Tribology

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Module no. # 01

Lecture no. # 02

Interdisciplinary Approach and Economic Benefits

Welcome to 2nd lecture of Tribology course, title of this lecture is Interdisciplinary Approach and Economic Benefits.

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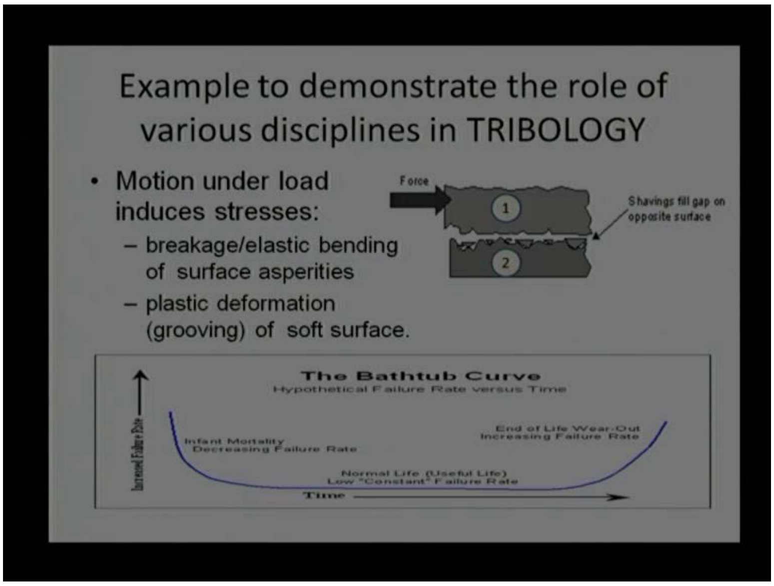

In previous lecture, we started with one example contact between two surfaces or more particularly contact between two rough surfaces, we say that there is a surface 1, surface 2 and there is a possibility of relative speed when we are applying some force on surface 1.

Due to this force, this component surface 1 will be pushed against the component two or surface 2, in that situation there are number of possible situations, one is that there is a possibility of elastic binding of asperities, second possibility is that breakage of surface asperities and third possibility is that plastic deformation of soft surface, what is the meaning of that, if one surface is much softer compared to other surface. In that case, harder surface will plow the soft surface will cut number of grooves in soft surface. We know to avoid failure to enhance the life of components, what we require? Only elastic deformation, we cannot tolerate too much breakage of asperities, we cannot tolerate plastic deformation of other surface, this will this will reduce life of component. Therefore, our emphasis will be more and more elastic deformation or no deformation at all between these two surfaces.

However, there is a problem, when the component is a new, there will be irregular surface that is why, there will be some breakages of asperities, which is tolerable, that is why we showed previous lecture, this bath tub curve. Bath tub curve clearly indicates initially wear out will be more or rate or wear will be more it will reach to an steady state condition and that steady state condition is going to decide, what is the useful life of the component, once that useful life of the component is over, again wear rate will enhance will increase and that will increase the clearance between component, will increase the noise between component, will increase the vibration between components and we need to change replace that component.

So, based on the tribological knowledge we can avoid excessive wear, we can minimize excessive wear and enhance the life. Number of possible combination or number of possibilities which we can think to enhance the life or something like we can use lubricant to avoid the breakages of asperities but lubrication itself is a subjective term where the thin film lubrication, thick film lubrication or just partial lubrication to quantify all this what we do we can define a parameter, what is called a plasticity index? Here it is the size equal to 0.6 in bracket we have E divided by H, here E appears to be young's modulus and what we are saying here, this young's modulus is a composite young's modulus or effective young's modulus, it accounts the both the surfaces, it accounts young's modulus of the both surface as well as poison ratio of the surfaces. Additional term is that, the square root of sigma divided by beta; here the sigma is a roughness, surface roughness of the component, while beta is a spacing between the two peaks at which we take at any time.

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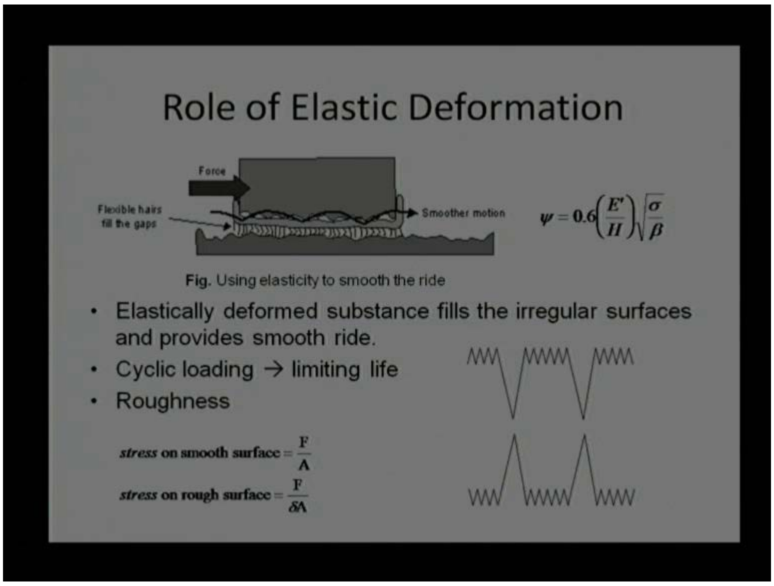

To continue with this we can say if plasticity index is very low value that means, it is going to give us more and more elastic deformation or laser breakages of asperities, services life will be much better. So, we need to keep this plasticity index to minimum, how can we do that? First is if the surface roughness value is high the typical figure is shown over here, we can see the surface roughness peaks and valleys, the certain peaks are coming out, that is harmful for the machine component, this surface roughness is higher naturally plasticity index will be high value and because of the high value of plasticity, index there will be some sort of deformation on the surface, that will lead to reduction in the service life.

Another one is young's modulus is interesting to know that, we are emphasizing on low young's modulus, low young's modulus will reduce the plasticity index. In general mechanical engineering and other extremes, generally, we prefer high young's modulus, but from tribological application point of view we prefer, low young's modulus, that is interesting thing, in addition we have another parameter, that is hardness, higher hardness will always be preferable. If you want lesser wear rate hardness high hardness will be preferable and high hardness also reduces the plasticity index, that means, if we are able to keep low plasticity index either by means of young's modulus or hardness or surface roughness or any combination of this, that will be good option for us or to increase the life of component.

