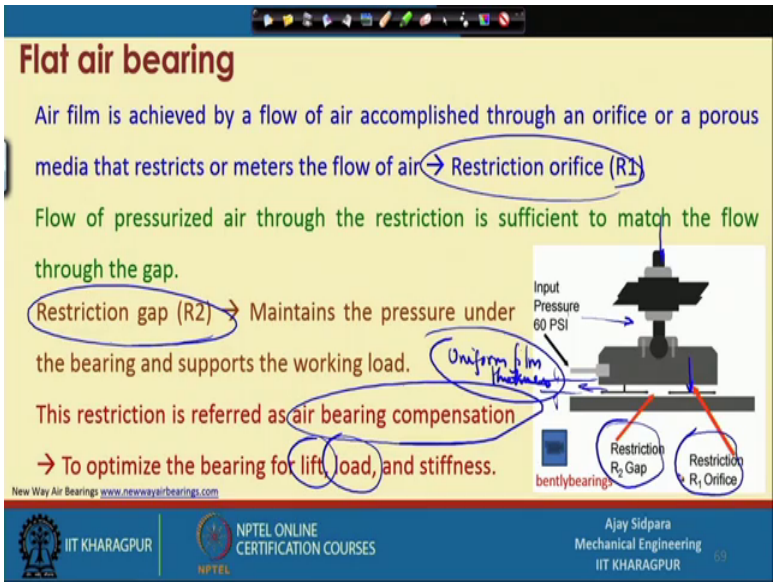

It maintains the pressure under the bearing and support the working load. So, we have to thinks that how much your pressurizing or we, how much we are supplying that is through the orifice that is applying and; that means, how much we are leaving it away. So, that is called the gap restriction, if the gap is more, what is going to happen that your gap restriction; that means, pressure will be very less here, because now area is increased.

So, in that case that is a big problem here. So, now, if you press it little bit more, your area is reduced. Now, your pressure is increased. So, again it will balance the thing that we have seen in the last. That animation of that, movie clip, where the, if it is displacing vertically, then automatically air was, maintaining that particular centre line between the shaft and the bushing. So, that is why you need two restriction; one is the restriction in the gape and one is a restriction in the orifice right.

So, this restriction is referred as air bearing compensation right. So, whenever there is a force is; that means, you have a encountered two different type of forces; one is the thrust force and another is the side force that is mostly going to happen in the milling

machine or different type of micro machining operation. So, what we have to do? We have to compensate this particular bearing by restriction of this particular thing.

Orifice is restriction in the gap, restriction and optimise the bearing for the lift load and the stiffness, because now we know the if your load is variable again you, to maintain both the thing, because your objective is to get a uniform thickness of the particular air film throughout the operation, whether it is a static condition or the dynamic condition, our objective is to keep this uniform or uniform film thickness correct.

So, that is the thing lift is also important. How much it is move upside down and the stiffness is important, because is to deform completely under a particular load. So, this whole thing is defined or it is considered in the bearing compensation and for bearing compensation, you have to pay attention to this two things. Restriction orifice and the restriction gape right.

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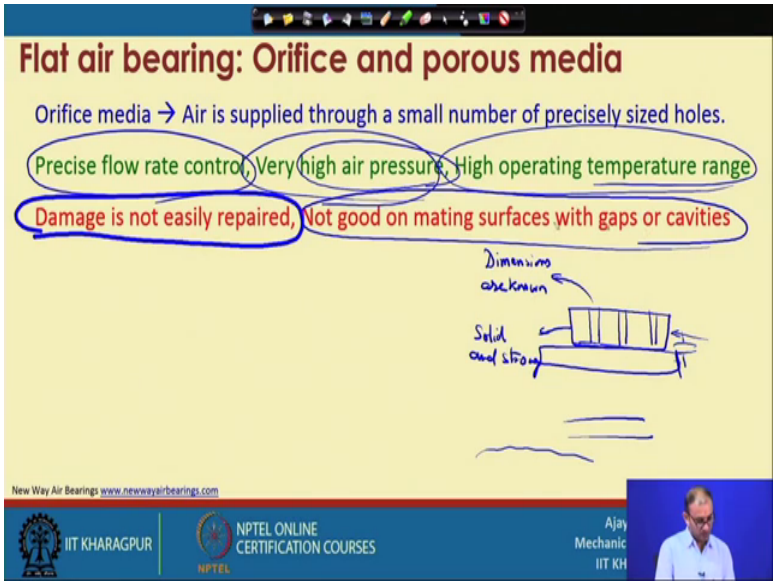

So, what are the two things? There are two ways you can supply the air through this particular part. So, this is one is called the, through orifice and another called is the porous media. So, when you are talking about orifice media; that means, air is supplied through a small number of precisely sized holes and precise flow rate, control very high pressure rate and high operating temperature ranges are there. So, what does it mean that; suppose, you consider that this is your plate and then you are drilling some holes here

and this is the bottom surface correct and you are supplying air from this, in such a way that air is passing through this side.

