Surface Engineering of Nanomaterials
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Lecture – 02
Friction Tribology

So, now we are going to start our second lecture on Friction Tribology. So, in these particular chapters we will deal with the different types of frictions, what type of frictions we are getting from different bodies? And what is the basic principle about those frictions? So, in a first case or may be the first slide we can see that there is some examples which some cases the friction is helping to us, some cases it also create certain kind of problems to us also.

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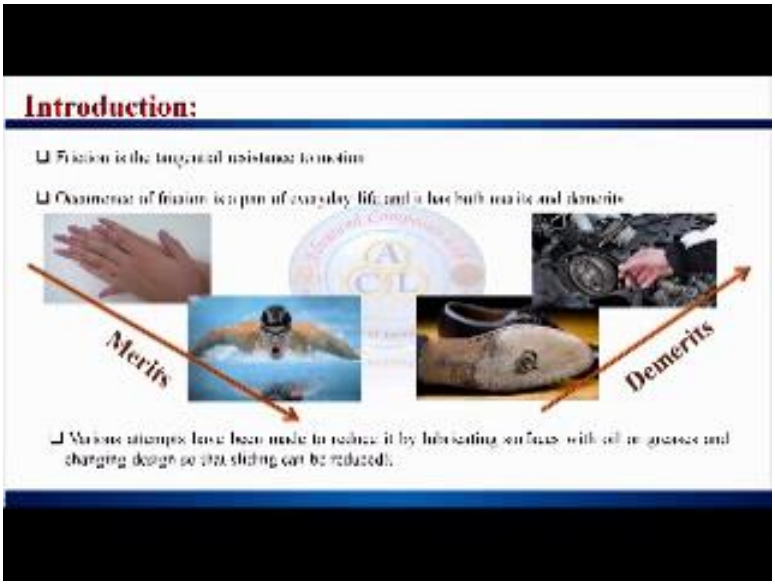

So, from the left hand side figure you can understand if there will not be any frictions in between our body and the water we can swim, not only that there is a another examples that if there is no frictions in between your match sticks and the match box, so it will not ignite and not only that in the winter also, if we rub our hands and there will not be any frictions in between that will not get any temperature to our body.

But simultaneously from the right hand side figure also you can understand that due to the frictions our shoe soles is continuously rubbing on to the road due to that the friction is taking place and our shoe gets wear. Also in the engine parts where we are using

certain kind of belts or may be any kind of gear or pinion, where there is a direct contact in between them it creates certain kind of frictions.

So, friction is having some merits as well as some demerits too. So, various attempts have been made to reduce it by lubricating surface with oil or greases and changing design, so that sliding can be reduced. So, from this particular aspects we can understand that there are a several applications, several types of remedies what we can adopt to reduce the friction. So, now, in the next slide we will start that what is frictions and how it is creating some problem to us.

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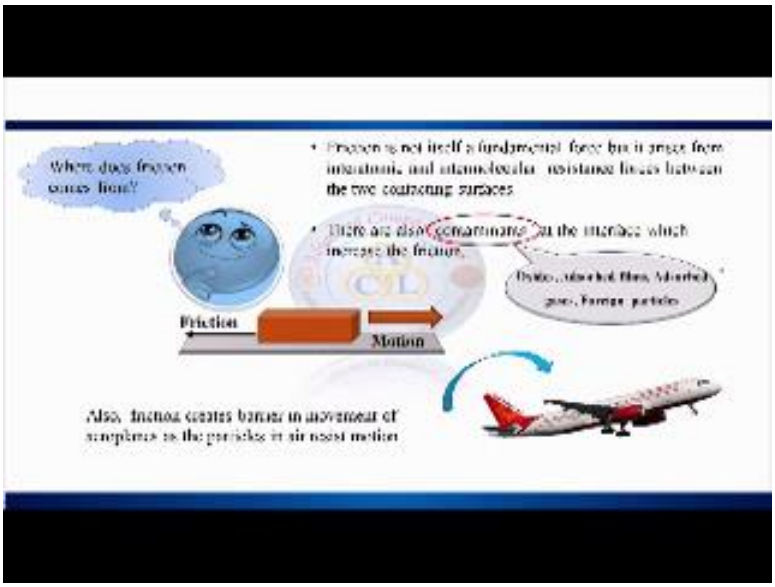

So, friction is not itself a fundamental force, but it arises from inter atomic and inter molecular resistance force between the two contacting surface.

So, suppose as example if I am having these erasers, if I can rub it on to this board and there will of course, a contacting area in between these two. So, due to that rubbing is taking place, but automatically there will be a friction in between these two also. So, from this particular figure we can understand that if a body is moving in to particular directions, the friction force will be generated into the opposite directions to the motions. Not only that sometimes when the space shuttles or may be aero planes or may be helicopters when it is going to the high altitudes. So, what is happening when it is going its outer surface is getting rubbed with the tiny Nano particles or may be a dust particle which is presented to the atmosphere. So, friction is taking place in to that point of view

also; that means, friction creates barrier in movement of aero planes as the particles in air resist the motion.

