Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-16
Surface Damage: Abrasive Wear I

Hello I welcome you all in this presentation related with the subject fundamentals of surface engineering and we are talking about the abrasive wear. We have seen that whenever a hard particle is rubbed over the another metallic surface the material is removed by abrasion. But there can be that 2 broad types of the abrasive wears, 1 were 1 had particle is firmly held and it is rubbed against the another surface.

And another type of the abrasive wear is when the hard particle comes between the 2 interacting surfaces and leads to the three body abrasive wear. So depending upon the loading conditions, depending upon the location where the abrasive particle is present it can be two body or three body abrasive wear. This is what we have already talked.

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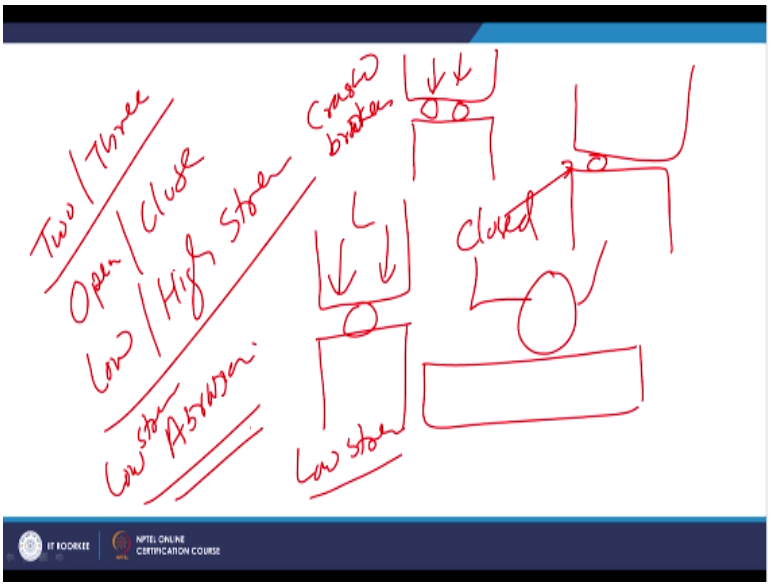

And then there can be open or closed type abrasive wear where hard particle comes between the 2 firmly placed components or surfaces like this then it leads to the closed 1 or 1 hard particle firmly held and pressed against the another component like (()) (01:48) and wherever polishing is performed. So that forms that close abrasive and when the abrasive particles are allowed to move freely then over the metallic surfaces then it leads to the open abrasion.

And then according to the kind of the loading where can be low stress abrasive wear condition or high stress wear conditions. So in case of the low stress abrasion the in case of the lowest abrasion wherever the conditions exist like in three body abrasive wear, the loading conditions are such that the abrasive is able to retain its size and shape and it is not crushed.

So that is the state of the low stress abrasive wear, while in case of the high stress abrasive wear wherever the particle is present loading is such that part the abrasive particle is crashed and it is broken, it is damaged under the high stress abrasive wear conditions. So this is the difference and other lowest abrasive wear conditions, so the particle largely retains its size and shape while under the high stress abrasive wear conditions there the particle is crashed.

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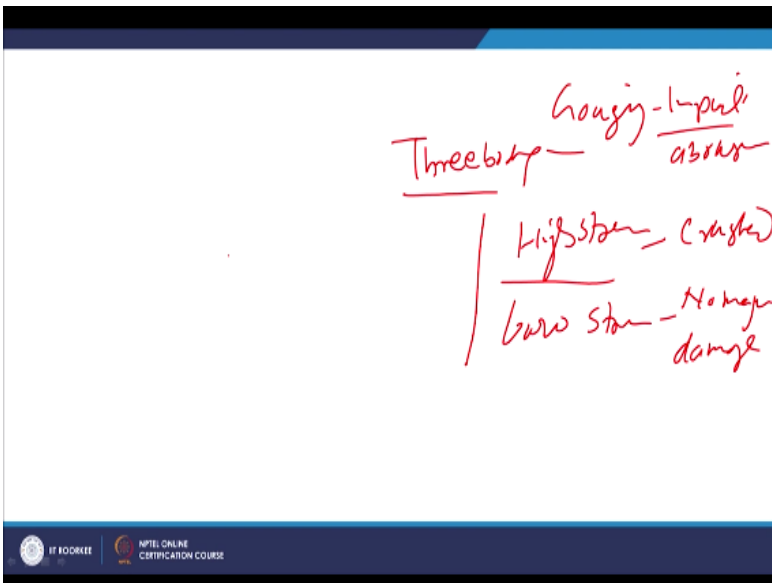

Then again under the category of the three body abrasive wear there is a 1 grousing which combines then impact+abrasion effect, then there is high stress abrasion where the abrasive particles are crushed and low stress abrasion where no major damage to the abrasive particles in course of the abrasion. So these are the as per the loading conditions as per the situation where abrasive particle is present.

