Surface Engineering of Nanomaterials
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Lecture – 01
Tribology and Its Classification

Hello. Today I am going to start our first lecture on Surface Engineering of Nanomaterials. The first lecture deals with the Tribology and Its Applications. So, first let us know that; what is the meaning of the tribology?

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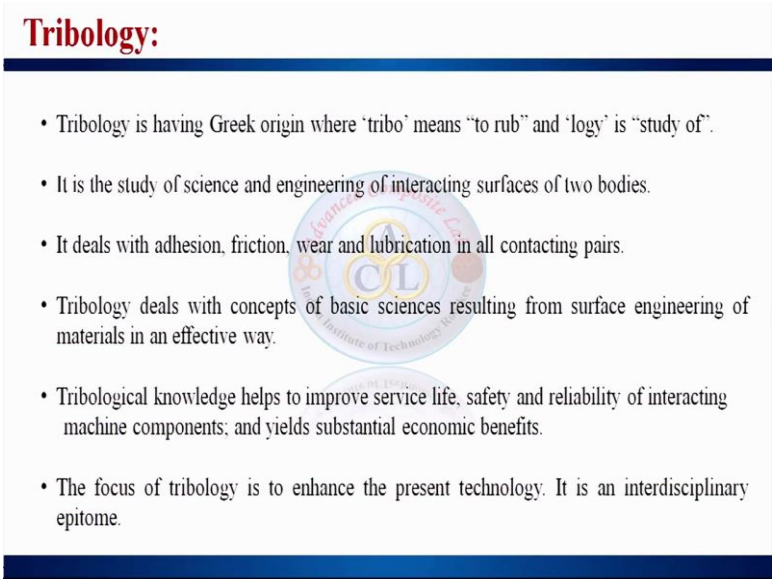

The tribology actually it is the Greek word of conjunction of two words differently; one is called the 'tribo' another one is called the 'logy'. The 'tribo' means "to rub" and the 'logy' is the "technology". So in overall functions it shows that, where there is a contact of two bodies and there will be a distinct patch in between the two bodies then only the tribology will occur.

Now, it is the study of science and engineering interacting the surface of the two bodies. That means, unless and until the two body will come in to the contact there will not be any tribology or any kind of mechanisms will take place. It deals with the adhesions, friction, wear, and lubricating of all the contacting parts. That means, if unless and until the body will directly touch each other or maybe there will be some lubrication or maybe there will be some greasiness, there will be some any kind of oil or may be any kind of

mediums are there; so if there is any direct contact or indirect contact in between the day, so tribology can occur.

So, tribology deals with the concepts of basic science resulting from surface engineering of materials in an effective way. In other way we can say that tribology is the prime factor by which nowadays we are going to do the surface engineering of any materials. So, tribology is the cause and the surface engineering is the remedy. Now tribological knowledge helps to improve service life, safety, reliability of interacting machine components, and yields substantial economic benefits. That means, the tribology the chapter if we deal it properly so what it will do, it will give you the better life of our materials, it will give you the better properties of our materials, it will give you the better surface life of our materials so that we can use that materials for a proper way and for longer time.

The focus of tribology is to enhance the present technology. It is an interdisciplinary epitome. That means, the tribology its itself is subject which is interdisciplinary one in between so many things; friction, wear, or may be the surface, or may be the properties of all the bodies.

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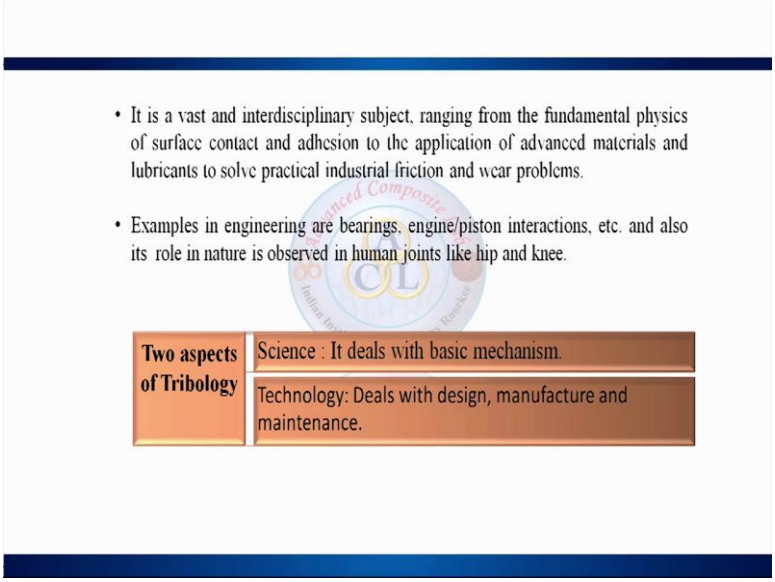

Also it is a vast and interdisciplinary subject, ranging from fundamental physics of surface contact and adhesions to the applications of advanced materials and lubricants to solve practical industrial friction and wear problems. So, now onwards we can

understand that tribology is a part which is a big factor when we are losing our material properties as well as our material properties are decreasing its all the physical as well as the chemical properties by which the logic behind is that friction and wear.

Examples in engineering's are bearings, engine pistons, interactions etcetera and also in role in nature is observed in human joints like hip and knee. They are numerous cyclic examples which deals with the tribology. So tribology is where; as I have already told that tribology is nothing the friction or may be wear or may be the interactions in between the two bodies. So there are several applications in our human body, we are having the knees or sorry, elbow joints then knee joints then hip joints so where all the bones are contacting each other, so in between that also there is creating some kind of frictions. And by body fluid or giving some kind of a other fluids we are making it more suitable slippery kind of things so that the friction wear and wear can decrease.