So, this is called the orifice media type; that means, you are, this are, this hole is there, that is you consider orifice right. So, this is the way, it is working in this particular case. So, what are the advantage? Advantage is the precisely rate can flow control, because now, you know the diameter of this particular, surface. So, whatever the hole you are drilling, you know the diameter of the hole. Very high pressure is possible, because everything is hole, it things correct.

So, let me go it again right. So, precisely control; that means, you know the size of this dimensions are known, known very high pressure it is achieved, because now, we know that this whole thing is a solid material, solid and strong material and high operating temperature, because now, temperature will not make much difference here, because this everything depends on the, what is the coefficient of thermal expansion of this particular material.

If you use very-very strong, high strength material then temperature is also note an easy you, but what is the problem that it damage, not easily repaired by chance, if something happened that you are not able to maintain that film and there is a direct physical contact between the two surfaces and then, at during most. It will damage and once, it is damage, at that time, it is very difficult to repair those thing.

You have to actually replace. Only repairing is mostly not possible, because diameters are in micron level and it is precisely measured and if the surface has some type of scoring effect or some type of scratching, then it will create a variable of the differential pressure gradient and that creates a problem and not good on mating surfaces with the gaps and cavities.

Now, suppose your bottom surfaces is both things, are not fluid completely bottom surface is something like this, then what is going to happen again your end up with the variable pressure and calculation of that particular. Maintenance of that particular field is very difficult in this particular case and that is the reason that orifice media type of a flat.

Air bearing is very difficult to use in particular application, but still this is a first type of air bearing, bearing which was developed and still many application. This is still

preferred, because of this, some of the advantages, because many times you will take care about this particular part by some type of gap sensing element or something sensor then usually, this is the more versatile more easy to use thing right.

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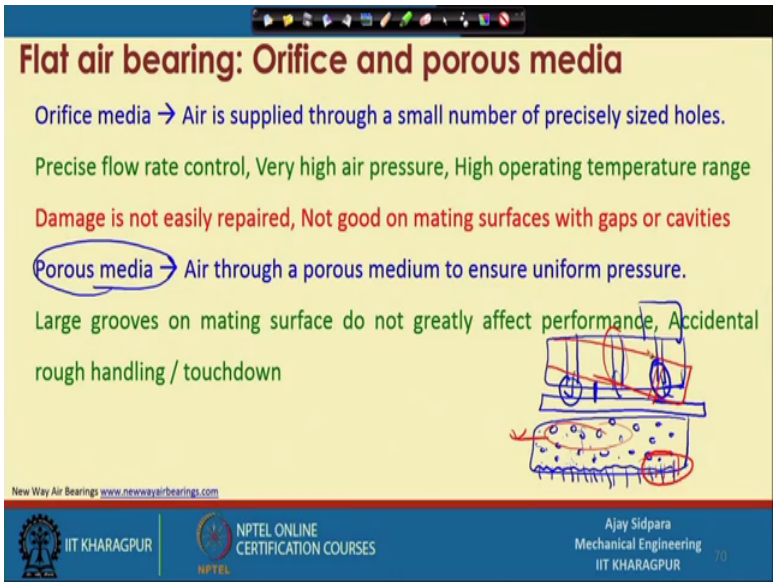

Another one is the porous media. So, now, what is going to happen that instead of those type of holes right. So, earlier we have seen that. These are the orifice now, instead of orifice, what we are doing? We are using one type of porous media. So, there are different small-small holes available, was some type of passage available. So, it is considered porous material right. So, what is going the air through a porous medium to ensure the uniform pressure?