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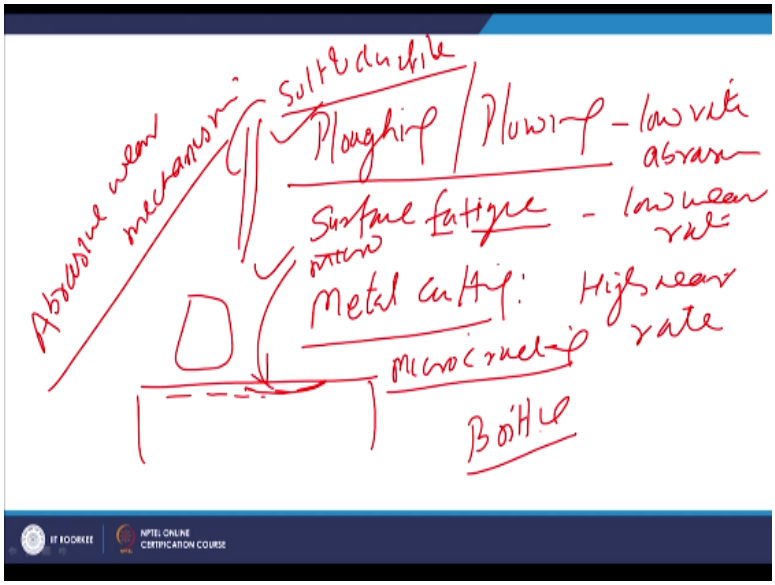

There can be various groups and classification of the abrasive wear it may be like open the closed it may be of two body or three body, it will be lower stress or high stress abrasive wear. Now we will see the way by which material is removed during the abrasive. So abrasive wear mechanisms basically there are two broad categories, but they are final other mechanisms one is called ploughing.

It is also written as plowing and then there is metal cutting or it is called cutting. So ploughing leads to the low rate of the abrasion while the metal cutting causes very high abrasive wear rate. Then there are other fine mechanisms one is called surface fatigue, this also leads to the low wear rate and it happens due to the continued subsurface layer deformation there after nucleation and growth of the crack leads to the removal of the material in form of the chip like this is a surface.

And it is being updated continuously so it will be the continuous surface layer and subsurface formation and crack is nucleated in the surface region and it is growth leads to the removal of material in form of the particles. So this is the like say for micro fatigue we can say micro fatigue, in case of the brittle materials there can be micro cracking also a mechanism which leads to the removal of the material.

So the ploughing and the metal cutting these are the 2 mechanisms which are mostly found sult and ductile metals while micro cracking mostly observed in case of the brittle materials however under the actual abrasive wear conditions there will always be combination of the

ploughing metal cutting and micro cracking as per the kind of the material which is being considered.

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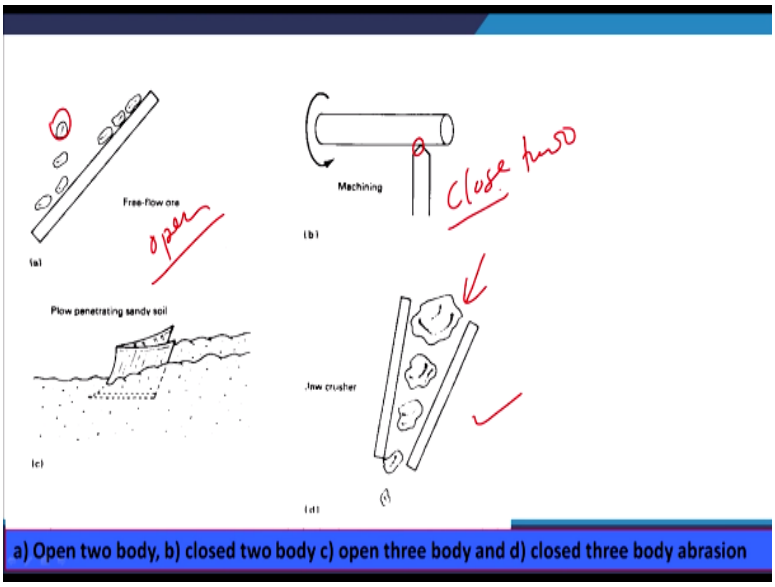

So in which way we can express and how is schematically we can understand these wear mechanism for that we need to see certain diagrams. So again going back to that what we have talked this is the open abrasion system this is a open abrasion system where open two body abrasion, if the abrasive particles falling freely on to the surface. So this is open two body operation system.