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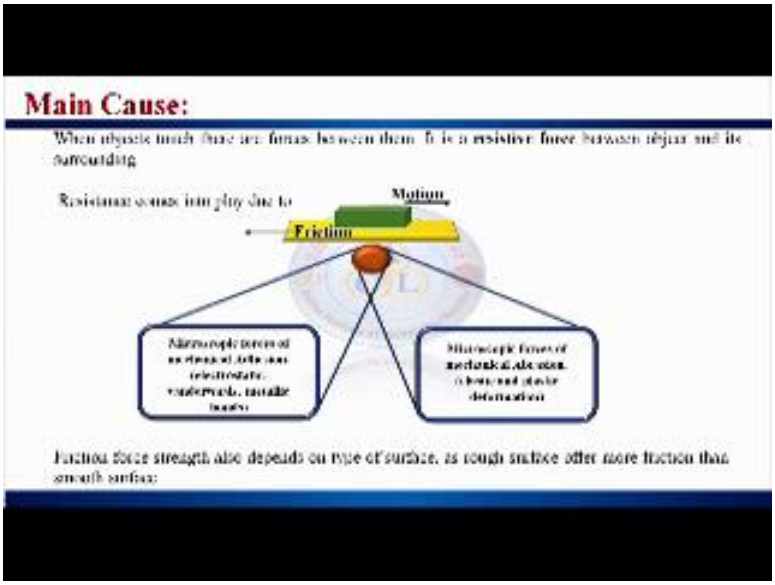

So, what are the main causes that which can creates the frictions? So, first is called the microscopic forces of mechanical adhesions, electrostatic, vanderwaals, metallic bonds and second one is called the microscopic forces of mechanical abrasions like elasting and plastic deformations. So, when a body is in moving in particular directions, the friction force is acting in the opposite directions to its motions; that means friction force strength also depends on type of surface as rough surface offer more frictions than the smooth surface.

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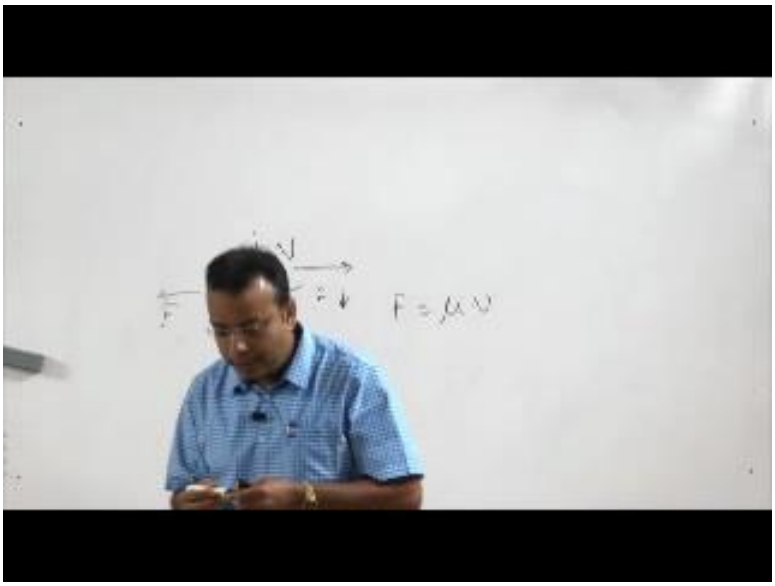

That means that if we are having two bodies and they are touching each other. So, there is a contact points in between these two surfaces and if the contact points will be more so; that means the frictional force will be more. If the contact points will be less or may be the touching surface area of two particular point will be less, automatically the friction force will go down.

In the next slide we will simply discuss about what is frictions. So, frictions is nothing directly dealing with the normal load applying to that particular body, which is known as n and the force generated opposite to the motions. So, suppose we are having two bodies and they are interacting each other than the normal load will acting in this particular point and then this body is trying to go like this.

So, if the motion of the body will be in these directions its frictional force will act in to these directions. So, what is the relation in between that? F is equal to mu into N where mu is nothing, but it is called the coefficient of frictions.

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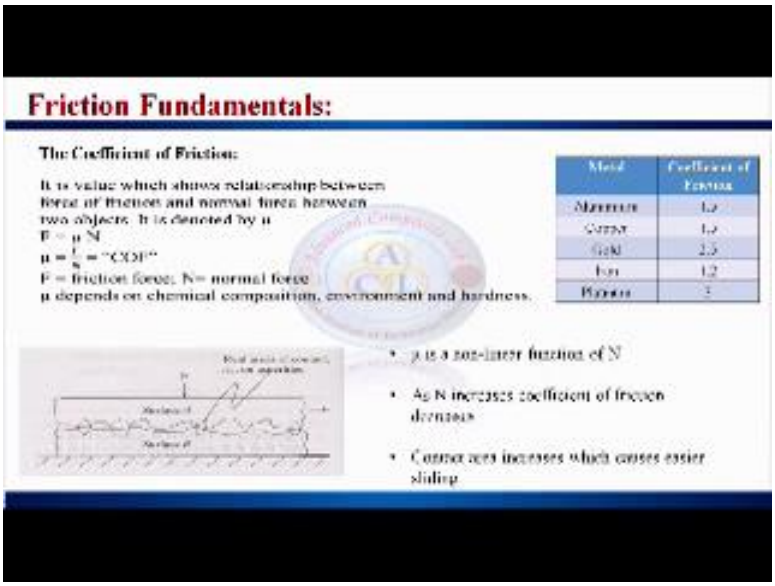

So, from this particular figure you can understand that there are two bodies having two different surface structures, in that particular point some points of that two bodies is touching together, some point is not touching. So, here the mu is directly depends upon the touching area of these two meeting points.

So, mu is a non-linear function of normal load, as normal load increases coefficient of friction will automatically decreases and contact area increases where it cause the easier sliding; that means, the surface area of these two contacting material will be increased. So, automatically it will create more sliding than the previous one.

Now, there is having some materials which can give you different coefficient of frictions. So, from a standard literature review we are found that aluminum is having 1.5, copper 1.5, gold is having 2.5, iron is 1.2, and platinum is 3. So, there are each and every material is having certain coefficient of friction value, depending upon that we can calculate that if we make any product whether it is some Nano sized product or may be macro sized product and if it can be used in our day to day life then how much resistance it can get from the environment itself.