Now, you can consider that here that depends on the, which are the location? Where you are providing the air supply at this location in this particular case, first case right. So, you know that if you measure pressure at this location to be very-very high, but if you measure pressure at this location. It will be less, because now, there is no flow of the pressure. So, if you see this particular pressure profile here, it will be different that will see in the next slide that. What is going to happen depending on the location of this particular, location of the orifice depend on the pressure again, but here what is happening here that, you are getting a large amount of small-small holes, because of the inherent porosity of the material.

So, air will pass through, this porosity and at the end, you may get a hundreds of holes through which you are getting a air supply right, but here, it is actually machine or manufactured thing here, it is a natural thing depending on the porosity of the material. So, at the end, you may get 1000s or 100s of holes, but that is not possible here, because here you have to maintained you to precise little, the how many holes are required.

So, that is the difference between the two things. What are the advantage, a large grooves on the mating surface do not greatly affect the performance, because now, we know that there are different type of context. Now, if this thing is bending here now, suppose, you are putting work piece here right. You are putting work piece here, load is on even in this way, this particular part will touch the surface right. When it is touching, this is the only nozzle, which is actually giving the compensation or the resting resistance to this particular compression, but this particular location will touch the surface. So, that is the problem in this type of cases. So, when it is tilting at that time. There is a problem in this particular case.

So, this is going to happen, but your nozzle is see here. So, it will not make much difference here, but the same thing happens your, what is going to happen? You have a hole on all the direction. So, even if it is tilted, then this particular hole will be under more pressure. So, it will stabilize again. So, that is the advantage of using, this particular part and it accidental rough handling and touchdown, it will not create more problem in this particular case, because it is naturally made this particular for porous media, but here, we have fabric editor designer issues right.

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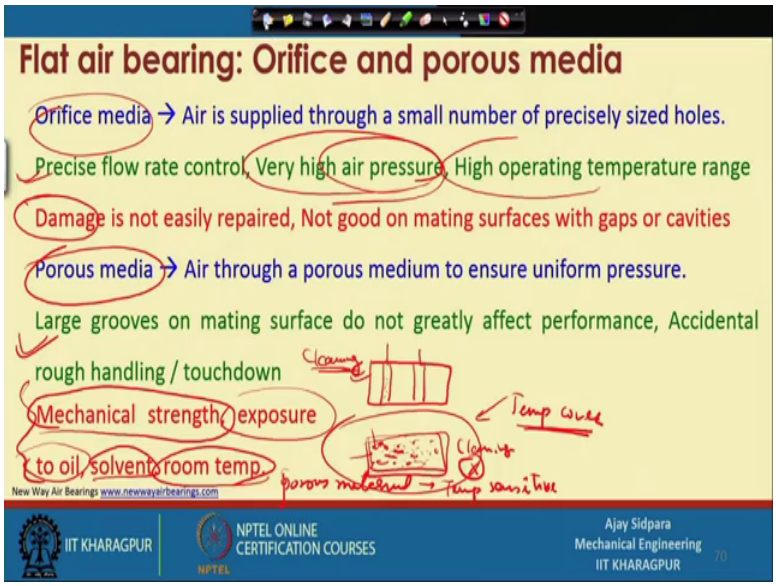

So, what are the things problem the mechanical strength is a big problem, because now, we can see that if you make something. So, this is the two or three holes available and we have this material. We are, they have porous thing. These are the porosity right. So, strength is a big issue, because now, how much pressure you are providing here. You can go with the high pressure.

We know that high pressure is not a problem, but if you provide high pressure here, what is going to happen that this material is very-very weak in the strength, because this inherent porosity will make this material little bit weak and when you are produce high, high pressure velocity of this particular air then what is going to happen that, this particular, whatever porous things are there it will try to merge with each and that will start deforming within the structure.

So, mechanical strength is a big issue, you cannot actually go beyond a certain pressure limit and that is not a issue here, everything depends on what material? You are using expose to the oil, because now, this is a porous material. This is a machine component by chance, if accidentally it comes into contact with the oil here, then you can clean it. So, cleaning is not a big issue here, cleaning, but here it is a porous structure.

Now, you can consider that if you are putting up sponge into the oil, completely abstracting the oil from this sponge is very difficult, because you cannot abstract every oil from this part and that will create a problem oil or solvent whatever, you are using, it

will start creating a problem. So, cleaning of this particular thing is very very difficult cleaning is not possible room temperature is also important because now it is very porous material. So, its surface area is very very high porous material. So, temperature is sensitive temperature sensitive right.