And when the 1 member and the two members are relatively fixed with each other and their relative positions are fixed and then there after relative movement causes the removal of the material like in similar to the machine in this forms the close two body abrasive wear and the open three body abrasive wear is this situation where are this which is the being used to remove the sand.

So sandy soil is being a penetrated with the help of soil or so this is the case of the open three body abrasive wear and this is the example of the close three-body abrasive wear where between the 2 jars the abrasive particles are fed and they are crushed. So these are the mechanisms about abrasive mechanism wear abrasive mechanism wear mechanism say about which I have talked like the gouging which combines the impact+abrasion.

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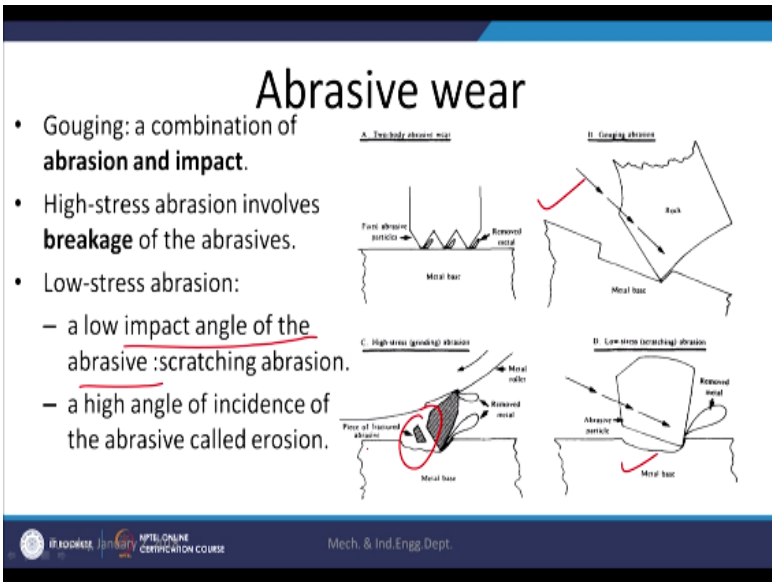

High-stress abrasion wear particles get crushed and lowest stress abrasion particles largely retain their size and shape but remove the material by abrasion through the metal cutting or the ploughing. So in case of the lowest abrasive the low impact angle causes the scratching abrasive while the high angle of the incidence causes the erosion.

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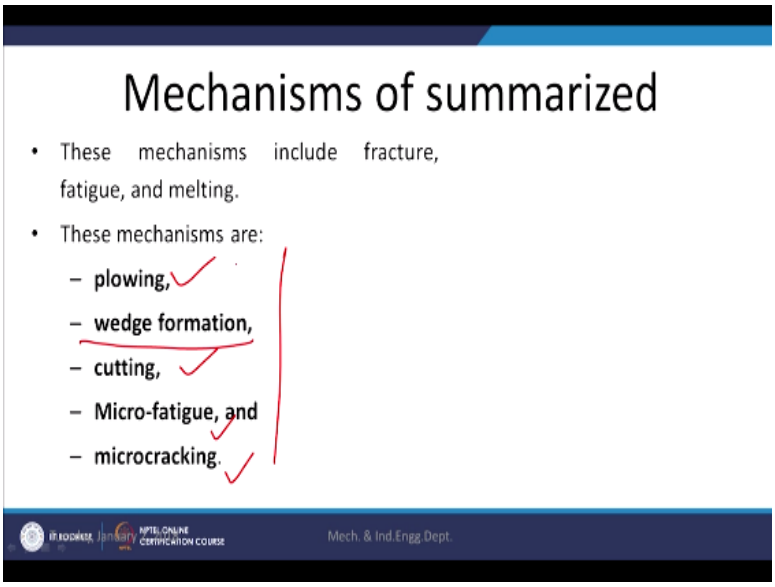

These are the 5 different mechanisms about which I have set the ploughing, metal cutting, micro-fatigue, microcraking which formation also sometimes takes place but these are the two mechanisms which do not contribute much towards the material removal by enlarge the material is displaced plastically. So in this case is this one plowing mechanism where like over a soft metal we forcefully penetrate 1 tool.

So the material is displaced side wise and once the tool keeps on moving or abrasive particles are moving, so this phenomena will keep on displacing the material side wise from the path of the particle.