So, there are two aspects of tribology: first one is called the science, which deals with the basic mechanisms of the tribology itself and the second is called the technology which deals with the design, manufacture, and maintenance.

Next slide just we will first discuss that; what is the benefits of the tribology. So, the benefits of the tribology that means, that why you were doing the tribology, why we are reading or may be starting the tribology, what benefit will get from the tribology science.

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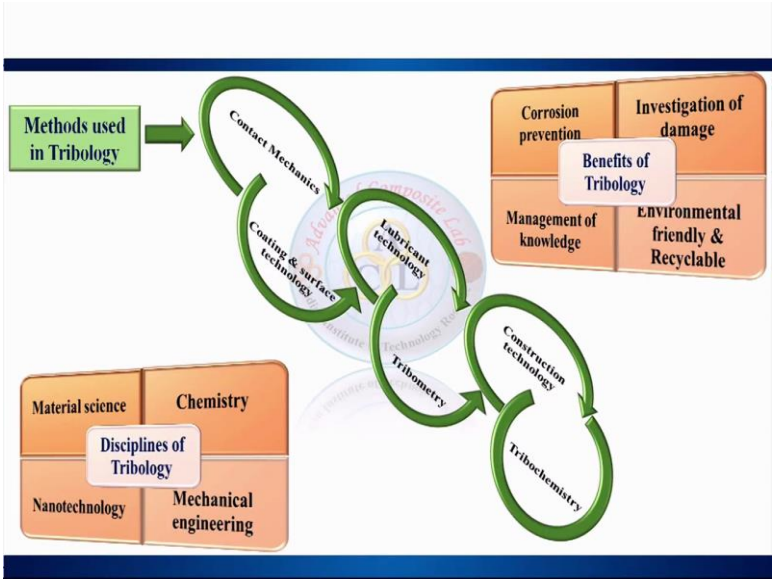

So, first is called the corrosion preventions. So we can do some kind of coatings or maybe we can add some kind of materials to the base materials so that it will be corrosive proof, so that we can keep that material longer time in to the environment set, so that there will not be any interactions in between the materials and the environment like moisture or may be humidity something like that.

Second is that investigation of the damage. Why this cuts contaminations or the material properties is going to be decrease and decrease all these things. Third is that management of the knowledge, so we can gather the knowledge about our materials. And then last one is called the environmental friendly and the recycle one. So, the material will be environmental friendly, it will be less hazard so that that material can be used for a longer time. Not only that after finishing the life of that particular material again we can modify that material and we can use for other applications also.

Second is that; what is the methods used in tribology. First one is called the contact mechanics, so all this whatever the methods has been written over here will come together in the subsequent slides. First one is called the contact mechanics, then is called the lubricant technology, then it is called the construction technology, then coating and surface technology, then tribometry and tribochemistry; all this six aspects is deals with the different methods whatever we are using in tribology.

Then, what is the disciplines of tribology? That means which branches, as I already said that tribology is nothing but the interdisciplinary subject. So, all these main branches like materials science, chemistry, nanotechnology mechanical engineering both branches are doing the tribology or rather they are doing the research on tribology. But, here a very few names has been written, others branches like civil or biotechnology each and every where we can see the tribology they are doing the research on tribology or maybe they are doing the work on tribology.

So, first before going to start that what is the concept behind the tribology first let us know that who has invented this tribology logic first, who has given us the first these fundamental things.

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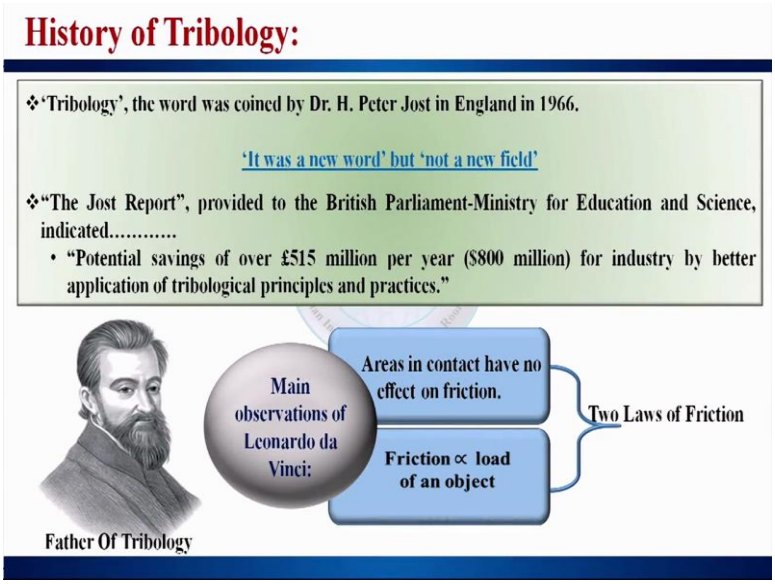

As I have already told that tribology is a Greek word so it means that it was a new word but not a new field, it has been defined by Dr. H. Peter Jost in England in the year 1966. That means, that word is coming for a long time in our history, but we have started doing the tribology or maybe we are started studying the tribology in very recent years; just to modify our samples, just to give the more life to our samples.