So, it is better to operating room temperature, if you want to operated high temperature, what you to do, you to provide a localised temperature, cover temperature. So, that you maintain that particular temperature throughout the operation. So, we can see here, the some of the things are good for the porous media. Some of the things are good for the orifice media also, but both have some of the disadvantages. So, depending on the application or where you want to use this particular thing has a different-different things.

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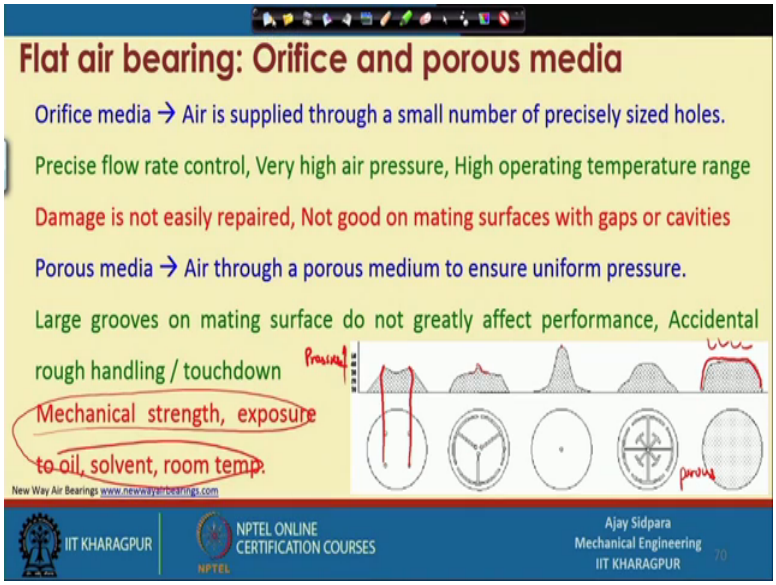

Now, you can see, this is the profile of the pressure. So, this is the pressure right. So, this is the orifice type and we are putting over orifice only. Now, if you can see that this orifice are matching with this particular peak pressure, you can see the, there is no material available. There no space available, nothing is available. So, you are getting a variation in this particular part.

Now, this is another thing that you have a continuous slot here and these are the orifice 1 2 3 and you can get a peak part here, here only single or is maximum pressure will be at this location and then remaining part, it is continuously decreasing and this is another way of the orifice. Where you are getting a different profile and this one is the porous

part right, in porous we know that holes are throughout, because of the porosity and you can see, the how uniform is the pressure profile.

So, this is what is required, because you do not want a non uniform pressure profile, where a work piece surface. So, that here the loading is uniform and on the loading is uniform. You may not encounter some type of deformation type of things or the, some type of alignment problems. So, this is the one of the good thing, but still it has limited by many things. So, it is up to the application engineer, which one is the good for that particular application right.

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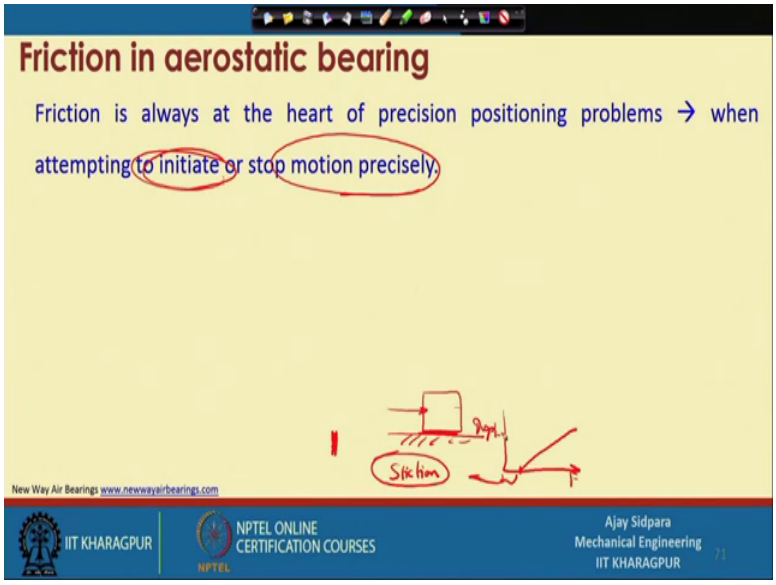

So, friction in aerostatic bearing; so friction is always at the heart of the precision position problem, because when attempting to initiate or stop the machine precisely, because where friction creates problem, friction creates problem at two location that is when to initiate the motion right. So, once at one particular thing is at the rest, then you have to apply certain pores, after that only it will move further in this direction right. So, this is the force requirement and this is a displacement. So, it will start. It will now start from the 0. It will start from one particular location, unless you cross that particular limit then only you will get the displacement right.