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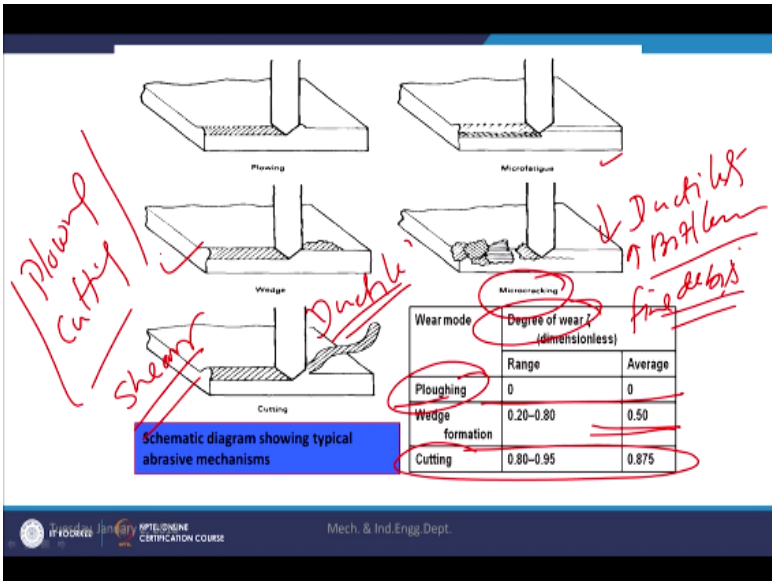

In this case there is no major removal of the material only the displacement of the material takes place. This is what we can see this material is being displayed by the hard particle which is being which is rubbing the surface and this displays material may look like this where this is the kind of the group which has been formed and this has been displaced sideways like this. So both side will see the some piling up of the material.

While in case of the wedge formation apart from this displacement of the material, material is 1 piling up of the material is also I will also be taken place ahead of the abrasive particles. In case of the microcracking continuous rubbing of the surface is by the abrasive particles leads to the deformation followed by work hardening and when work material loses its work hardening capacity then crack nucleation and their growth.

And subsequently the coalescence of the cracks or joining of the cracks leads to the removal of the material firm of the debris. So this what happens in case of the micro-fatigue. So since during the operation if the material is continuously displace from its position due to the abrasion action then when the continues deformation will be causes the significant work hardening which eventually loses its ability to get work harden further.

And in that case cracking starts with crack nucleus and its growth lead the collections of the cracks and which find leads to the formation of the wear and debris. So this is what we can see here in case of the micro-fatigue and in which formation also there is no measure of the material in case of the microcracking this happens when the material is having the limited very low ductility and brittleness is high.

So whenever the abrasion particle will be moving it will try to displace material but due to the limited ductility is deed of getting displayed, it will lead to the formation of the number of cracks and number of cracks when is having limited ductility. So the formation of such kind of cracks will be removed material in form of the fine debris particles. On the other hand when the abrasive particles work at a particular critical angle it leads to the formation of the chips in by the shearing action.

So this is typically observed in case of the soft and ductile materials where large amount of the material is removed by the cutting action. So if we see here the degree of way in which is compared to the different mechanics in case of ploughing the removal of material is very limited somewhat removal of material takes place in the reverse formation and maximal removal of the material takes place in case of cutting.

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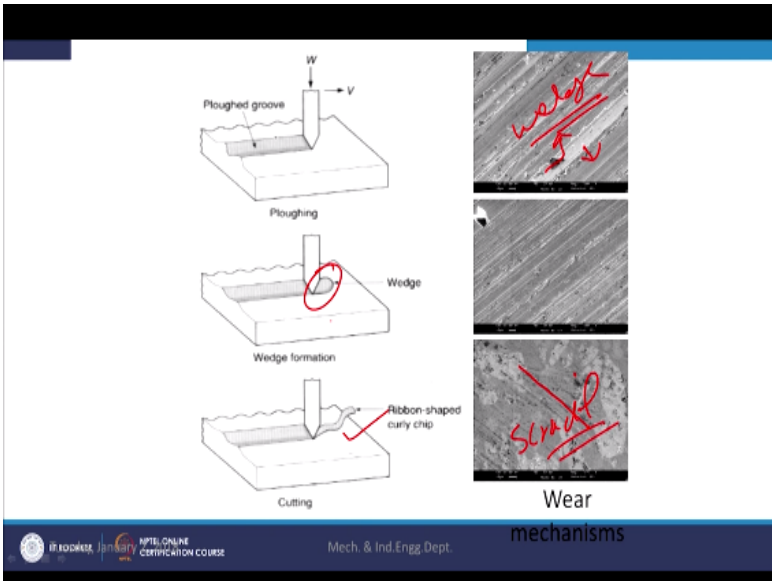

So the ploughing and the particular these are the 2 extreme mechanisms which we will see how this will be wearing with the variation in the hardness of the material. So these are the this is how we can say when our their material is subjected to the ploughing, then it leads to

the displacement of the material sidewise and it forms the wedge like this under these conditions there is a limited removal of the material.

But whenever the metal is having limited ductility and then in that case the deformation sideways flow of the bottle will also be lifted and it forms the deep scratch and such kind of the scratching causes the loss of the material. This is like a material of the material by the cutting in form of the ribbon form of the chips and here some of the material is it displays the head of the abrasive particles.