One of the easiest method to that, to achieve low plasticity index is use a third substance between two substances. Let us take at this example, here we are showing the force is pushing the one component, I am assuming this is the trolley and there is a another component over here may be I am assuming there is a ground, we are trying to push trolley on this ground and there is a carpet in between, in this carpet has a some fibers, we know carpet fibers will be elastically deformed, if there is a force by trolling and elastic deformation of this fibers will not take too much force it they will be easily bend, as they are easily bendable friction force on this will be much lesser and wear will be almost negligible and that is preferable for us.

Now, coming to the mathematical term, we say generally we find a stress, linear stress or we say uniaxial stress, that is stress can be figured out or can be calculated can be estimated by using force divided by area expression, here area in this case is apparent area which is generally used in mechanical engineering, but when we talk about the tribological components we need to take only fraction of this area, we know very well whole area cannot be in intimate contact due to the asperities, and because of the asperities effective area or real area will be much lesser, 99 percent this area has a lesser than 16 percent of total area, as lesser than 16 percent, so I can say effective stress on machine component will be almost six times compared to what we calculate with ordinary formula.

There is a possibility of six time (()) or other one possibility is that, if there is a high stress; a stress is equaling to the elastic limit naturally the component of asperities will bend and will allow other asperities to come into picture or in other words, if the load is more and more and more asperities will come into contact reduce a stress back to the stress elastic limit stress, that is preferable and maximum in that case, if the whole area whole real area is equivalent to apparent area then in the situation, we can say that can tolerate that much maximum force.

Now, I can add one more sentence is that, see the why we prefer elastically elastic deformation of the gamma asperities reason being that, due to irregular surfaces or irregular surface where the peaks and valleys are there if the peaks are bending easily and then they are getting filled one way, another way to the other irregular asperities, then it will provide us very smooth surface, it will provide us plain surface will much laser irregularities and that is what we really require from tribological point of view, we can say that, will provide us smooth ride. However, there is a limitation; we know from fatigue point of view if any component is elastically deformed again and again and again and again, there will be cyclic loading that will experience cyclic loading, it will experience fatigue. And if this fatigue having some endurance strength, a stress is a beyond or more than, that a stress a component will be having limited life. We now other than iron or ferrous material not a single component has any endurance strength, that will be continuously decreasing or component will tolerate or can tolerate much lesser stress and high number of cycles. So, almost all the components other than iron will have limiting life if I am using any lubricant, that also will have a limiting life, that is why we need to replace lubricant frequently or depend on duration may be say after ten is to six cycle, may be ten is to ten cycle for which it was designed.

Now, who will this slide was related to the surface roughness, hardness and young’s modulus, has been experienced the surface roughness plays a major role compared to other properties young’s module and hardness reason being surface roughness will continuously change.

Initially, may be surface roughness is a one value after operating some operating hours the surface roughness value will change, it may be better side, may be the worse side, if we are able to achieve better surface roughness that means, component is coming to the steady state it will survive for a longer duration, but if surface roughness is enhanced or increased the value of surface roughness is increased, then in that case component is going towards failure it is not reached to the steady state condition, but it will be subject to the frequent failure.

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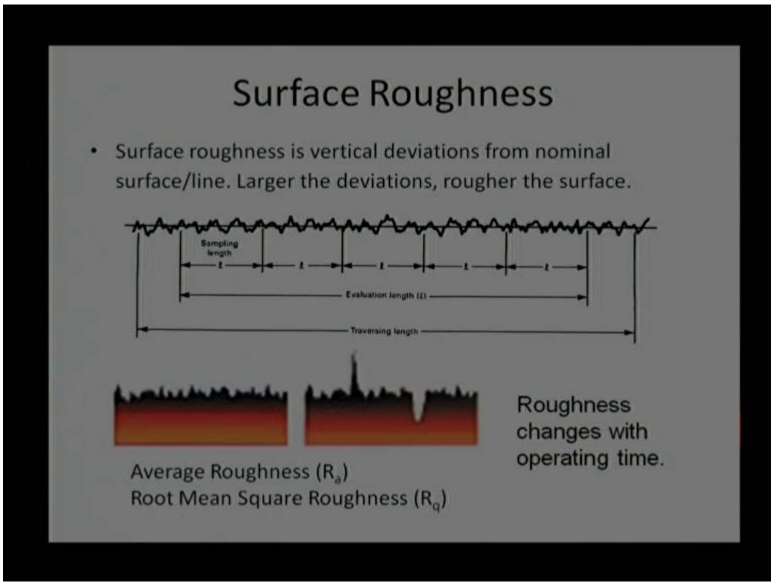

So, there is a need to give couple of slides or explore couple of slides on the surface roughness, that is what I am projecting this slide we say the surface roughness and a meaning of the surface roughness is the vertical deviation from a nominal surface, nominal line. If there are larger magnitude deviation is the larger naturally surface will be rougher and that is why there are this line shows, there is a nominal line is passing through almost the center and these are the peaks and valleys these magnitude, this amplitude shows the surface roughness larger the amplitude, larger will be the roughness. To evaluate this surface roughness often use a measuring equipment and when we try to measure this surface roughness we account three lengths, one is (()) traversing lengths, other is evaluating lengths and third one is the sampling lengths, reason being why we are choosing three length is that, we do not want to account start and its stop of measuring equipment.

There is a possibility that, this start some jump phenomenon happens and similarly the access and some some jump phenomenon happens, so we want to avoid first and last portion, we want to account only five portions remaining and this sampling lengths is I am assuming there is a one portion. We know this surface roughness is statistical we cannot find a single value, so what we do in that case, we try to average this five sample lengths and whatever the data comes that will be means surface roughness, so there will be some main value of surface roughness as a rest under deviation have more number of sampling lengths it will groove better reason, but it will consume more time and that is why as per the standards, they have come to the final figure of the five sampling length, that gives a reasonably good results to us, that is why we are choosing this mode.