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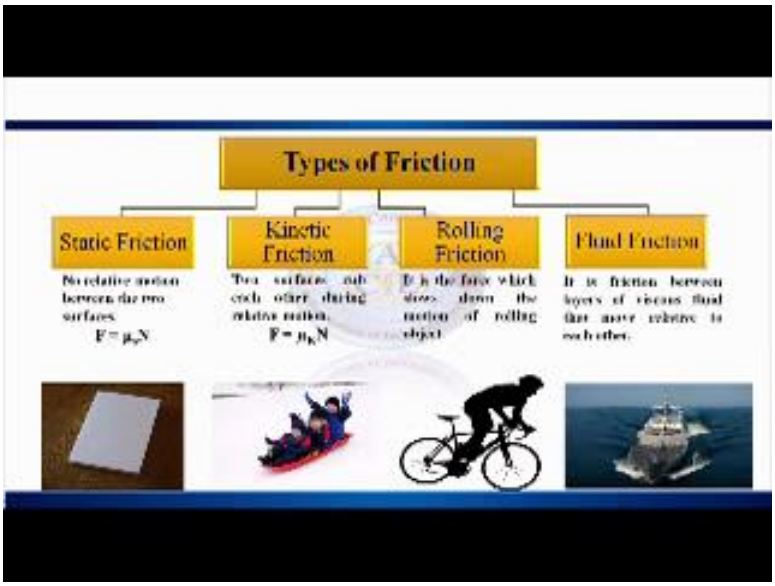

In the slide we can see that there are several types of frictions. So, from the last slide we can conclude that the friction is in generates only in between the meeting parts, whether they can in the stationary motions or maybe they can into the movable motions. So, if the two bodies is in the stationary, they are not in to into moving theta friction is known as the static frictions. So, in the static frictions means suppose I am keeping a book on to a table. So, there is no motion in between these two, but still they will generate certain kind of frictions which is known as the static frictions.

So that means, there is no relative motions in between these two surface, in that particular case the relation will be the normal relations what we have explained earlier that is F equal to mu into N, and not only that here only mu will be known as mu s, which is known as the coefficient of friction in static.

Next the second one is called the kinetic frictions; from the name itself you can understand that kinetic frictions deals with that where that the two bodies in to ice getting devices that or may be that ice getting play stations, which is rubbing on to the ice itself. So, here the motion is in to one directions and the frictional force is acting in to the opposite directions. In this particular case the relation will be F is equal to mu k into N, where mu k is known as the coefficient of friction for kinetic motions. Turbine is called the rolling frictions; in our day to day life everyday when we are coming to office when we are going to school, we are availing the bass, car everything. So, when the car or bass

or any kind of automobiles things it is rolling on to the road. So, through its tire it is generating certain kind of frictions in between the tire and the road surface, that friction is known as the rolling frictions; when the force which slows down the motions of the rolling object.

Last one is nothing, but the fluid frictions. So, a fluid friction means it is the friction which deals with the motions of a particular fluid in to some medium. So, it is the friction between layers of viscous fluid that move relative to each other. Suppose a ship is going through the water or may be in our body when the blood is going through the vessel it is creating certain kind of frictions in between that. So, due to that fluid whatever the friction it is generating it is known as the fluid friction.

Then first we are having a simple example by which we can describe about the static frictions and kinetic frictions of a particular body.

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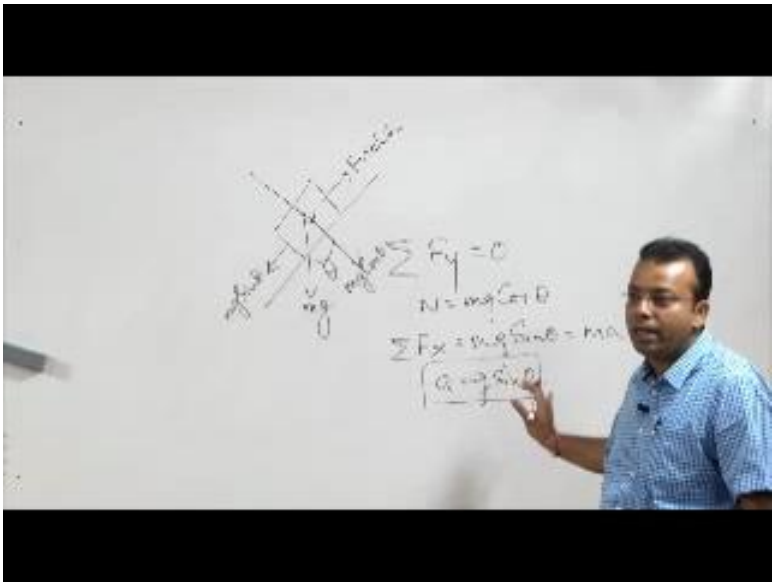

So, suppose I am having a body resting on a surface and its having some mass, the mass is nothing, but the mg. So, I am denoting that mass into mg over there.