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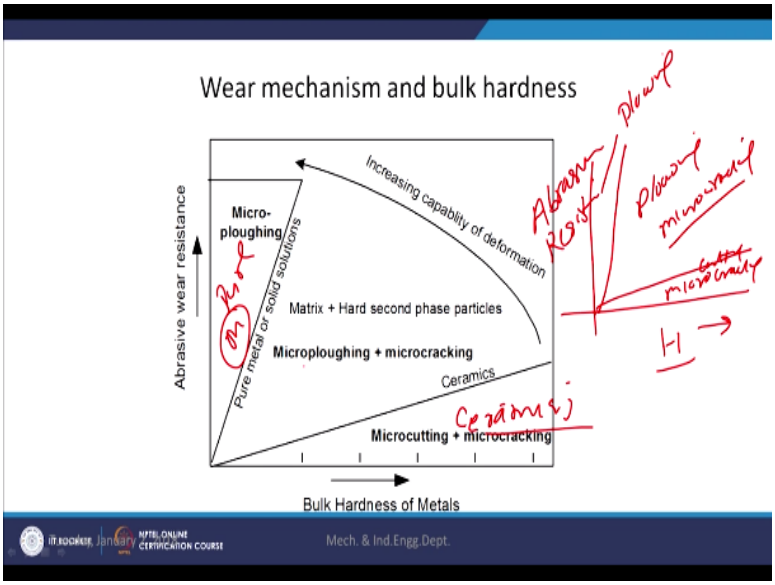

This is why some of the material will be displaced side wise , this figure particularly this shows when which type of the abrasive wear mechanism will be dominating. So what we can see here when the material is really hard we can see then also in axis we have the hardness of the material and in the y-axis we have the abrasive wear resistance.

So abrasive wear resistance here what we can see when the metal hardness is high mechanism responsible for removal of the material is basically microcracking and some micro-cutting will be taken place. On the other hand material is having very low hardness then it is basically the ploughing which will micro ploughing which will be taking place in between it will be the combination of the ploughing and the microcracking.

So if we see which kind of the metal system will be subjected to the ploughing, the materials which are pure, soft and ductile. So pure metals on the other hand the hard and brittle materials like ceramics will be experiencing the microcracking and the combination the micro

cutting and deploying and microcracking combination of both these is observed in those metal systems which will behind the combination of the both hard and soft.

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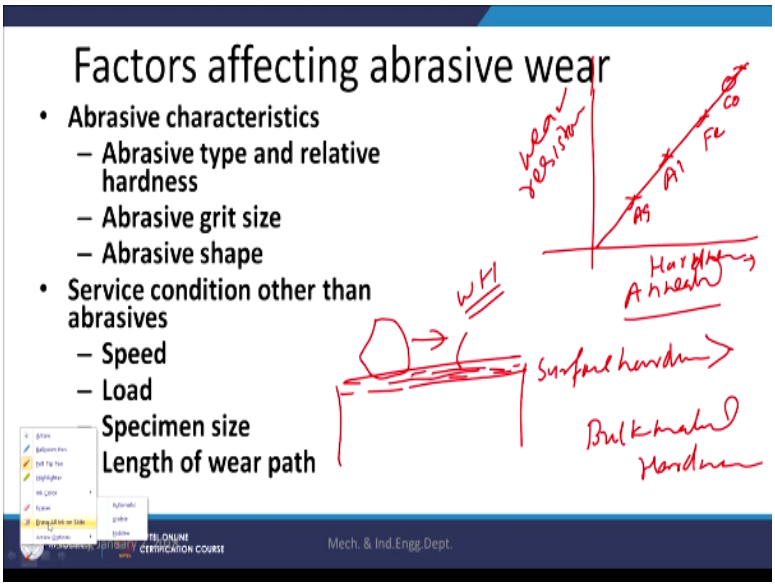

The second phase particles like matrix is a soft and tough while ceramics particles are other particles second phase particles which are hard and brittle. So in that case a combination of the ploughing and the microcracking will be observed. These are some of the characteristics all the factors which will be affecting the abrasive wear of the material. So now we need to see one simple diagram how the material hardness changes.

So if we see there are different metal systems which will be showing the different value of the hardness in annealed condition annealed condition means with material is subjected to the high temperature exposure for longer period. So that it does not have any work hardening effect. So soft metals like silver, then aluminium, then iron, then cobalt, they may have the variation in the hardness like this.

And accordingly what we will say so material hardness in annealed condition, hardness in annealed condition and what it will be showing the wear resistance increasing wear resistance. If we see in annealed condition it will not have any work hardening effect there will and the flow stress will be same as that of the yield strength of the material. But we know that whenever any material is subjected to the surface layer deformation either during the adhesive wear or during the abrasive due to the effect of the abrasive particles movement under the external load surface layer deformation will be leading to the work hardening effect.