Now, from tribological point of view, as I earlier mentioned we will be choosing we will be preferring low surface roughness value, surface compared to the high surface roughness, so in other words I will be choosing or I will be preferring left hand side this image, compared to the right hand side this image, there is a possibility may be the average surface roughness of these two comes to the same, because there is a valley over here, there is a peak over here, if I sum up these two I may get a same results, but I will be preferring this portion compared to this portion, because of the lesser surface roughness in this line or lesser value of the peak.

But this again at the start only, if there is a possibility or fracture of this sharp peak at the start itself, then there is no problem we can choose this surface roughness at this surface also. However, to intimate this kind of approach we generally use running in time between a components, we know when we buy a new car or new automobile it has been instructed or generally people instruct, company instruct us to drive, that vehicle at the lower speed. So, that all running in or dudding in time is over at the lowest peak does not cause a catastrophic failure, after driving low speed for some time we change oil that means, all the large size asperities are broken or tear away from the surface they get, they get mixed with oil and we replace that oil and we get good surface for the longer life after that, we can speed up vehicle we can drive vehicle at a higher speed.

Now, there are number of surface roughness parameter what we call a peak amplitude related parameters also, most commonly used surface roughness parameter are average surface roughness, where we take peaks and valleys and sum up and take average value of that, how about when the root mean is square roughness we again peak and valley we square, it we average it and then we take a square of that.

In tribology we generally prefer R q value over R a value or we prefer root mean is square roughness compared to the average surface roughness, reason behind this is that, average surface roughness does not signify completeness of the peak and valleys, we said that, we want to panelize peaks slightly move compared to low peaks I may say that, high peaks should be panelized, more than low peak values if I count only the average surface roughness then, there is equal Vertis given to the low value, low peaks and high peaks while when it is we are taking the root mean is square roughness or R q value in that case the more penalty is paid by high value peaks.

And as I mentioned earlier roughness changes with operating time, so, whenever we are designing component we need to design component according to the time is a short life component is a long life component if I have to design component only for the 10 hours naturally, I will keep adding in time at the own industry I will not give that component to the customer at all, but if I know the life of the component is 15 years, 20 years, then may be the bedding in time can be given to the customer, let them have feel that they are buying a fresh component they are buying a new component and new component will have always asperities and values and let him judge his component as per his wish.

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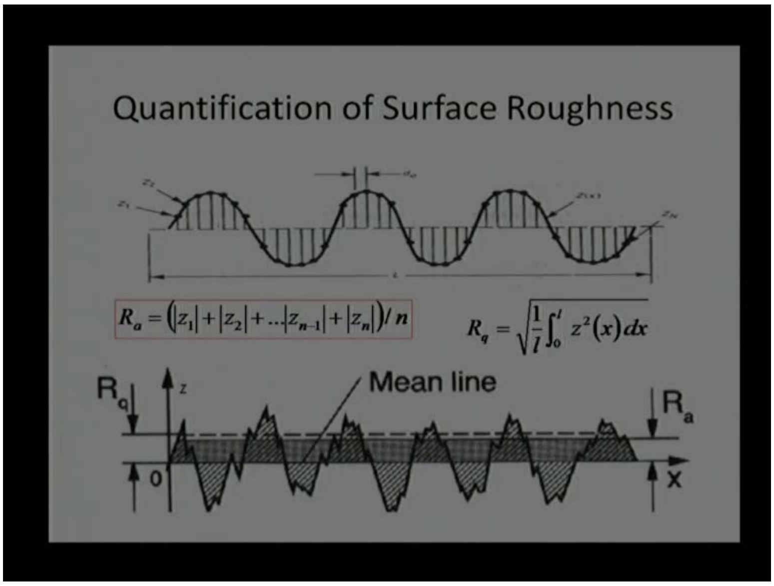

To quantify surface roughness as I mentioned we use equipment and what equipment and then it does it breaks a whole surface and number of digits or number of points and like in this figure, we are showing there is one surface and has been divided may be sixty divisions and then this sixty division we try to find out what is the peak value, to first simplicity it is shown on your sinusoidal profile, but in actual case it may be any random surface, what we do, we divide component whatever the analog signal we get we divide in number of parts and based on the division, we evaluate what is the z value, what is the peak value, what is the amplitude of surface roughness at that point, we sum up to avoid getting a zero value of surface roughness, we take absolute values as is in this case, we are taking absolute Z 1 absolute Z 2. Similarly and then we take absolute Z 11 and Z 12, then we will be able to get really good average surface roughness it is sum up and is a total number of points which we have accounted.

As I earlier mentioned there is a another surface roughness parameter which is preferred in tribology division or tribological application is R q value and interesting thing is that R q value will be always higher than R a value, that is good for application point of view we are taking more conservative approach and as I mentioned earlier, that we panelize peaks. So, if Z is lower may be say one unit it is going to get only one unit, but if Z is two units is result is going to be four units, so the more penalties are paid if z is three units z is curve return out to be nine units, so much higher penalty on that, that is the reason, why R q value is preferred or R a value it gives much more meaningful result from tribological application point of view.

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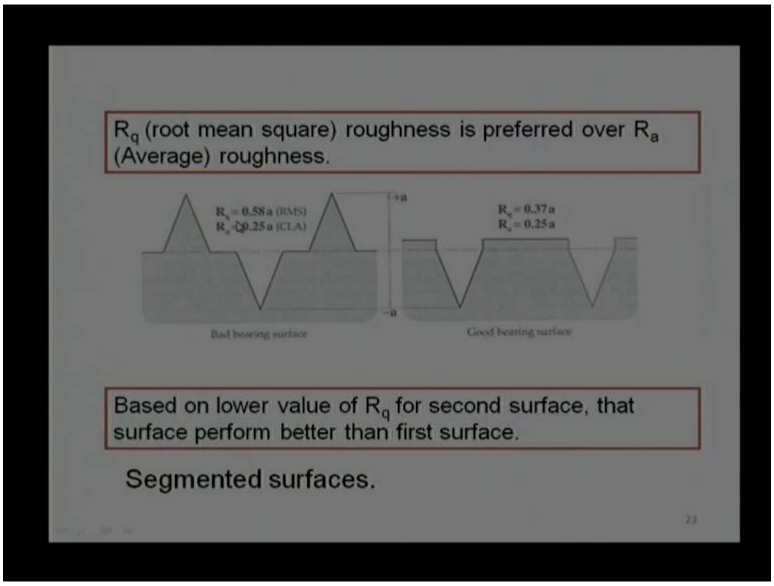

Now, we have studied R a and R q values, let us say which surface will be preferred and where we are choosing R q as I mentioned earlier there is a penalty more penalty on high peaks, particularly in R q value. Let us see at this example, the this is one surface this is another surface, now I am trying to find out R a value and R q value for this surface as well as this surface what I find R a value is a 0.25 microns in this example, similarly R a value 0.25 in this example, however this has a number of values, now coming to the R q value, in this case R q value is 0.581, in this case R q is 0.37, so what we are saying whatever we were planning to give more penalty to high peak value that is been imposed on this, we can say based on R q high R q value, this bearing surface or this surface is bad surface or this surface is good surface and again these are only comparative terms they are not absolute terms, I am saying that this surface or this portion right hand side portion, is better than left hand side portion, we are not saying an absolute this is the best much better values can be obtained right.