Next "The Jost Report", provided to the British Parliament-Ministry for Educations and Science, indicated that "potential savings of over 515 million pound per year for industry by better application of tribological principles and practices". Then there is a here you can see the figure of the famous painter, because we know he is a famous painter- his name is Leonardo da Vinci, but simultaneously he was a very good scientist too. So he has given the fast two laws of friction which is very important which is related to the tribology. So that is why nowadays we are calling it as a Father of Tribology too.

So, one is called the areas in contact have no effect on frictions and the second one is friction directly proportional to the load of an object; so from these laws totally the tribology science deals.

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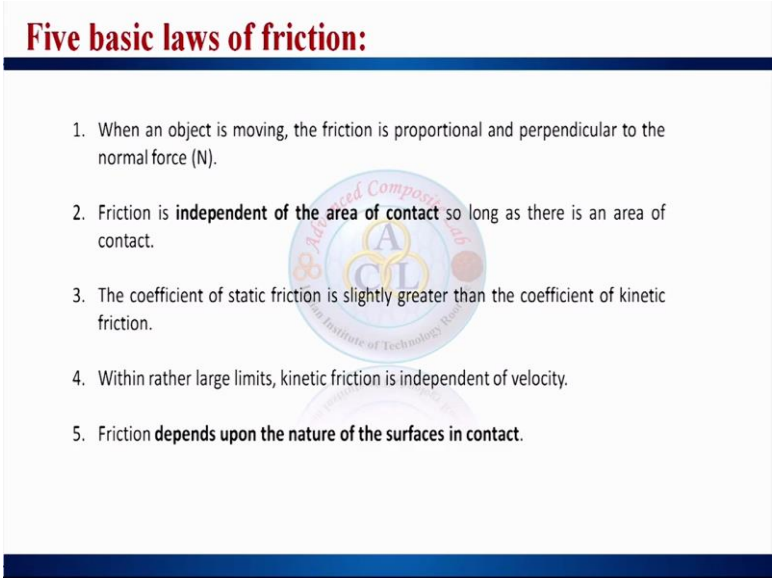

So, there are five basic laws of frictions, what are those. Number one laws state that, when an object is moving the friction is proportional and perpendicular to the normal force. This is the basic fundamental of any tribological aspects. Then second one is that, friction is independent of the area of contact so long as there is an area of contacts. So, this is known as the second law of tribology. Then third one is known as the coefficient of static friction is slightly greater than the coefficient of kinetic friction. And forth one is called the, with rather large limits kinetic friction is independent of velocity. And fifth is known as friction depends upon the nature of the surface in contact.

So, in the next subsequent slide when we will go in to the deeper in to the tribology we will discuss about all the five basic laws of tribology. Then, we have to know what is the realistic importance of the tribology because why we are doing the tribology what is the basic needs, what is the background of doing the tribology. So first two is that, because these all are the examples that why we are going to do the tribology in today's era.

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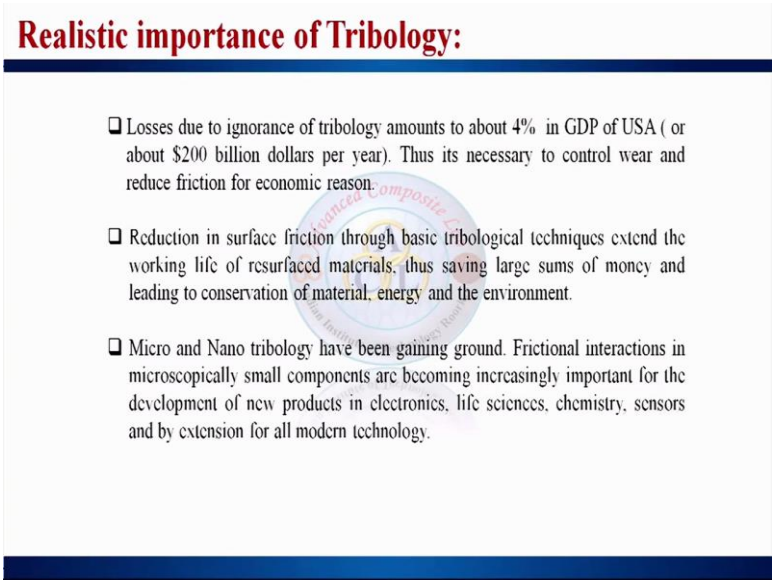

So, first is called the losses due to the ignorance of tribology amounts to about 4 percent in GDP of USA- or about 200 dollar billion dollars per year. Thus it is necessary to control wear and reduce friction for economic reason. So, from this particular figure you can understand that one countries GDP is totally depending upon the loss and wear of particular materials. So, if we improve those material properties, if we though improve those materials characteristics so that we can minimize these losses.

Reduction in surface friction through basic tribological techniques extend the working life of resurfaced materials, thus saving large sums of money and leading to conservation of material energy and the environment. The meaning of this sentence is that whatever the materials nowadays we are preparing, so after using certain time either its properties is going to be decreased or maybe it is changing its characteristics. So, by doing the tribology studies or by doing the surface engineering studies what do it can do, we can do the modification of the surface of that particular material so that it can be reused further.

So what will happen? It will reduce the total operating cost of that particular material simultaneously it will reduce the maintenance cost of that particular material too. How, because if I will reject this particular material and I will make that new material so the cost will be almost double, rather just to modify the outer surface or do the repairing by this science or may be by this technology so that we can set the money.