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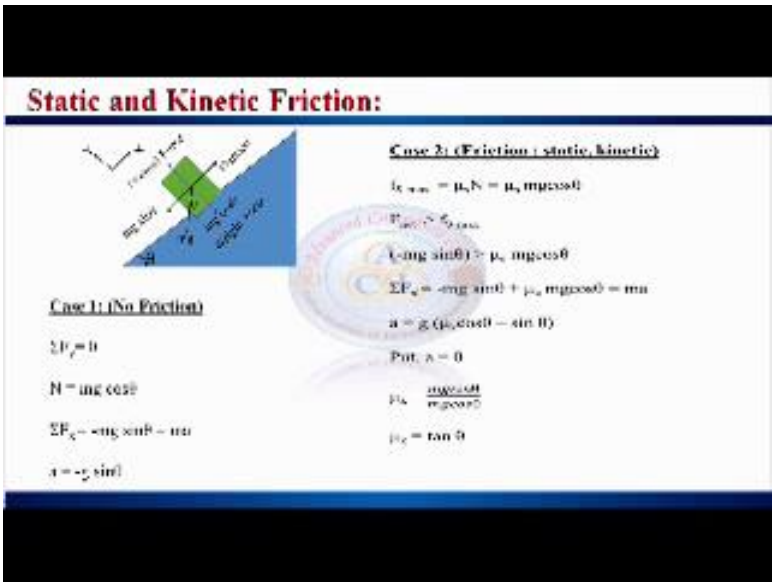

So, when in the first case when I am talking about that there is no friction; no friction means the body is not moving it is in to the static portions right. So, in that particular case what is happening if it is in to the static motions, if it is it can go in this side, automatically the frictional force will act in to the opposite side, but in this particular case the body is not moving at all.

So, if the body is not moving at all its sigma F y. So, frictional force will be totally zero over there because it is into the static conditions and also due to its mass, the mass will act into these directions, which it is relating with the theta angle. So, automatically it will give you mg cos theta right and your mg sin theta will be acting towards its x axis. Now when we are dealing this particular equations from this particular figure we can understand that just simply to normalize these force, that mg cos theta is acting on to the surface of that particular area; then here your end will be mg cos theta which is acting towards this y directions and next as its move function is totally 0 so only this mg sin theta will acts to its x axis, which is nothing but the ma; what is that ma, m is the mass of that particular body and a is the accelerations of that particular body.

So, from calculating this equations we will get the accelerations is g sin theta, but there is one small problem because as these will be in to the opposite directions of that, it should be the negative value, the final equation will be a is equal to minus g sin theta.

Next we will go for the case two applications. In the case two applications from these particular figure we can understand that here we are thinking that body is in motions. So, suppose I am a body, unless and until I will get any pressures, I will be in the rest positions. So, when some pressure will be applied on us, first that force will acting on me. So, I need certain time to get start then only I will try to move. So, automatically there will be two types of friction which takes place which is known as the static frictions and another one will be the kinetic frictions.

So, when we are talking about the static frictions. So, static friction will be simple in will be the mu s into N that nothing but the mu s mg cos theta because N value we are getting from this first equations. Then our total net frictional force will be more than the frictional force in to the static directions, why it is? Because unless and until there will be the force more than the frictional force of my static case, otherwise I will not in to come in to the moving conditions. So, I need extra force just to react above against the environment.

So, from this particular equations we will get that if net is nothing, but the minus mg sin theta, which one we are getting is from this particular equations is nothing, but the mass in to accelerations of that particular body is more than equal to mu s into mg cos theta. So, from these equations we can calculate the value of a accelerations of that particular body is a is equal to g into mu k cos theta minus sin theta. Now if the acceleration will be 0, here we are keeping a is equal to 0; that means, we are keeping the velocity in to the constant, there is no accelerations of that particular body, in that particular case your mu k will be mg sin theta by mg cos theta, if we cancel that mg, mg. So, sin theta by cos theta it will give you the mu k is equal to tan theta. So, from that particular figure you can calculate the frictional coefficient or in to its kinetic motions, which is nothing but the tan theta of that particular figure.

Next one is called the rolling frictions; as I have already explained that when a tire or any movable part is moving on to a surface, it will generate certain kind of frictions. So, that friction is known as the rolling frictions the force that resists the motion when a body rolls on a surface is called the rolling resistance or theta rolling frictions.

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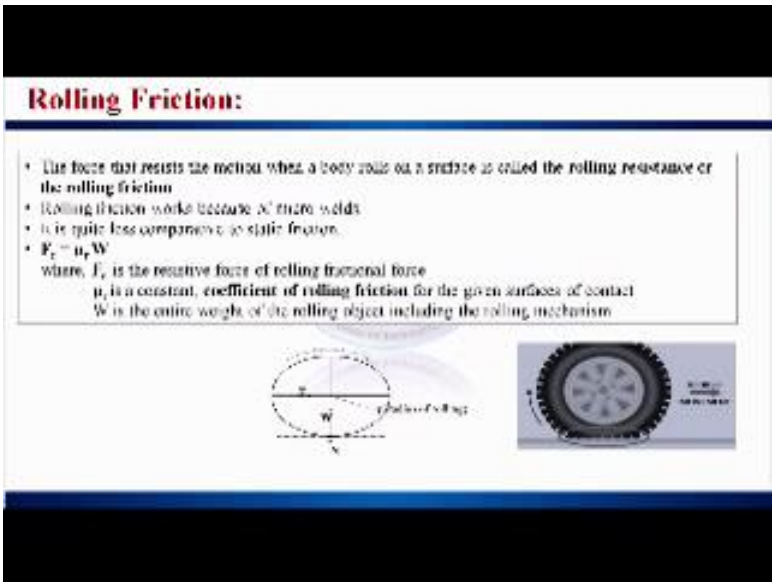

The example of the rolling friction is a tire is moving on to the road or may be any kind of cycle tire or may be car tire or may be automotive tire it is continuously rolling on to the road surface and it is doing rubbing with the road surface and it is creating certain kind of frictions, against the motion or may be the velocity of that particular body.