So, this is particular called the stiction. So, you need a minimum force to reduce that is called static friction. So, you require minimum force to movable one particular object. So, for initiating something, you need some force here, if that is when you have a friction

between the two contacting surface and once it is in motion and you want to precisely local stop, at this location, then there is again one problem, because when it is in friction after that you are not able to stop at one particular location, because you do not know that how much is the time required to stop that particular thing, if there is a friction into consideration right.

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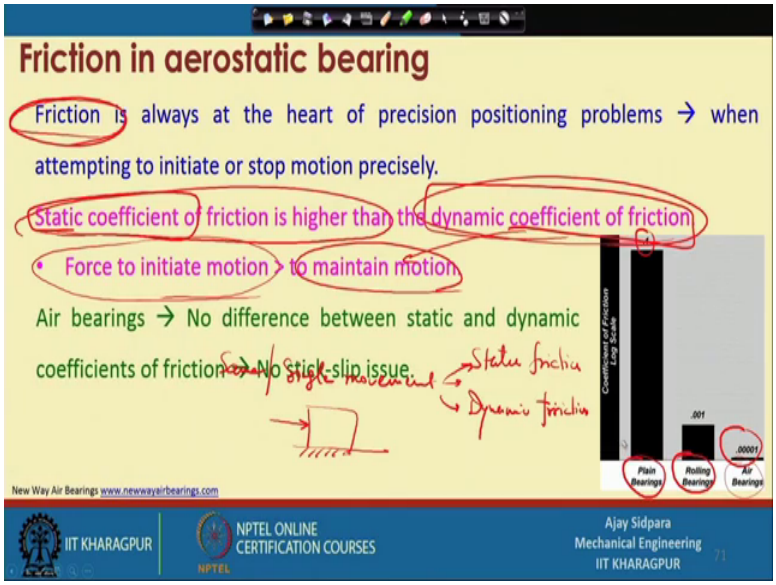

So, this is the coefficient of friction on the log scale, you can consider that this is a plain bearing, whatever we talking friction of coefficient of friction is 0.1 around. This is the rolling bearing and this is the air bearing, you can see, it is a very-very small almost is a negligible coefficient of friction and that is what is the advantage of using aerostatic bearing for a high precision applications right. Static coefficient of friction is higher than the dynamic coefficient of friction in this particular case, because when it is in static condition.

We know that we can easily maintained that part, but when it is in moving the component at the time. It will be little bit low in that case, but still it is on both the cases. It is higher other type of bearings, but within this particular bearing static component is higher than the dynamic coefficient. Force to initiate motion and to maintain that motions. So, what is the advantage here, when this particular case happens here.

So, because of the friction, what is happening that, whenever you are starting the motion here, that is, what is we have seen here. So, this is the component and we are moving this

thing. So, initially you need one force to move this particular component in one direction. So, once you initiate the motion, then you do not require same friction for continuing in that motion. So, that is why it is static. Coefficient of friction is higher than the dynamic efficient of friction correct. So, here, because of that your, you are getting a single motion, single moment or we can say same moment. We are getting two friction that is called static friction and dynamic friction correct.

So, both things are different and this that is the problem, when you are talking about the friction. So, that is the first thing is the force to initiate, the motion that is, what is it is required and second dynamic friction is the, to maintain that particular motion. So, this both things are present, when there is a fiction present and both things are different, but what is the advantage of air bearing that it does not have difference between the static coefficient of friction and dynamic coefficient of friction. So, that is the reason. This is the advantage of using this particular part, because we know that there is no direct or physical contact between the two surfaces and when that is the thing that the time.