And under the work hardening effects obviously the hardness of the surface hardness will be greater than the bulk material hardness. So this leads to the somewhat better resistance to the abrasion and this is observed primarily due to the surface layer deformation and the work hardening effect. So if we see the another interesting diagram then what we can observe this like work harden condition.

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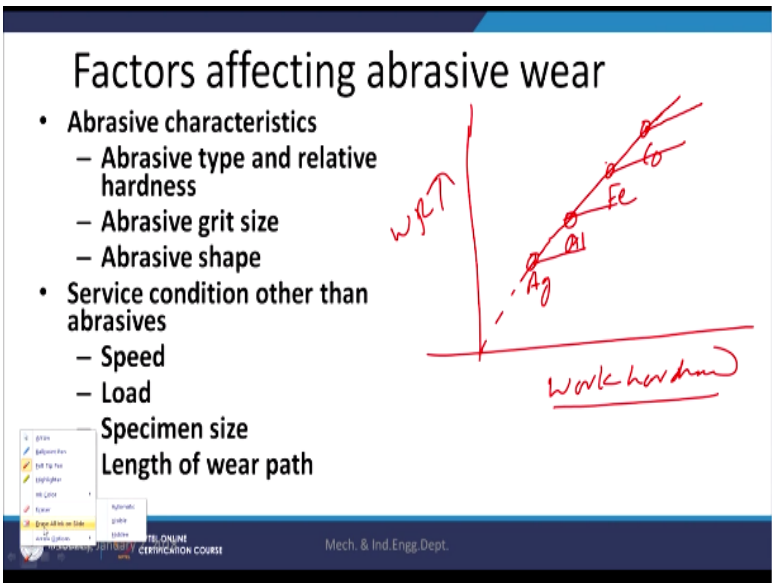

So it will be going like this for the pure metal hardness variations say for silver, aluminium, iron, cobalt. So when we work hard in the material this is for the pure, when we work hard in there is increase in the hardness. So hardness will be increasing as with the deformation. So what it is showing there is a division from the hardness of the material in the anneal condition hardness increases.

And increase in hardness due to the work hardening effect increases the wear resistance. So this is what is the typical diagram which shows that work hardening conditions shows the better abrasive wear resistance as compared to that anneal condition. Now this slide basically shows the different factors now which will be affecting the abrasive wear. So there are basically the 3 types of the factors, 1 is service condition related factors.

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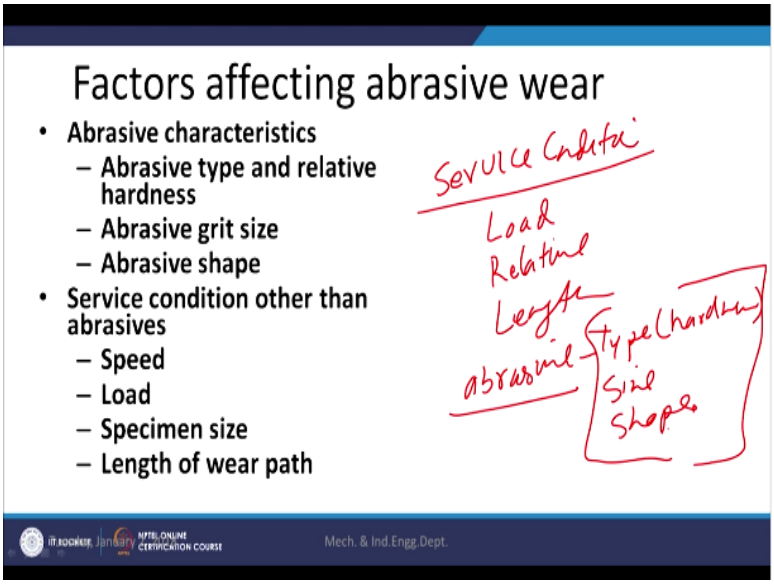

Service condition related factors means what is the kind of the load, what is the kind of the relative speed of the abrasive particles, what is the distance travelled are the length which will be covered by the abrasive during the surface, then what are the kind of the abrasives which will be interacting with the surface of the material like their type of abrasive affecting or determining their hardness.

And then the size of the abrasive particles, shape of the abrasive particles, these are the very important factors which will be governing the abrasive wear behaviour of the material, apart from this there are other material related factors and the surface condition related factors like the abrasive particles are interacting with the surface under the ambient condition or at high temperature in the dry condition or humid conditions.