Third one is called the Micro and Nano tribology have been gaining ground. Frictional interactions in microscopically small components are becoming increasingly important for the development of new products in electronics, life science, chemistry, sensors or by extension of all modern technology. That means, nowadays we are making our devices smaller and smaller, so it is going in to the small size, it is more complex than before.

So, if we see the previously whatever the aerospace shuttle or may be the computer hard disk or may be the mobile or may be any kind of electronic gadgets whatever we are using that was in the bigger in size and heavier in weight, but nowadays whatever the mobiles or may be computers or may be laptops I pads whatever may be we are using all the electronic gadgets are becoming smaller and smaller. That means, we are making it simpler, we are making it more complicated a chip type of things so that its size will be reduced, its weight will be in the less, but its function will be the more.

So, by doing this what we are doing, we are making the whole design in to a smaller box or may be in a smaller way. So, automatically there will be a contact in between the devices, there will be a contact in between the instruments or may be the chips. So, when there will be a contact in between the chips or may be the devices so automatically the fictional force or the where generation will be taking place.

Now in the next slide will see; what is the fundamental aspect of tribology.

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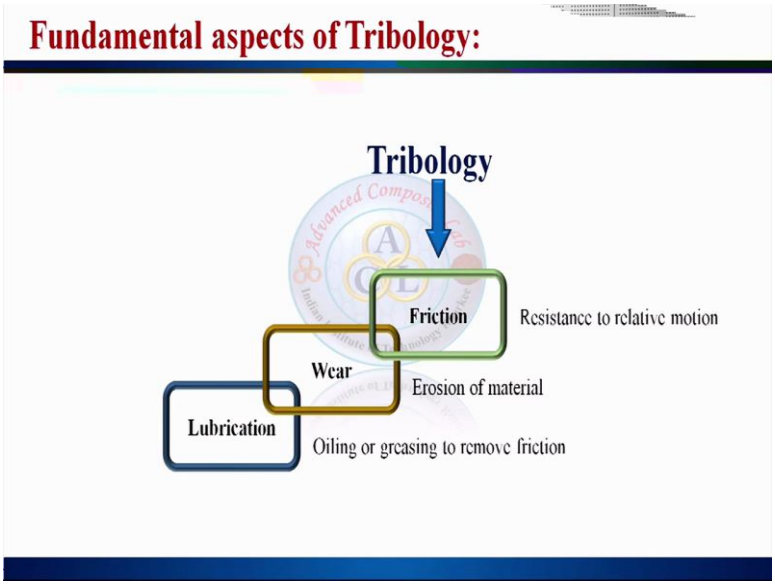

So, if we divided the fundamental aspects of tribology in three ways. So, generally first one is called the frictions, which is nothing but the resistance to the relative motions. If I give a load to a particular body si what it will do, it will try to resist its motions right. So, when it will try to resist its motion then automatically the frictional force will be generated.

Second one is called the wear. Wear is nothing but due to the frictions, whatever the material loss will be taking place. And third one is called the lubrications. Lubrication is nothing, but the reducing of the friction. So that by using the lubrications like any oil or maybe grease or maybe any kind of slipper in mutual as well as slipper in materials we can put it in between the contact surface of these two meeting parts so that is the automatically the lubrication it will be lubricated and the frictional force will be going down.

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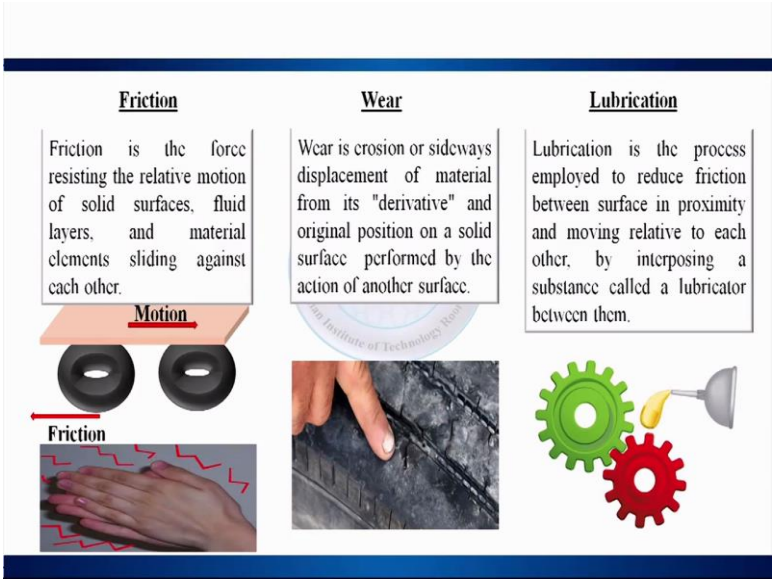

First we have to know, what is the friction? Friction is the force resisting the relative motions of solid surface fluid layers and material elements sliding against each other. As I already told earlier that if there will be a contact in between the two surface and the two surface is having some motions opposite to each other it may be one surface in to the static another surface will be the in to dynamic or may be both will be in the dynamic or may be both will be in the static also; each and every time the friction will be taking place, but the amount of friction will be different for each cases.

So, from this particular figure you can understand that if we rub our hand, so automatically it will resist each other so that it will be heated up. The best example is that in winter conditions when our hand is getting cold so that we are rubbing our hands to generate certain kind of heat, so that we can save our body temperature.