So, rolling frequency works because of micro welds; it is quite less comparative to the static frictions because static frictions means it is totally depends upon the contact area of two particular bodies. But rolling frictions sometimes one body is into the static motions, another in to the dynamic motions. So, that is why the rolling frictions generally little bit lesser than the static frictions.

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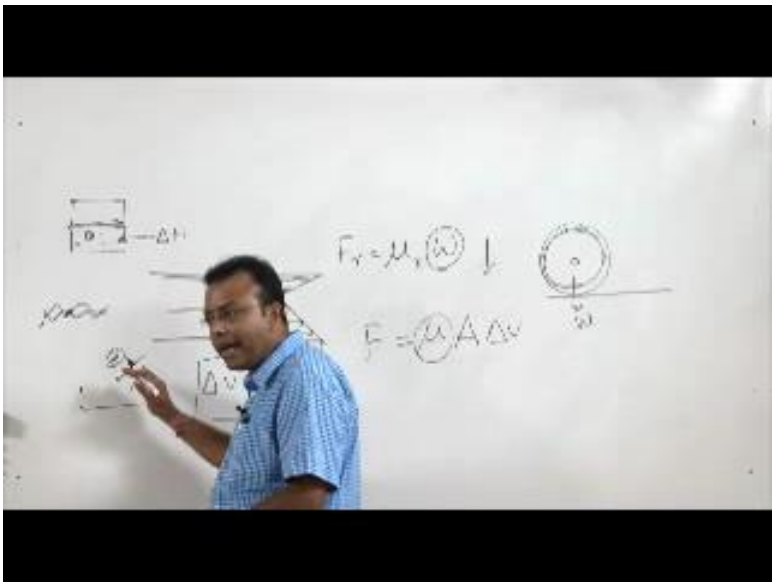

So, the simple equations of that rolling friction is equal to F r is equal to mu r in to W; these W is nothing, but the weight of that particular object or may be the body either it may be tire or may be it may be bicycle tire or may be any kind of globe or any kind of materials which is having circular in shapes not only that we can use these techniques for the ball bearing too because ball bearing also shape is round shapes.

It is having the globular shape, which is having a W, so it is totally depend upon the weight of that particular material. So, from this particular case you can understand the tire is rotating in these directions, vehicle movement is in these directions, automatically the friction will force in to the opposite directions of the motions.

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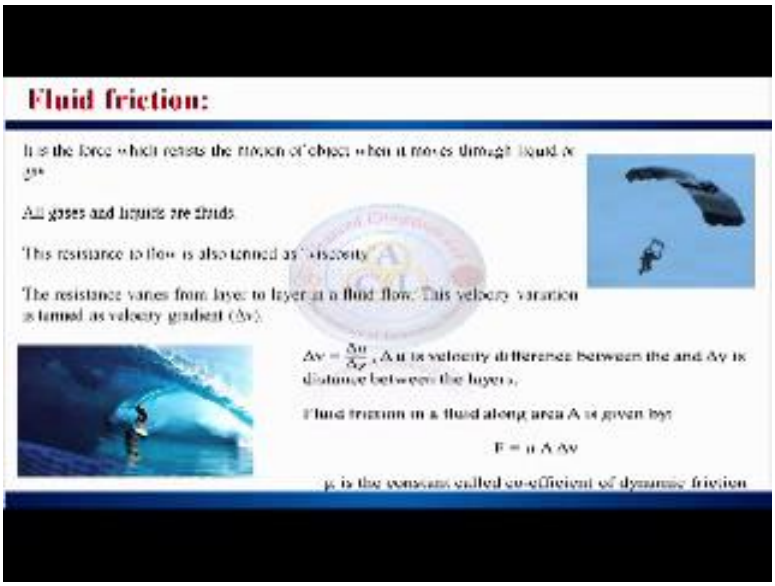

Next if called the fluid frictions; a fluid friction is nothing but as I have already explained that when we are swimming in to the water, so our water is giving some resistance to our body by which we cannot go further or may be in a high velocity, so that friction is known as the fluid frictions. So, fluid frictions means it is the force which resist the motion of object when it moves through liquid or gas, also the best example is that when we are taking certain kind of medicines like tablets or may be capsules through water we are taking it and directly it is going in to our stomachs. So, when it is going through our stomachs. So, through water also it is creating kind of frictions by which the outer surface of the capsules is getting melted and the only medicine is directly going in to our stomach and it can do the remedy to our body.

So, from this we can understand that how the fluid friction is helping to our body. So, all gases are liquids or a fluid this is the normal as we know the resistance to flow is also termed as the viscosity. So, in this particular case whatever the resistance the material is getting while it is going through the fluid is known as the viscosity. So, the resistance varies from layer to layer in a fluid flow, the velocity variations is terms as the velocity gradients. So, suppose we are having some pipes and if through that pipe the water is going in a particular velocity. So, if we see that the velocity of that particular will be higher at the adjacent layer of the pipe itself and if the velocity of that particular water at the middle of pipe will almost became zero, then again it will increase up to the outer most layers.

So, the velocity will be like this here like this way. So, the velocity will be varies in such a manner. So, in this particular case when you are calculating the velocity gradient Del v. Del v is nothing, but the Del u by Del y. So, Del u will be the velocity difference in between the first layer and second layer and Del y will be the distancing between the first layer and second layer. So, from this particular case we can calculate the del v is equal to del u by del y, and whatever the friction is generating over here, the friction generating at the fluid will be F is equal to mu into a mu into A; A is the area at that particular point into del v. So, this mu will be the coefficient due to the fluid.