So, and I can conclude on based on this diagram is a based on lower value of R q second surface right hand right hand side surface, will perform better than first surface. However, there is another clue about this surface, you can see they are valleys many times we say these valley these valleys are helpful to us, as a storage of lubricant. If I supply lubricant that will get dumped in these valleys, so it will provide me a so resist space, I do not have to keep larger clearance between two surfaces to keep lubricant firm, if the lubricant can be stored in this valleys is more like I am getting a natural resource in a surface itself, so that will give me a good result.

In addition this kind of surface is preferred from wear point of view, we when wear is one surface wears of other against the other surface there will some generation of particles and if these particle come between two surfaces they will reduce area of contact, real area of contact, that is harmful again there reduction under area of contact will re-increase the stress value and there is a possibility of jamming two components harm high wear rate. So, in that case particularly this valleys will act as a dustbin if the particle debri is generated it will get bumped in this surface, it will not be between two surfaces, it will not kept as longer time in between two surfaces, so that is the beneficial for us.

So, in short we can say this right hand side surface performs better, from lubricant esterase point of view to remove debris from this contacting surface, from these two point of view is very good results it is going to give us good results, that is why many times we use the word as a segmented surface. This surface is more like a segmented surface and to some extent people can appreciate this surface from energy point of view from heat dissipation point of view. In this case, heat will be there if I only the straight surface plain surface is here, effective area of heat distribution will be lesser compared to heat dissipation area in this surface or available on this surface, so this kind of segmented surfaces this kind of punch surfaces or nodular surface will be preferred over irregular surface.

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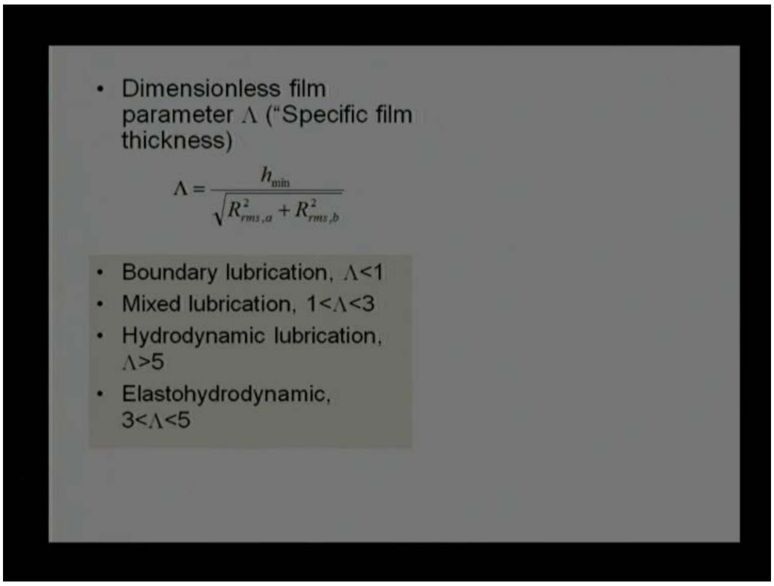

To add some more value to find whether the solvent mechanic should be used, fluid mechanic should be used, material science should be used or chemistry should be used or a combination of all four subjects should be used simultaneously, we can define one parameter that is known as a dimensional less from thickness parameter, it is a ratio it is a ratio between the separation or between the two surfaces over what is the composite surface roughness. So, here r m s value of surface a, r m s value of surface b is accounted, so if r m s value of any one surface is higher than overall this thickness ratio or is a dimensional less from parameter or lambda will be lesser.

To increase this lambda value we need to increase separation between two surfaces that means, if we are providing lubricant layer between two surfaces or we are providing some soft material between two surfaces or some poultry material between two surfaces, that is going to increase this capital lambda value, if the capital lambda value is higher than operating mechanism will be different and overall result may be in favorable sight. So, we generally divide in four domain compile lubrication mechanism in a four domain you say now a lubricant is a negligible that means, there is a hardly an a film thickness between two surfaces in that case, capital lambda will be lesser than one that means, surface roughness is a higher value compared to film thickness.

However, if we are providing some lubricant, partial lubrication then this value will turn out to be lesser than 3, but greater than 1, if we are providing thick film lubrication it will be lambda will be greater than 5. So, what we can say in that case, this is the hydro dynamic lubrication, they will not be any contact then life of between two life of the interacting surfaces, contacting surfaces will be infinity, they will not be any wear they will be only friction and we are saying that, because of wear component has a restricted life.

Anyway, there is a possibility intermediated stage, where the lambda is greater than 3, but lesser than 5, in this view particularly they will not be any asperity contact, but there will be elastic deformation of asperities while in earlier case hydrodynamic case there was no deformation of surface at all, no deformation of asperities also. While in this case deformation of surface is accounted which is a more natural phenomenon, we have so many bone joints in our body and almost all the joints work on Elastohydrodynamic lubrication mechanism even the gears, bearings, common follower they work on Elastohydrodynamic lubrication mechanism, that is a most economic Economic tribosphere for us.