Second one is called the Wear. As I already told that wear is nothing but it is a result due to the friction. So, when there will be some friction, automatically there will be some heat will be generated and the material loss will be taking places. The material loss is will be occur in terms of wear. So, wear is the erosions or sideways displacement of material from its derivative and original positions on a solid surface performed by the action of another surface.

And the third one is called the Lubrications. As I already told that we are using certain kind of greasy materials oil or may be certain kind of other materials to make the slippery in between the mating parts so that there will be a less contact in between the parts so that friction generation will be less.

Then, what are the applications? Applications are numerous, if we think that the because it is very difficult to count nowadays because in that advanced technology it is very difficult to count that how much is the applications for any tribological aspects.

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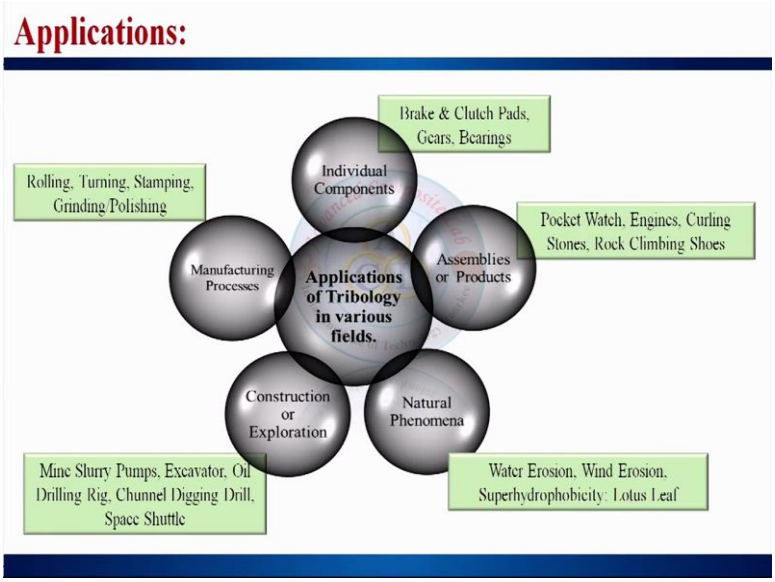

So, first one is called the manufacturing process. So, manufacturing process is deals with the rolling, turning, stamping, grinding, polishing. There are n numbers of applications which we are facing day to day life. Then individual components like brake, clutch, pads, gear, bearing where the tribolgy or may be the friction is taking place. Assembles of products pocket watch, engines, curling, stones, rock, climbing shoes; so each and everywhere, not only that when we are putting our hands inside the pockets also it is also creating some kind of frictions and the tribological aspect is going on.

Then the natural phenomenon; water erosions, wind erosions, superhydrophobicity, lotus leaf; so when the on the lotus leaf also the water droplet is coming it is also creating some kind of friction over there. So, each and every case not only that when the rain is coming and the raining is dropping on to our vehicles or may be on our bodies also there is certain kind of frictions is taking place, though the value is very very less or may be the negligible, but still there is certain kind of frictions is taking place.

Then constructions of explosions; mine, slurry, pumps, excavator, oil, drilling rig, channel digging drill, space shuttle. So, these all are the different kinds of aspects where we can generally face the tribology.

So, next is called what are the new areas about the tribologies.

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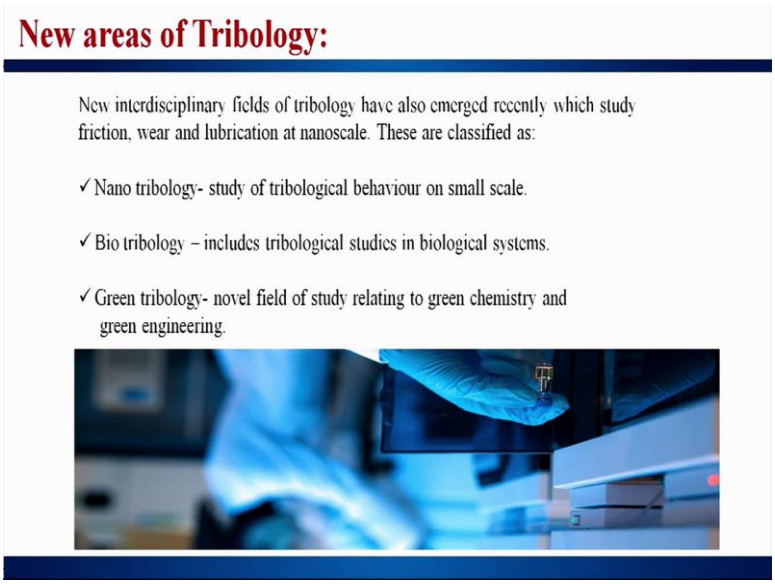

So, first one is called the new interdisciplinary fields of tribology have also emerged recently which study friction wear and lubrications at nanoscale. Nowadays we are talking about the nano, nanotechnology or may be nanoscience is a science which deals with the particles which are in to the nano meter range. Till now we are discussing about the macros, so now you are coming to the nano.

Actually, if we see that nano materials though it is very very small we cannot see it by the naked eye also, but when they will interacting each other there is also generating certain kind of frictions in between the them, they are also creating some kind of tribological aspects in between them. So, first one is called the nano tribology which is a study of tribological behaviour on small scale or may be the nano scale. Bio tribology- includes tribolgical studies in biological systems; green tribology- novel field of study relating to green chemistry and green engineering.

So, from these we can understand the tribology is basically divided in to three parts. First is called the nano tribology, second one is called the bio tribology, the third one is called the green tribology or may be the green chemistry.