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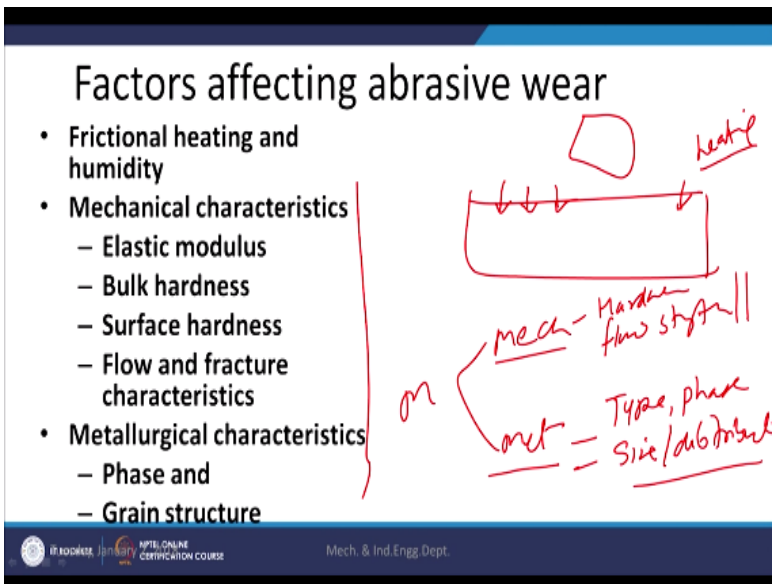

So these factors will be affecting the abrasive wear. For example if some kind of the heating is taking place of high temperature will be lowering the hardness of the surface layers reduction in hardness will be increasing the abrasion tendency and so the abrasive wear will be increasing. Similarly the material related factors there are 2 broad categories as per is the metal is concerned mechanical properties and metallurgical properties of the material.

So in the metallurgical properties basically what type of the face is it is having which type of whether it is simple soft matrix or it is a combination of soft hands of matrix in the hard particles like carbides. borides and oxides are also present. So basically type of the phrases or the constituent which are present. The second aspect is what is their size and distribution, in what size these particles are present and how are they distributed.

Among the mechanical properties it is basically the combination of the hardness and the flow strength of the material. These are the 2 important mechanical properties which will be governing the abrasive wear behaviour of the material. So now coming to the parameters which are relay abrasive particles characteristic. So abrasive particles are normally harder than the workpiece material surfaces.

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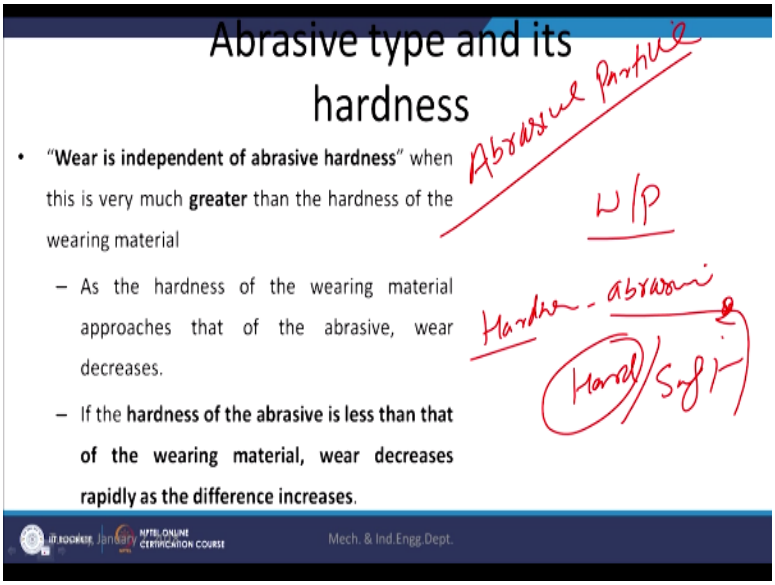

But these can be the softer also. So with respect to the work piece material what is the hardness of the abrasive that is used to define the abrasive as a hard or soft abrasives. So hard abrasives are those which are having the hardness greater than the workpiece material and soft abrasives are those which are having the hardness less than the workpiece material. So most of the time what will see that receives is harder than the workpiece material.