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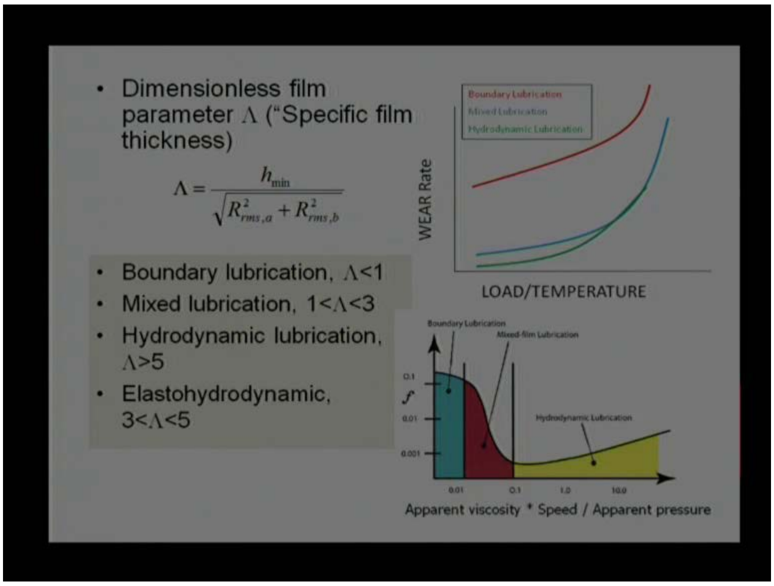

To give more insight about this we can plot one sommerfeld number what we call as a where the viscosity of the lubricant is accounted relative speed between two components accounted and pressurized apparent pressure which is applied on the surface is accounted if you are using the word here apparent pressure, because it is not real pressure real pressure, real pressure may be greater than this apparent pressure, we in this case we are directly using the word force divided by area which is apparent pressure and real case it will be force divided by real area and the pressure may be six time or seven time more than apparent pressure.

Now, when we plot coefficient of friction with this sommerfeld number what we find? When the sommerfeld number is a low coefficient of friction is high and that is the signifies the boundary lubrication, boundary lubrication coefficient of friction is relatively high. However, there is a lot of discussion keep going on on this survey whether they really initially coefficient of friction may be that low, that is difficult to achieve, because we cannot achieve zero speed whenever there is a zero speed or zero viscosity or infinite ratio we cannot get any result.

So, that relation, that is why, there is a now always possibility to leave a slight gap between this and y axis the coefficient of friction axis. Now this figure shows as a apparent as a sommerfeld number is increasing which may increase due to the apparent viscosity may be speed or reduction in ratio any any one parameter or a combination of all three parameters, the coefficient of friction is going to decrease it reaches to the bottom or the minimum value and after that again increases.

So, we are always targeting if I want to design a tribosphere, if I want to design a machine component, it should prefer this lower portion, where the coefficient of friction is in minimum, that should be our target and if it is not as achievable, then we may negotiate with the hydrodynamic lubrication or to some extent mix lubrication mechanism depend on operating condition, depend on the device for which we are working.

Now, if I see the wear behavior, ideally they should not be any wear for hydrodynamic lubrication and mix on the this what we say, this line as elastohydrodynamic lubrication in reality it will always be there due to start, during start, during its stop or some transient force operation there will be some film, that is what the minimum wear is shown in the case of hydrodynamic lubrication, that is the green color line over here.

Now, we are using two parameters here, one is a load if the load is increasing slowly hydrodynamics lubrication will turn out to mix lubrication to the boundary lubrication and if the temperature is increasing which will reduce the viscosity same thing again will happen indirectly it is going to increase the load, now if I try to relate this parameter over here what we are saying the load is increasing sommerfeld number is decreasing that means, if the sum component was and the hydrodynamic lubrication slowly slowly is moving towards the left hand side it will see the red color portion and then if you still high load is applied or temperature increased, then it will turn out be boundary lubrication mechanism.

So, every hydrodynamic lubrication mechanism if subjected to higher load or sever load it will turn out to be mixed lubrication mechanism or it will turn out to be boundary lubrication mechanism. If I for the same load condition and different area condition if I assume, we find always the wear rate in boundary lubrication mechanism is much higher compared to hydrodynamic and mixed lubrication mechanism. So, we should avoid as far as possible boundary lubrication mechanism, we should provide some lubricant one way or another way, I am not saying that it has to be a liquid lubricant it can be any lubricant, it can be hydrodynamic lubricant, it can be gases, it can be solid lubricant which can be utilized two lubricate to surface, which will be detailing when we treat a friction or wear topic of this course.

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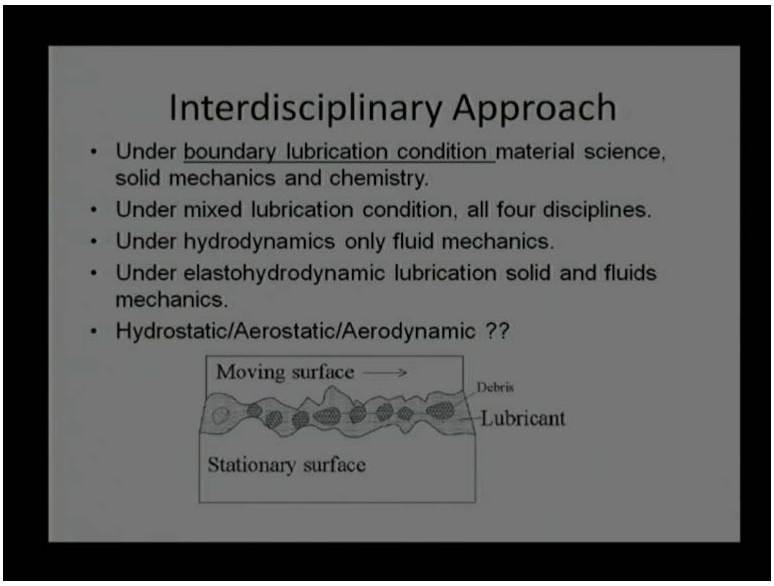

Now, we require really a true interdisciplinary approach to find out the real good results, if I treat or deal with only boundary lubrication mechanism I require material science I require solid mechanics and I require chemistry. Chemistry is required to find chemical reaction between the surface and contacting surface or contacting lubricant layer under mixed lubrication condition we need to have all four disciplines, we cannot avoid any single discipline, we require material signs, we require fluid mechanics, we require solid mechanics, we require chemistry, all four disciplines are essential to find out true mixed lubrication results and hydrodynamic lubrication, which is one of the simplest and most extensively used in number of text books and number of lectures is fluid mechanics is one of the simplest one.