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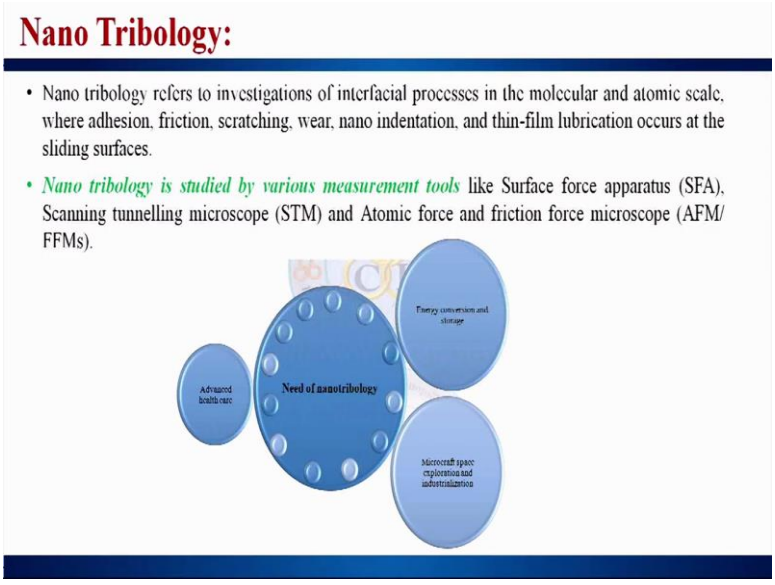

First let us discuss, what is nano tribology? So, nano tribology refers to investigations of interfacial process in the molecular and atomic scale, where adhesion, friction, scratching, wear, nano indentation, and thin-film lubrications occurs at the sliding surface. As I already discussed that nano tribology is deals with the particle size having a

very small dimensions. So, when the small size particle will interact each other that is known as the nano scale tribology.

So, nano tribology is studied by various measurement tools like surface force apparatus, scanning tunneling microscope, and atomic force microscopy, friction force microscopy; so these all are the devices which can detect, which can investigate, which can measure the tribology in to the nano scale level. Here, why we need the need of nano tribology, because nano tribology dealt with three different aspects; one is called the advance health care, second is called the energy conversions and storage, third one is called the micro craft space explosions and industrializations.

So, when we are talking about the advanced health care; as we know nowadays we are dealing with the targeted drug delivery so we are putting certain kind of nano particles through some tablets or may be some kind of capsules then we are swelling it, and then it is directly going to the effected part of our body. And directly it can react with the effected part and it can recover that particular part. So, when that nano particles is going through our body it is dealing with some kind of tribological aspects inside our body itself, with the fluid like blood or maybe any kind of body fluid.

Then second one is called the energy conversion and storage. Nowadays we are talking about the super capacitor lithium and batteries, solar cell, where we are using several types of nano fillers; we are incorporating the nano fillers, not only that we are using it for the sensors, actuators, space, shuttles, everywhere any kind of electronic device. So, when we are injecting any kind of nano fillers we are mixing the nano fillers with the matrix then it is going in to the materials, and then again it is rubbing each other or maybe it is trying to interact each other so by which the tribology aspect or may be the tribology properties can enhance.

Third one is called micro crafts space explorations and industrializations. For the latest purpose suppose any kind of vehicles or may be any kind of shuttle space shuttle where we are using certain kind of nano particles then when it is going to the space then while coming back it is abrading with the year, so that it can create certain kind of tribological aspects.

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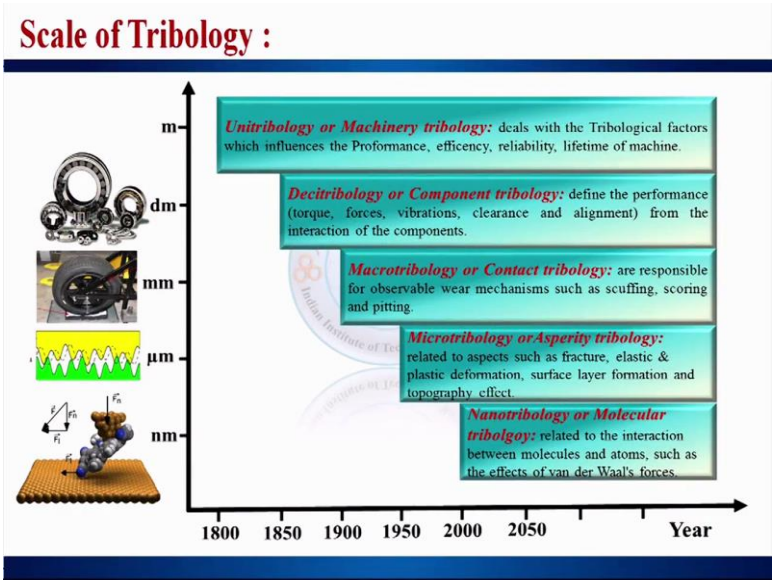

Then, next one is the scale of tribology. So, we can divide this all this nano tribology in to different scales. First one is called the in the meter range whatever we are doing that is known as the Unitribology or Machinery tribology: deals with the tribological factors which influence the performance, efficiency, reliability, lifetime of machines. When we are coming to the decimeters, so Decitribology or Component tribology define the performance, torque, forces, vibrations, clearance and alignment from the interaction of the components.