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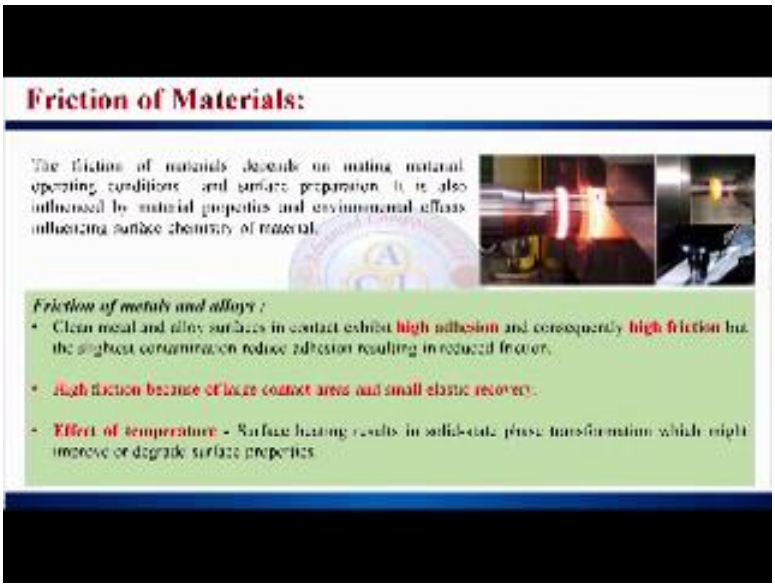

Next we are talking about the friction of materials. So, as I have told in our first slide and in the subsequent slide also that friction can occur to any material, whatever the material we are using in our day today life. So, the friction of material depends on material operating conditions and surface preparations. It is also influenced by material properties and environmental effects influencing surface chemistry of material.

So, the thing is that from this particular line we can understand that unless and until the two materials will not come in to the contact there will not be any friction. So, friction of metal and alloys clean metal and alloy surface in contact exhibit high adhesions and consequently high frictions, but the slightest contamination reduce adhesion resulting in reducing frictions. That means, if I am having two bodies and if the two bodies is touching each other means the contact area in between these two bodies is higher, then it

is very difficult to detach these two bodies; that means, frictional force is more in this particular case and if in between these surface, if I put certain kind of fillers which is into the very small size or maybe I can put certain kind of dust particles over there or maybe any kind of lubricants. So, the automatically the sliding in between these two will be increased. So, automatically the friction force will be reduced.

Then second one is call the high friction because of large contact areas and small elastic recovery; the third is that effect of temperature because effect of temperature also creates a big role for any kind of frictions because the surface heating results in solid state phase transformations, which might improve or degrade the surface properties. So, when we are preparing certain materials and we are adding certain kind of fillers into it. So, when we are giving a particular heat to that this material, maybe this particle will be activated, due to that activations maybe this outer surface may get lubricated, due to that maybe friction can be decreased or maybe sometimes it can be opposite also that the resistance in between these two can be increased so that the friction will be more.

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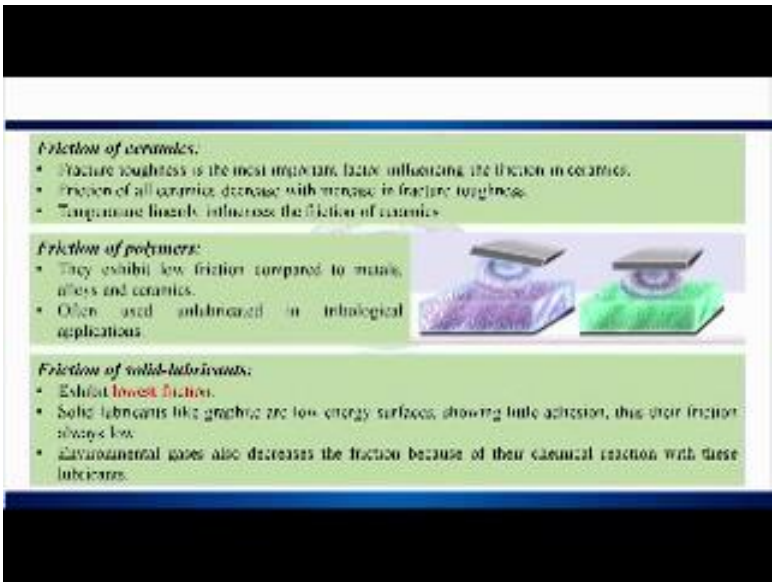

Then the example for friction of ceramics what does it means? Fracture toughness is the most important factor influencing the friction in ceramics; friction of all ceramics decrease with increase in fracture toughness, temperature linearly influences the friction of ceramics. So, any kind of ceramic materials when we are dealing this kind of materials for the high temperature applications because as we know that ceramics has the ability to

withstand high temperature; in this particular case the fracture toughness is the main factor for any ceramics materials.

Then friction of polymers they exhibit low friction compared to metals, alloy and ceramics only used unlubricated in tribological applications because polymer is having certain kind of lubricating type of nature, by which it can generates the less resistance in between them, so that its friction is little bit lesser in compare to ceramics and the metal surfaces.

And the last one is call the friction of solid lubricants exhibit lowest frictions because you are using here certain material, which itself acts as a lubrications. So, for this particular reasons they are creating some kind of lubricating material in between the melting surface, thus low lowers the here frictional force at that particular juncture. So, solid lubricants like graphite are low energy surface showing little adhesions thus their frictions always low.

Environmental gases also decrease the friction because of their chemical reactions with these lubricants. So, generally when we are talking about any kind of Nanomaterials, any kind of Nanofillers, generally we prefer to use any kind of carbonaceous materials because carbonaceous material having less frictions. So, it will generate less friction, less temperature for that particular material, so that that material can use for longer time.