And and a elastohydrodynamic lubrication mechanism we need to use solid as well as fluid mechanism, we may not use in this case material science to a great extent only material properties are required which generally are covered in solid mechanics and we require fluid properties, then fluid effect effect of loading condition on the fluids. So, that can be utilized in a fluid mechanics, so for elastohydrodynamic lubrication we require both solid and fluid mechanics for hydrodynamics which is one of the very simplest simplest one is it requires only fluid mechanics one one of the difficult or say one of the most difficult is mixed lubrication mechanism, where we require all four disciplines where we require a number of iteration to get real good solution.

Now, there some other points are, so we say that we are not covered hydrostatic aerostatic and aerodynamic in this case, so that question is obvious in this case; we have assuming that hydrostatic is more like hydrodynamic only the pumping source is getting changed in hydrodynamic, case pumping source is self acting is a relative speed and a combination with the load. While in hydrostatic it is a extra pressure or external pressure which is fed between two surfaces to levitate one surface with related to other surface same thing with the aerostatic; in case of aerostatic we are putting gas, this gas can be anything it can be nitrogen, it can be any neutral gas, it can be air also which is not going to curve the surface, that is the only our aim.

Otherwise any gas can be utilized, so that way we can say aerodynamic bearing will be the cheapest, because the sources are naturally available I can directly pump or pressurize and pressurize here, between two surfaces, but there is a difficulty in this case particularly viscosity of air is much much lower than any fluid viscosity. So, we need to have much smoother surface for aerodynamic bearing which is very difficult to achieve that is, why it requires sophisticated manufacturing processes to find out, to develop a aerodynamic mechanism or aerostatic mechanism.

Another interest interesting fact which I want to highlight is that, may be some time we use you came keep using only hydrodynamic lubrication mechanism; assuming a two surfaces are always separated and we are accounting at the initial level or the start level and end level. We are pumping liquid we are levitating two surfaces or one surface related to other surface and we are always trying to keep mechanism or contact pair under hydrodynamic lubrication, but it is not a general case, if there are some third particle passing in liquid, they can occupy the space between surfaces and then they can reduce particle film thickness or you can increase effectively the surface roughness.

So, are we hydrodynamic mechanism can be shifted to the mix lubrication after operating condition, so we need to in real sense we need to account all four disciplines whenever we want to attack any tribological problem or any tribology problem.

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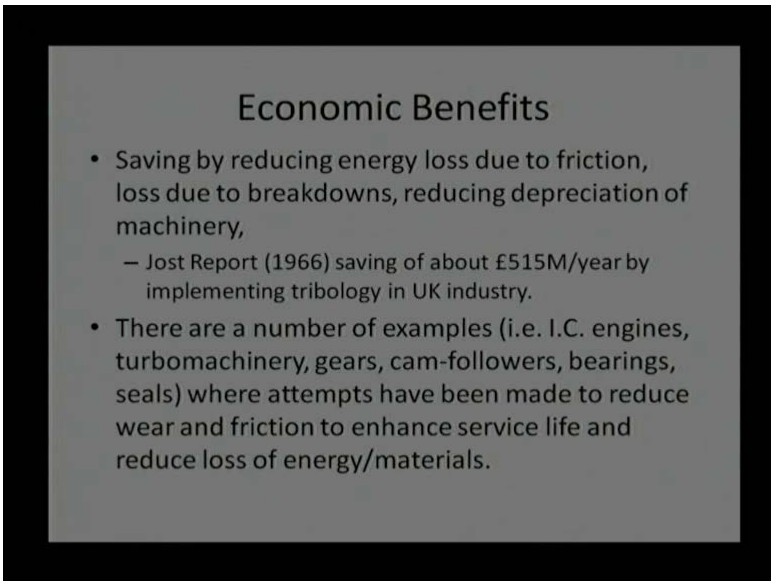

We have number of benefits, which we can gain when we apply tribological knowledge may be say if we learn all four disciplines and coupling between all four disciplines, we can utilize those equations that knowledge to increase service life reduce friction losses increase wear life or you in reduce material wastage which is been done either a lubricant form or an solid form, that can be saved to a greater value.

This was pointed out in 1966 by Jost Reporter or it was pointed out in Jost Report by Peter Jost and his company, his committee members he pointed out that we can save or U K government can save 515 million pounds per year, just by implementing tribology knowledge in U K industries, to avoid breakages between the components to reduce down time, to reduce inventory cost, he could calculate 5 15 million in 1966, we know number of machine have increased now drastically compared to 1966, there are many new machine have come up much more sophisticated machines wheather, the earlier tribology was not required, but now it is required.

So, if you count those many application we can save a lot of money, we can save lot of money for our nation and that can be used for some other good purposes compared to just getting wasted in tribological components, it is been observed that this kind of tribology can be used in all I C engines irrespective of type all I C engines, it can be used in all turbo machineries for all kind of gears, all kind of camp fall over mechanisms, all kind of bearings, including magnetic bearings, all kind of seals. So, this kind of knowledge can be utilized for so many components because I have not seen any machine without any bearing or it does not have any support system, almost every every machine has some support system that means, every machine requires a tribology if we are able to implement that that is going to save lot of amount, lot of cost which is incurred otherwise.

Now, I will take a couple of examples to convey my meaning or of the saving related to the nation; let us take an example of hard disk drive, we know the hard disk drive is based on a magnetic read and write, data or printer are written on the disk using the magnetic media and in one hard disk there may be a number of actuators, number of plats, higher and higher capacity is always demanded. Earlier, the if you say we required a memory in K B’S then in M B’S now in G B’S and now we are talking the terabytes the capacity of the hard disk is continuously increasing, what is the reason behind that, if I go in detail I find that all rotary actuator and hard disk they act as a hear bearing they make hear bearing.

So, this blur color is I am assuming, that is the developed surface is a magnetic disk and this is a read and write head, when magnetic head is available here if gap between head and disk is very nerve, very low value, then there is a possibility of boundary lubrication there is a possibility of surface roughness of magnetic disk may hurt head and damage a head, there is a possibility; however, if we design this properly then, that possibility can be reduced.