And then when you are talking about the milli tribology to a macrotribology rather we can say it or contact tribology are responsible for observable wear mechanisms such as scuffing, scoring, and pitting. Then we are talking about the microtribology. So, Microtribology or Aspertry tribology is related to aspects such as fracture, elastic, and plastic deformations, surface layer formations, and topography effect. And then last the nano tribology is coming. So, Nano tribology or Molecular tribology related to the interactions between molecules and atoms such as the effects due to the Van der Waal's force interacting in between the molecules.

Then second one is called the Bio tribology. So, bio tribology is nothing but the tribology which depends upon or may be which can create by any kind of biological materials.

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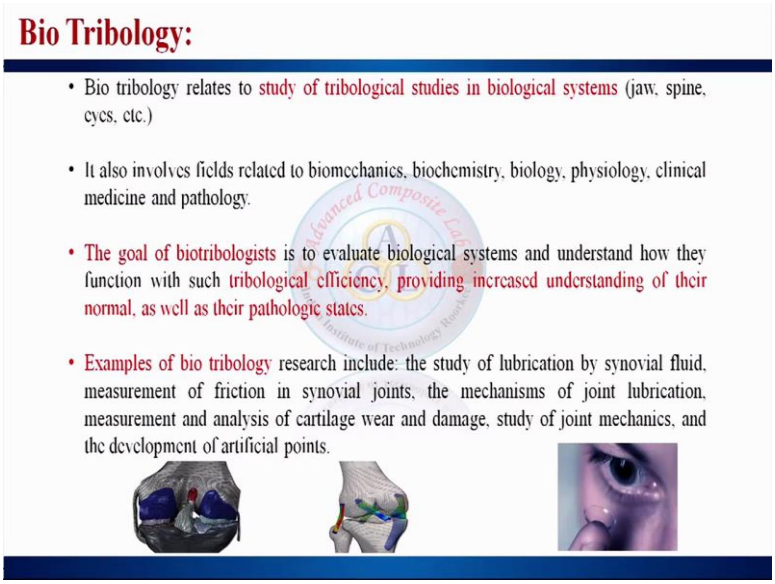

So, biotribology relates to the study of tribological studies in biological systems like jaws, spine, and eyes. So, when we are blinking our eyes, that our eyelids it is rubbing on to our eye balls, so automatically it is generating certain kind of tribological aspects over there. So, for which what we are doing. So, we are having some kind of eye fluid which is acting as a lubricant in between that. But sometimes we can find that our eyes is getting reddish or maybe it is paining, so that times generally doctor advise to put some eye lubricating jell over there. So what it will do, it will make a lubrication or may be lubricating it is acting as a lubricating fling in between your eyelid and your eye balls so that automatically your friction will be reduced.

Also it involves about some field related to biomechanics, biochemistry, biology, physiology, clinical medicine and pathology. The goal actually of the bio tribologist is to evaluate biological systems and understand how they function with such tribological efficiency, providing increased understanding of their normal, as well as their pathologic aspects.

So, from these particular figures you can understand there we have given certain kind of joints over there. Joint structure, in our maybe elbow or maybe knee or maybe hip where constantly from day to night that tribological aspects or may be the friction is going on. Also when we are using the contact lens in our eyes also that contact lens is continuously rubbing with our eyelids. So, automatically there is a tribological parameter is going on.

And the last one is called the Green tribology.

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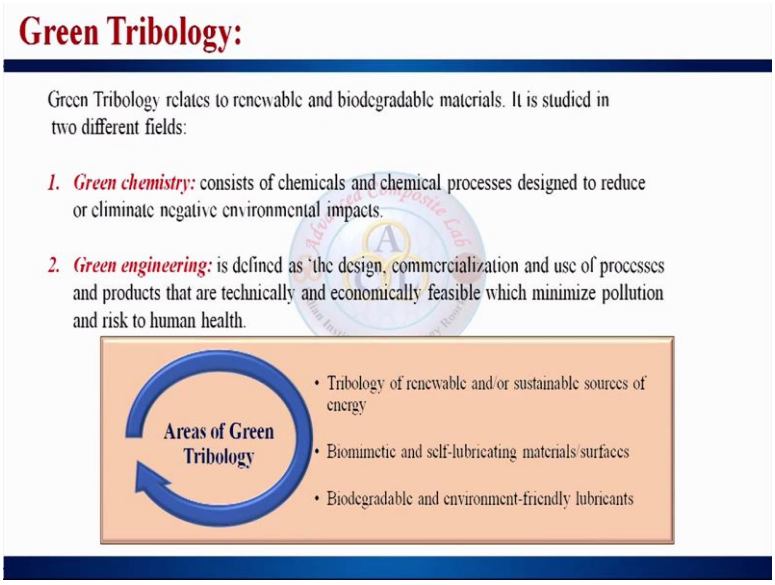

So, green tribology refers to the renewable and biodegradable materials. It is studied in two different fields: one is called the green chemistry another one is called the green engineering. So, consists of chemical or chemical process designed to reduce or eliminate negative environmental impacts from that is particular things you can understand when we are talking about the green; green means that whatever the material, whatever the wastage we are producing that will not be harmful to the environment and that will not create any kind of hazardless to the human being.

Next is the green engineering which is defines as the design commercializations and use of process and products that are technically and economically feasible which minimize pollutions and risk to the human health's. So, it will not create any problem to us. Areas of green tribology, so there are three areas where we can look: first one is called the tribology or renewable or sustainable sources of energy, second is called the biomimetic and self lubricating materials or surfaces, and third is called the biodegradable and environmental friendly lubricants where we can do the green tribology.