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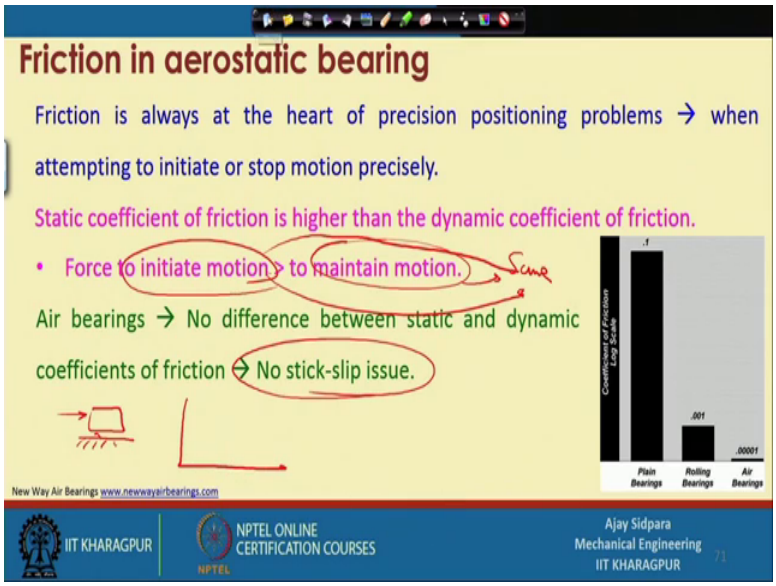

You can easily start the component, because now, we know that there is nothing in between these two only, air is flowing. So, your force to initiate the motion and maintain the motion both are same right.

So, if that is the case, what is going to you will not encounter the stick slip issue, because if you see that particular thing that, this is a particular graph, you maintain. Let me see, if

that graph is here it is not there. So, what is happening here? In this case stick slip phenomena. So, this is the friction.

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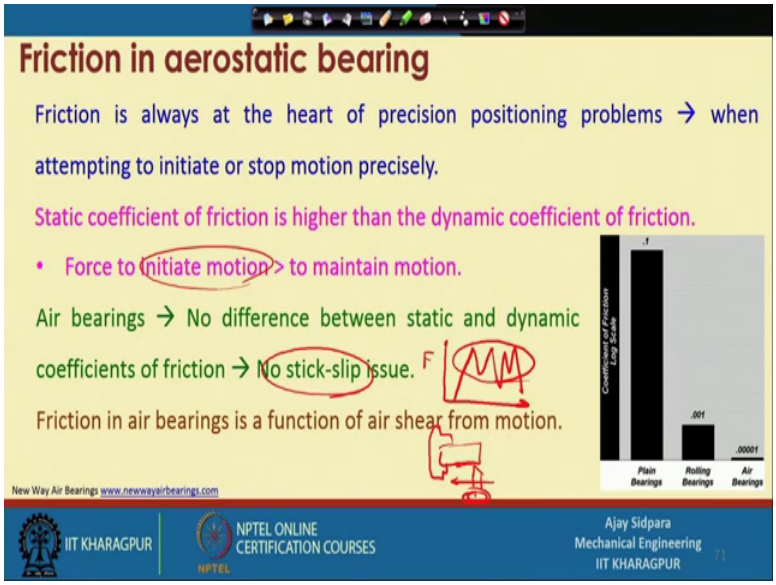

So, when you start the motion at the time, you will require some force, but as soon as you achieve, this particular initiation of the motion you have. Your force will decrease little bit and then it will actually move in between, these two and then you will get the high variation in this particular part, when you stop and. So, this is called stick and slip phenomena that is most will happen, when you want to rotate something by your hand.

If you consider your garage, you want to rotate on to the, when you want to penetrate your tool into the workpiece and then you are going motion by a wheel right. You have a handle here, circular handle and then you are moving this thing at that, you will feel the stick slip phenomena in the machining process that is very common issue.

Friction in air bearing is a function of the air shear of from the motion. So, here also there is a friction, but that friction is not, because of the thing, because of the mechanical contact, but, because of the air shear, because now, we have one particular surface and there is a air supply between the surface and this is the another surface. This card, how much is the shear of this air that will create a friction, but that friction is still much lower than the friction, achieve by the different type of, bearing surfaces right. Another thing is the wear component of the friction we have seen now.