What is the advantage of reducing the gap between this magnetic head and a magnetic media, can be elaborated through this mechanism, you see if the distance between the head and the disk is lower than data loss or signal to noise ratio will be very high if the head is very close to this the data can be directly picked up, if the this disk this head is slightly away then there is a possibility of external or other data getting captured by the head. So, signal to noise ratio will reduce that will help me in other way also, if I am able to reduce a gap between this concentric circles right or the radius of the one concern disk cycle is slightly lower or slightly moved, than other circles, that will be preferable compared to distance between these circles if is a very high.

You say that if I am taking a radius of one M M A radius of 1.01 may be say ten micron difference, then that will be preferable compared to 1.0, 1.1 M M radius, if there is a shrinkage or there is a very narrow domain available signal to noise ratio will improve as well as the is going to save a disk space in the same size disk I can store more number of data. So, that is the demand we want to enhance storage capacity without increasing this space and that is achievable due to tribology. Now the surface is how been generated in such a manner lubricant layer have been generated as made in such a manner, then that is there is no loss of the data and it can be read and write can be repeated yen number of times avoid you to the unavailability of the good lubricants if was very difficult to achieve zero wear or negligible wear, of the magnetic disk, but now that is achievable that is possible; now we are talking about the this height are roughly 25 nano meter, 25 nano meter is very low value our ordinary air thickness comes roughly 60 to 70 micron.

And we are talking one thousand lesser than that that means, if I do a parallel cutting; however, here when I can divide one air in thousand or more number of pieces we are talking about that distance that is achievable because of tribology.

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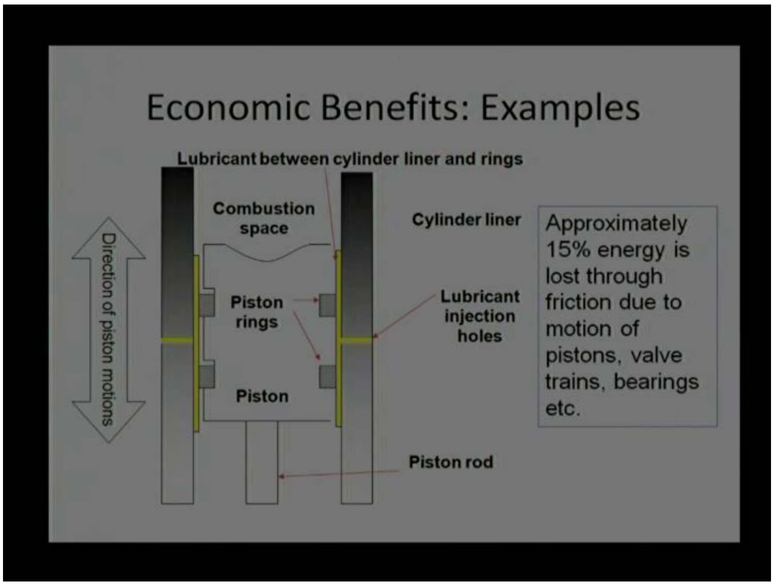

Let us take another example what we are talking about cylinders, alloy engine cylinders we now piston is generally supported on the piston ring and it reciprocates in a cylinder head and lubricant layer is provided over the piston rings. So, that it can freely reciprocate in a piston, but it has been estimated this is one of the major source of friction in I C engine.

If I along with that if I account other sources is something like wall mechanism, we know very well walls are used in I C engine to open the port for the fuel and air and close the port for compression and expansion stroke and finally, open the cylinder for expelling out the exhaust cases. So, those walls get very high temperature and they have to reciprocate in a cylinder, along with that there are number of bearings in I C engine if I try to control all this, if I try to utilize good tribology or good tribological knowledge on those I C engine components there is a possibility of reduction in friction by 15 percent; 15 percent is been generally targeted people have accounted that even they have achieved around 20 percent saving in friction their mechanical efficiency has reached to 95 percent and older time the mechanical efficiency was some may be say 60 percent then 70 percent and may be say around 3 4 years back it was 85 percent, now people have achieved in a 95 percent the great saving due to tribological knowledge is possible.

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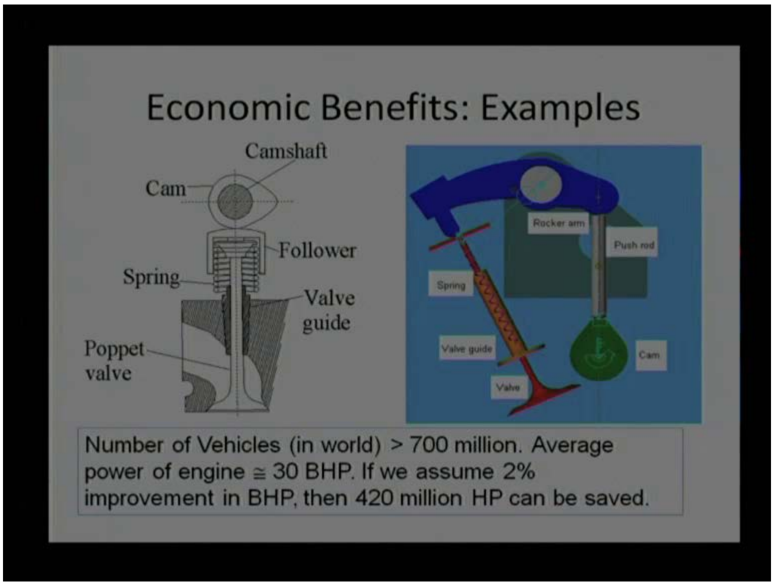

Now, there is another change in technology to avoid or to reduce the tribology knowledge in older time this kind of this kind of the wall mechanism are used, there was a cam, push rod, rocker arm and the rocker shaft and ampli this signal was amplified to push the piston, push the wall in wall guide. So, we can find out there are number of tribospheres say wall and push rod, there will be some friction there is mechanical contact there is a loot applied and there is a relative speed. Similarly this is the contact sphere push rod and rocker arm, rocker arm and shaft, rocker arm and wall and wall and wall guide, so there are too many tribospheres in that and almost every tribosphere causes some friction losses.

That was replaced with over head technology the now there is a cam there is a follower and directly wall, so all intermediate links have been removed, we know very well the free remove intermediate link one is reliability is going to improve or reliability of system will be higher in addition to that there are number of tribospheres which have been eliminated. So, friction loss will be reduced; however, there was only one problem how to use or how to carry lubricant from cam case to the camshaft, now that also has been resolved they are able to provide good lubrication or the inverted head condition also or we say that over head condition also.