Then the next slide will see that how we can control the friction in between the melting bodies. So, as already I have told you that by using any kind of lubricant, by using any kind of grease we can reduce the friction in between the melting bodies.

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So, controlling frictions in an important parameter for smooth function of machines and improving their life; various methods can be used for this, number one is that add lubricant for smooth functioning you can use certain kind of lubricants, so that it can lubricate or maybe make it slippery in between the melting surface. Replace rolling with sliding, since rolling fiction is low as I have already explained that rolling friction is much lower than the static friction. Smooth the surface as rough surface provide more frictions, from the particular first image if you can remember that I have shown that if our surface is not so smooth. So, there will be a chance of that contacting area which can create some kind of interlocking in between them so that automatically the friction force will be more (Refer Time: 25:05).

Fourth one will be the put ball bearings in wheel. So, that it will create certain kind of rolling frictions instead of making any kind of static frictions, use of Nanofillers to control the frictions, that is why generally we are using certain kind of carbonaceous fillers like carbon Nano tubes, graphite, grapheme then fullerene, then carbon dots, so that it can reduce the friction force in between the materials.

Then next slide we will see that for losing the friction, why we are doing the surface engineering right. So, just to reduce the friction we are doing the surface engineering; by means of any kind of coatings or maybe by adding any kind of Nanofillers to a particular

materials or maybe the material itself is acting as a self lubrication or may be self lubricating.

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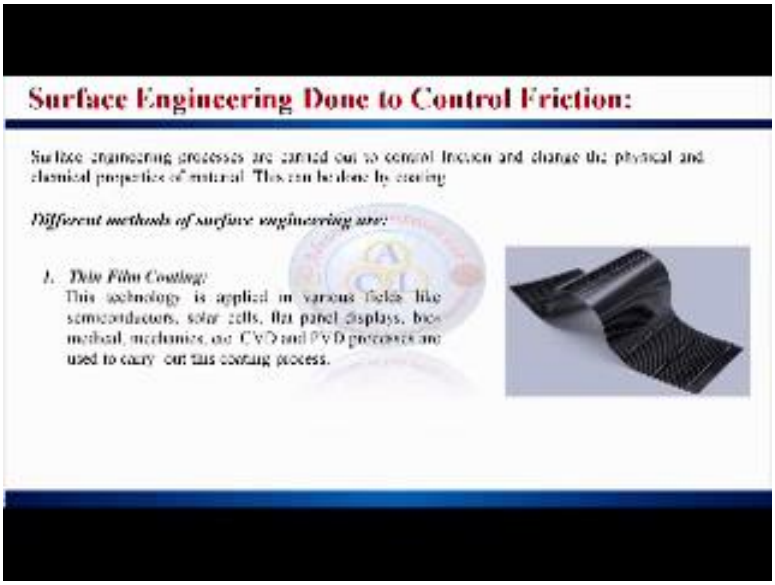

So, surface engineering processes are carried out to control frictions and change the physical and chemical properties of material this can be done by coating.

So, first one is known as the coating, what are the coatings? Thin film coating; generally we are making certain kind of materials on top of that we are doing certain kind of coatings or maybe using certain kind of materials, which is reducing the friction itself. How we are doing? Generally we are doing it by the CVD chemical vapour deposition method, PVD physical vapour deposition method by (Refer Time: 26:32) technique. So, there are several types of process by which we can do the coating on different materials like semiconductors, solar cells, flat panel displays, biomedical machines, so any kind of things we can do it.

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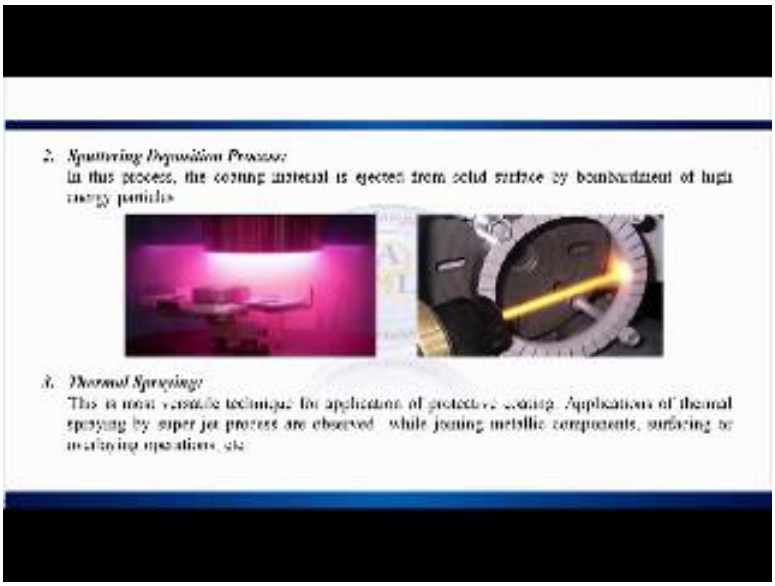

Next is called the sputtering deposition process: in this process the coating material is ejected from solid surface by bombardment of high energy particles. So, we are having any solid particles over there, now we are doing the bombardment of electron on that particular material, so that this material will getting into the vapour conditions and then that vapour will deposit on to some materials. So, that it will do the coating of that particular material.

Last one is call the thermal spraying; thermal spraying is nothing but the we are having some material, we are heating that material that material is coming into the liquid formations, then like painting we are allowing those material to fall on a particular body, so give a coating, this is known as the thermal spraying; this is most versatile technique for application of protective coating, application of thermal spraying by super jet process are observed while joining metallic components, surfacing or overlying operations.