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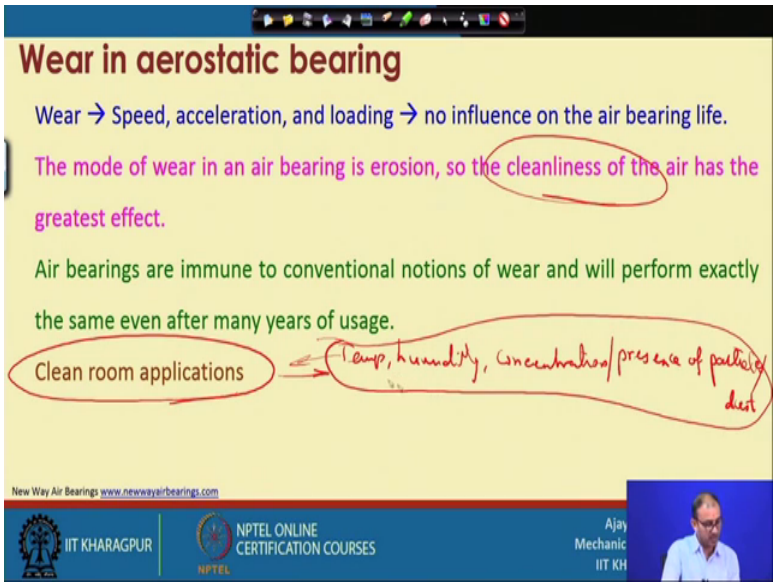

What about the wear, because wear has directly connection with the speed acceleration and loading right, if you increase the speed, your wear rate is high, if you increase acceleration, your wear rate is high. And if you increase your loading again, your wear rate is high, if there is a direct or the physical contact with the surfaces.

But this thing will not create any problem on the air bearing life, because air bearings are behaving different way, because no physical contact, no directly wear component and loading is also independent of that part and acceleration. You can achieve with a very-very high rate. So, for air bearing this particular thing is not a issue. So, wearing is not a problem, because not coupled component or no physical contact of the surface. So, you are not getting this thing, the mode of wear in the air bearing is erosion. So, the cleanliness of air has the greatest effect.

Now, this is the only way, but it can be reduced. It can be completely illuminated, if you filtered the air perfectly. So, this is what is happening. So, this is the air in, if some particles are here, but this is the air film and then air is moving here. So, particle will actually air road the surfaces that is at the longer long time, after usage and that particular erosion is happen, because of this presence of the particle. So, if you maintain the cleanliness of the air, most probably you will not encounter this type of problems right.

Air bearings are immune to conventional notion of wear and will perform exactly the same even after many years of usage. Now, see, what is the advantage of using this thing that, when you are working with a contact type or roller bearing and we have seen in the linear bearing video also that, if the 90 percent of the components are perfectly matching, if condition, that is the 50 kilometre of total life or their reaching the one particular life, where the 10 percent of the components are failed within that particular time, but still we can see the, those type of things, we are easy to calculate also, but here what is happening that, this particular thing.

Whatever variation you can do here, there is no physical contact or no wear. So, if you start using your air bearing today and if you use air bearing after 10 years of usage, there will not be any type of problem or, no any type of performance related problem, if you maintain the cleanliness of the air correct.

So, that is the biggest advantage of using. It is a very-very high long life, within a permissible limit of the operating condition. So, that is the very-very big things. None of the other bearings can give this type of, advantage right. Clean room application is important here, because now, if you see, if you want to use any type of other bearing considered the full contact bearing, because of heat generation. So, heat will again create a problem, when you are using in a clean room.

So, let me tell you what is the clean room. So, clean room is the one of the, specification where you can maintain the temperature humidity, temperature humidity concentration or presence of particle concern or presence of particles or dust or you can, can maintain many different other thing.

So, if you maintain one particular limit then there are some type of clean room. So, clean room, clean room requirement 10000s clean room, 1000 clean room, 10 10 clean room, one higher is the rating, higher is most peak is the, maintenance of this particular see, if you are maintaining a particle present within a volume like a, 0.5 micron particles are presence in a 1 meter by 1 meter area or something like that. So, in that case you are maintaining a perfect condition for different type of application. So, that is equal clean room, because here we know that only air is coming out of the system and it is completely filtered. So, you do not need any type, you will not get any type of, problem from the foreign element, which may create a problem when you are using a other type

of bearing, even hydrostatic bearings also. You have to create a complete close loop and spillage of the oil and other liquid will create a problem at the later scale.

So, clean room applications mostly, mostly it is related to the I C fabrication that is, where you are making some type of integrated chip on the silicon surface is over some type of lithographic processes, where you do machining at that time. It will create a great things here.

So, let me continue this stiffness of the bearing air, bearing in the last class. So, till now, whatever we have discussed, those things related to air bearing and will continue this air bearing topic in the next class also.

Thank you very much.