So, if we implement all this condition if all implement all this mechanism there is an huge saving and a rough estimation says, that number of vehicles in the world are more than 700 millions, if I count, power range of all vehicles I can find out average value will be roughly 30 H P by one motor vehicle which is on lower side which is more on conservative side we are doing a rough estimation and in verse to verse case. If I assume we are able to save two percent of that energy using tribological knowledge I am going to view what we are going to achieve is something like a 420 million H P that is a huge saving that means, even the delta improvement on the tribological level is going to help us drastically.

So, we should implement we should learn tribology, we should learn how to apply this tribology in couple of applications once we learn that application how to implement for couple of application, we can enhance we can say enlarge our domain for other applications. So, tribology or bio tribology is one of the coming up area and people have worked they have really designed good prospective joints based on tribological knowledge and they are able to achieve joined efficiency as well as a life up to 20 years.

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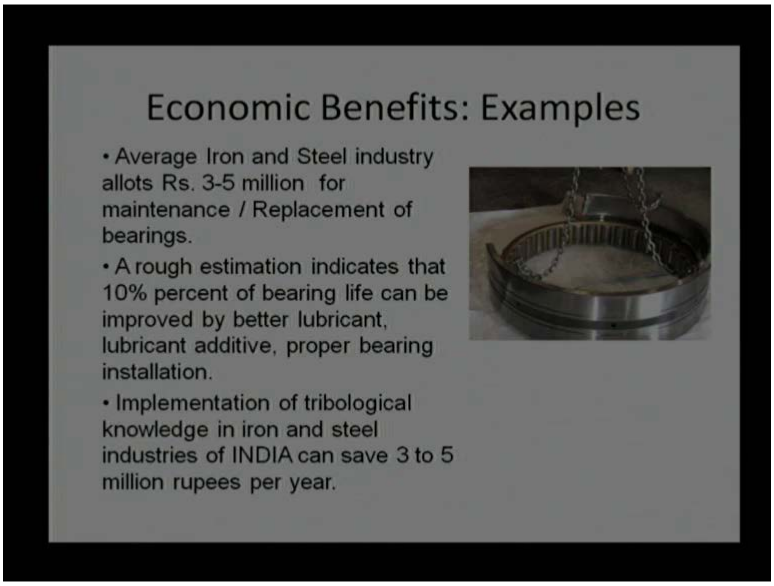

Let’s take another example, this bearing example is related the roller bearing is a multi row roller bearing and it failed due to misalignment due to wrong mind thing or due to wrong impression of the mounted may be the person who mounted he was not knowledgeable how mount it and carry over the fast of work he mounted this bearing and this bearing frict with in 100 hours there were two bearings or one bearing failed 100 hours and other bearing failed in 300 hours.

While estimated life of this bearing was roughly 4000 hours, so there is a percentage hundred hours verses 40000 hours 40000 is very huge amount and almost 4 years 5 years duration while this turn out to be less than one month. Now this kind of bearings are very cam this bearings are common in steel industry and we know almost every industry use the bearings I am just taking only this one example and when we estimated all iron and steel industry they divide or maybe they keep some money for bearing replacement bearing purchase capital inventory whenever there is a bearing failure they just simply replace without really going through or without diagnosing properly.

So, they keep generally 3 to 5 million for maintenance and replacement of the bearings that is a huge amount roughly in India we have ten plus this kind of industry and if I am targeting if I am thinking at least ten industries I am leaving all other part this industries are able to save this much money, that will be very helpful to us and you say that worst to worst if I am able to save 10 percent of the bearing life as per my understanding bearings are mostly failed, because of the maintain, because of the maintenance problem if that can be avoided or I am just saying the rough estimation 10 percent can be avoided later keep a 90 percent same.

Even in that case, we are going to save roughly 3 to 5 million per year just based on ten iron and steel industry if I am counting all other if I start counting other bearing industries or other industries if the bearings are used, naturally saving will be huge.

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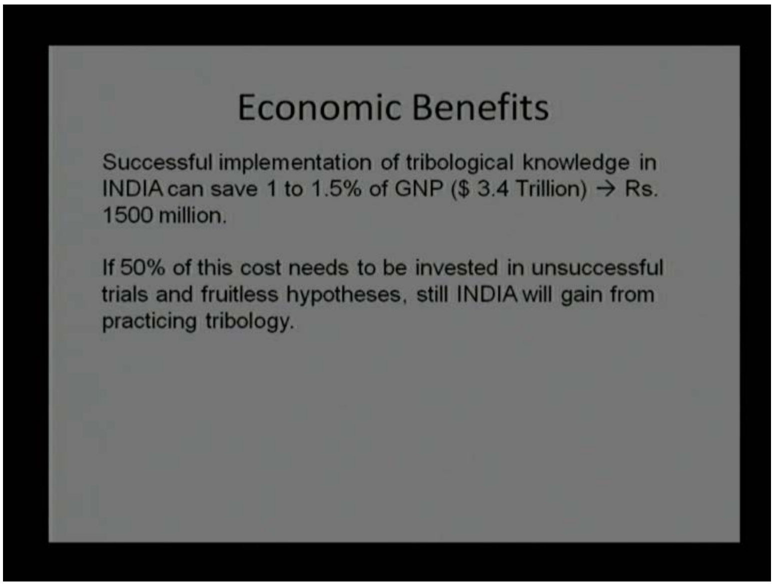

In short I want to conclude whether this light it says that rough estimation say, we can save energy, we can save material and if I talk in a rupees and I talk in monetary point of view we say that, we say that we can save almost 1to 1.5 percent of GNP avoid GNP GNP was a 3.4 trillion dollars.

So, what we are talking about roughly the 15000 million rupees can be saved by implementing right tribological knowledge; however, there is always a problem people say not all efforts will be always successful. So, I agree with that, we say may be assuming only 50 percent efforts are success and 50 percent efforts are not successful, we are wasting half of money and just putting efforts we are not getting returns, but only half money which we put that, we are getting returns saving in that case saving will be huge, there is a significant amount of the saving we are going to achieve if we implement tribological knowledge. Thank you for your attention and we will be covering friction topic in our next lecture.