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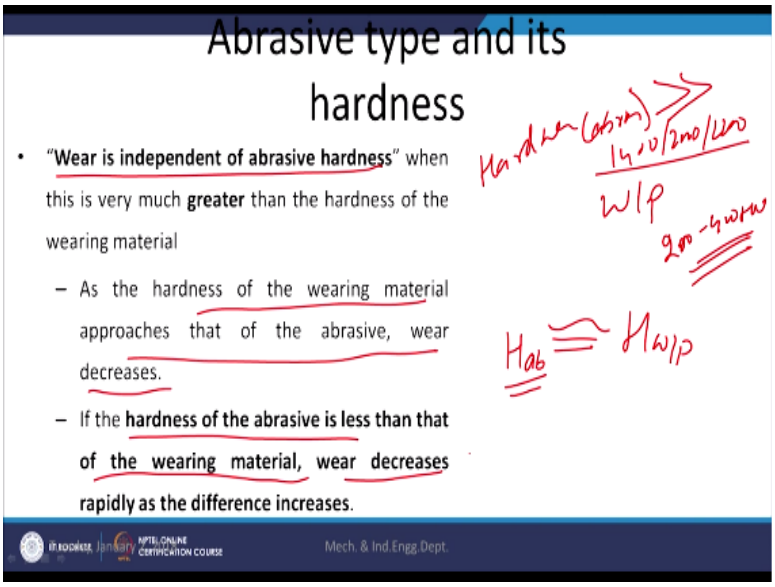

So when the hardness of the abrasive is too high, hardness of the average is significantly higher than the work piece like abrasives which are harder than maybe like say 1400 hvr 2200 or 2200 hv so it is very hard abrasive as compared to the workpiece which may be like 200 to 400 HV hardness values. So here if the hardness of the abrasive is very high then it does not affect the abrasive wear behaviour appreciably.

So this what is written wear is independent of the abrasive hardness if the abrasive to hardness is too high than the workpiece of the material as the hardness of the wearing material approaches the abrasive then the wear rate decreases or wear starts decreasing. So if the hardness of abrasives is almost close to that of the hardness of the workpiece then it plays a big role as far as the abrasive is concerned.

So if the hardness of the abrasive is less than the workpiece material then the wear decreases rapidly with the increase or difference which means if the abrasives are very soft then and as the difference of abrasive softness increases means the difference in the hardness of the workpiece and abrasive increases as far as the lower hardness of the abrasive with respect to the workpiece is concern then it will be leading to the reduction in the abrasive wear.

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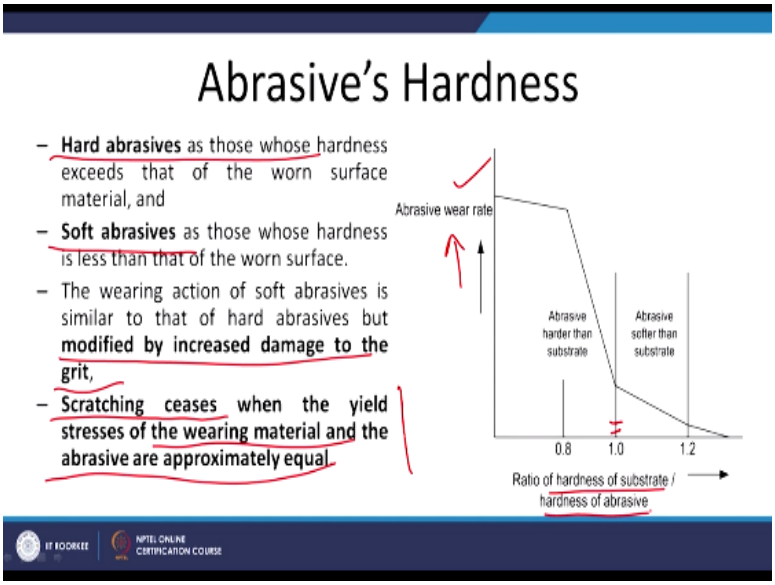

So if we ou compare the hardness of the abrasive and work material that we can find the ratio. So ratio of hardness of the substrate and hardness of the abrasive. So if the hardness of the substrate is less and hardness of abrasive is more then it will be causing the higher wear rate. So greater is the lesser is the value of this ratio greater with abrasive wear rate or abrasion of the material. If the 2 are very close the substrate hardness and the abrasive hardness is very close.

Then it will be causing the lesser wear rate lesser abrasion and further if the ratio is greater than 1 means the hardness of the substrate is more than the hardness of the abrasive and this will be reducing the abrasion of the workpiece further. So if the hardness of the substrate is very less and hardness of the abrasive is more then it will be causing the higher wear rate. So this what has been detailed out here in this slide.

Hard abrasives are those who is hardness is greater than the workpiece hardness and soft abrasives are those whose hardness is less than that of the work piece hardness and wearing action of the soft abrasive is similar to that of the hard abrasive but what it is modified with increased damage to the great size. So soft abrasives will be modified very rapidly as compared to that of the hard abrasives in course of the abrasion.

And when the scratching action is stopped or it is reduce the significantly when the yield stress of the wearing material and the abrasives are approximately same. So means if the hardness of the workpiece and abrasives are almost close to each other then it will be causing the lesser abrasion. Now here I will summarise this presentation. In this presentation basically

have talked about the various factors that affect the abrasive wear behaviour of the material, thank you for your attention.