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So, there are twelve principles actually which deals with the green tribology. First one is called the minimization of heat and energy dissipations. So, whatever material we are preparing that should not release much heat to the environment or may be that should not produce high energy so that it can create to the human being or may be the to the animals.

Next minimizations of the wear, so that automatically the friction will be less so the material loss will be less. Reductions are complete eliminations of lubrications and self lubrications. And if we make certain kind of lubrications, so there should be any bio comfortable products attach to that so that it will not be chemically hazard. Next natural lubrications generally prefer, then biodegradable lubrications also we can use. Sustainable chemistry and green engineering principles, where we can maintain the green chemistry; biomimetic approaches, surface texturing, environmental implications of coatings.

So, if we are doing certain kind of coatings on to material to safe its life to enhance its service life so that we can use certain kind of coatings which is made by any biodegradable product; design of degradation of surfaces coatings and tribological components, real time monitoring, and sustainable energy applications.

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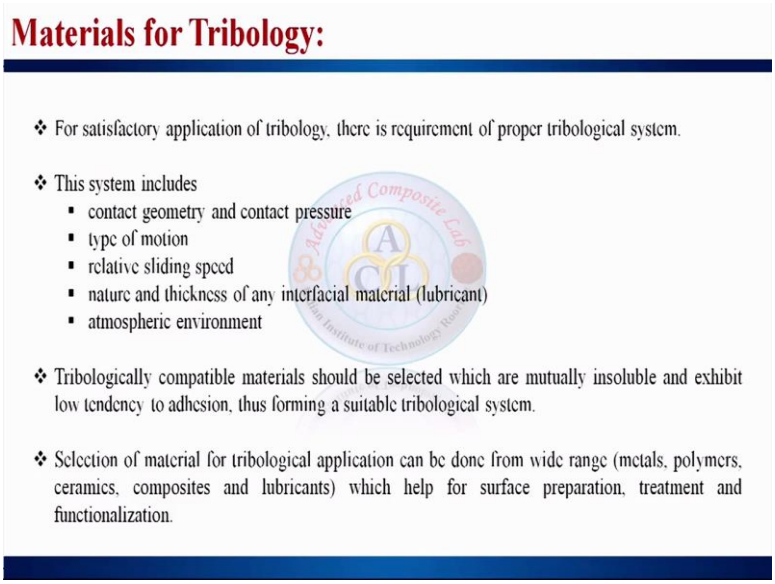

Then, what are the materials of tribology? So for satisfactory applications of tribology there is requirement of proper tribological systems. So, there are any types of materials we can use, but that material should have the capability that it will generate the less frictions, it will generate the less heat so that the material properties will not diminished.

This system includes contact geometry and contact pressure, type of motions, relative sliding speed, nature and thickness of any interfacial material and atmospheric environment. So, whatever the material we are going to use that material should have all these capabilities so that they can satisfy the tribological aspects so that there will be a less lubrication less frictions and less wear will be taking place. Tribologic compatible materials should be selected which are mutually insoluble and exhibit low tendency of adhesions, thus forming a suitable tribological systems.

Selection of materials for tribological applications can be done from wide range like, metal, polymers, ceramics any kind of materials which we are using in our day to day life that material can occur any kind of a tribology. So just to solve these tribological problem we can do the surface preparation properly treatment and functionalization of that particular material, so that it will not generate that much of frictions, that much of heat, that much of wear.

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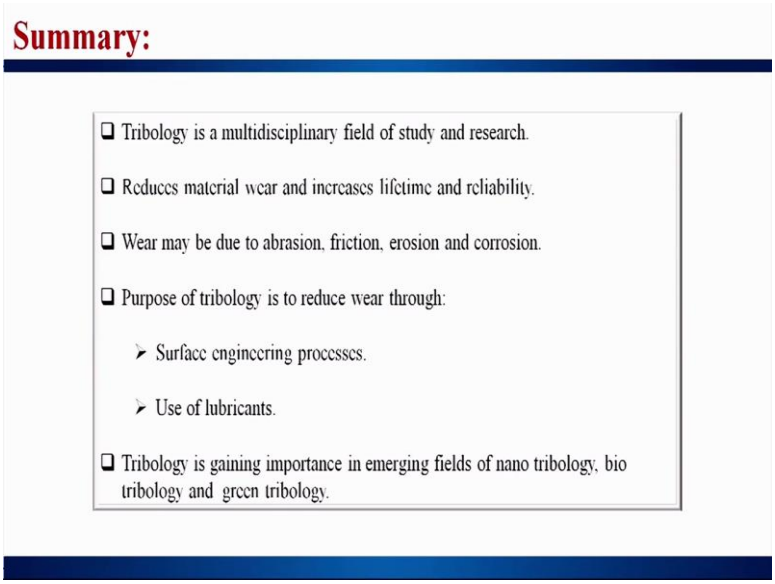

So, as a summary we can conclude our first lecture that; tribology is a multidisciplinary field of study and research. Reduce material wear and increases lifetime and reliability. Wear may be due to abrasions, friction, erosions and corrosions which will study in our subsequent slide. Purpose of tribology is to reduce the wear through surface engineering process that is also will come in later. Use of lubricants: that it will generate less friction, so that the material will go on in its own properties. And last one is the tribology is gaining importance in emerging field of nano tribology, bio triboloby and green tribology.