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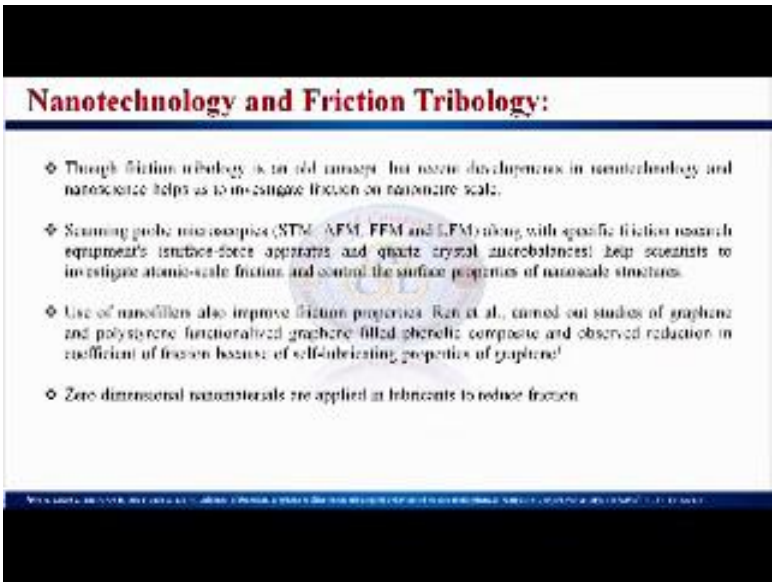

Now, we will discuss about the Nano technology and the friction Tribology, what are those? So, nanotechnology is nothing as I already discussed is the dealing of the materials or maybe the particles which are into the nanoscale. Now as I already told that when this particles we are using in our day to day life product or maybe in our day to day life, automatically these particles also getting come into contact with each other and they are creating certain kind of frictions; to avoid those frictions whatever the technology we are adopting that is known as the nanotechnology against frictions or maybe the friction Tribology.

Though friction Tribology is an old concept, but recent developments in nanotechnology and Nanoscience helps us to investigate friction on nanometer scale. There are several techniques by which we can measure; we can detect the frictional Tribology onto the Nanomaterials. Those are like STM, atomic force microscopy, then FFM, LFM along with specific friction research equipments, surface force apparatus like quartz, crystal microbalance, which has scientist on investigate to measure that there is any kind of frictions on to the Nanomaterials or how to control their properties. Use of Nanofillers also improve friction properties like Ren at al., carried out studies of graphene and polystyrene functionalized graphene filled phenolic composite and observed reduction in coefficient of friction because of self lubricating properties of graphene.

As I already explained that the carbonaceous materials is having that capability that it can acts as a self lubricating material. So, that is why nowadays the researcher the scientist are trying to use this kind of Nanofillers for making any kind of products so that there will be a friction less product and its life and other properties like mechanical properties, chemical properties, will also be increased. Last one is call the zero dimensional Nanomaterials are applied in lubricants to reduce frictions, any kind of carbon blacks maybe carbon dots; we are using to reduce the frictional properties.

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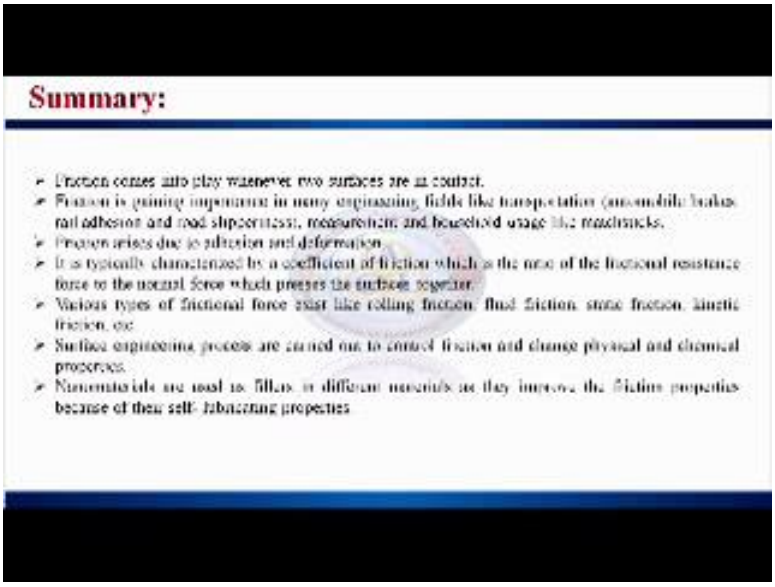

So, in summary we can say that friction comes into play whenever two surface are in contact; friction is gaining importance in many engineering like transportations, automobile brakes, rail adhesions, road slipperiness, measurement and household usage like matchsticks, friction arises due to adhesions and deformations; unless and until two body will come into the contact there will stick together, there will not be any friction. So, automatically there will be a resistance in between the two bodies then only the friction force will be generated.

It is typically characterized by a coefficient of friction which is the ratio of the frictional resistance force to the normal force, which presses the surface together. Various types of frictional force exist like rolling friction, fluid friction, static friction, kinetic friction etcetera already I have explained in our earlier slide. Surface engineering processes are carried out to control frictions and change physical and chemical properties in our

subsequent slide or maybe in depth. In our next topic we will discuss that how surface engineering is effecting the frictions, how it is helping to reduce the frictions so that material properties can be increased.

And the last one is the Nanomaterials are used as fillers in different materials at the improve the friction properties because of their self lubricating properties; not only that that Nanofillers is only increasing its frictional properties, also it is increasing its mechanical properties, electrical properties, thermo chemical properties, any properties. So, now a day's Nanofillers is playing a very vital role for doing any kind of surface engineering, to reduce its frictional resistance and also to increase the mechanical and other properties too.

Thank you.