Manufacturing Processes II
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Lecture No. 30
Superfinishing Processes

Welcome to this lecture session on Superfinishing processes.

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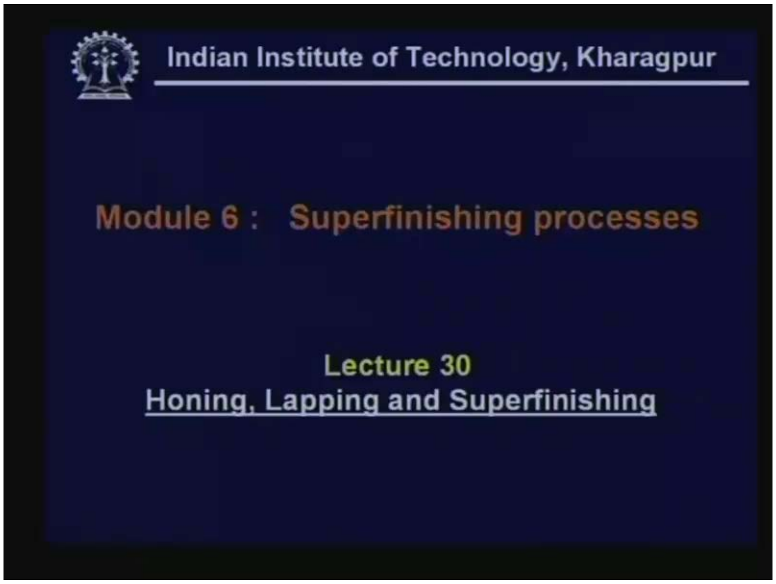

High performance machineries designed for faster operation, reliable operation over a longer period of time requires the following characteristics. It must attain high level of dimensional accuracy as well as form accuracy on the components which are used for building the machine. Similarly the surface finish of those components should be of very high value. Last but not the least the surface integrity should also have marked improvement.

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Now here what we can see that this high dimensional requirement, surface finish requirement or surface integrity requirements. These are actually influencing the functional characteristics of the each individual component like wear resistance, resistance to fatigue, resistance to corrosion and also the minimization of the friction. As we understand for a mechanical machine, reduction of friction is extremely important. Similarly fatigue resistance for high-speed operation with alternating load, the surface should not have any flaw. Similarly it should be protected against any possible corrosion over a longer period of time.

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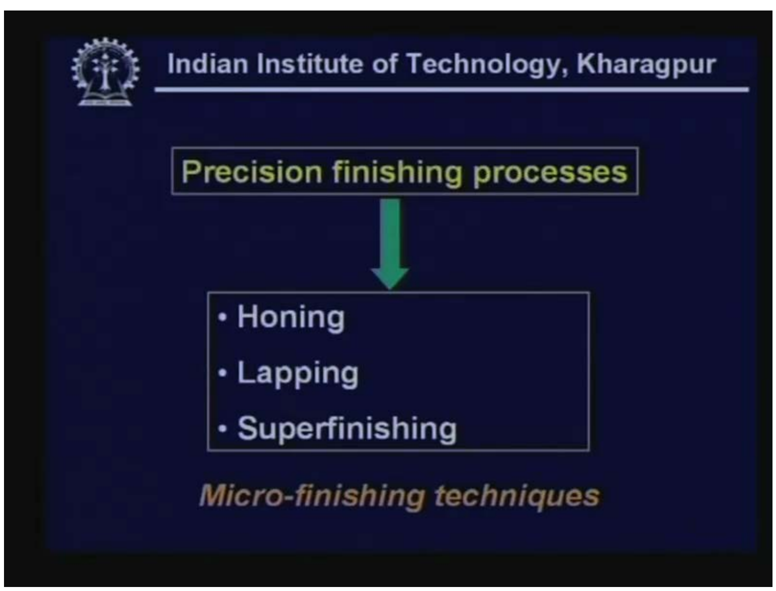

As we understand that to get this surface, the work piece has to be processed. Here the processing means removal of the material in the form of chip. We know that, there are already some existing processes like turning, shaping, milling and also grinding. Unfortunately, what we find here that this stringent requirement of this extreme or ultimately accuracy on the dimension or on the profile or very high level of finish or the enhanced or augmentation of the integrity of the surface just cannot be achieved by following this above said processes that is why came in to being, this precision finishing processes which includes honing, lapping and super-finishing. Now this three honing, lamping and super finishing are also called the system of micro-finishing techniques.

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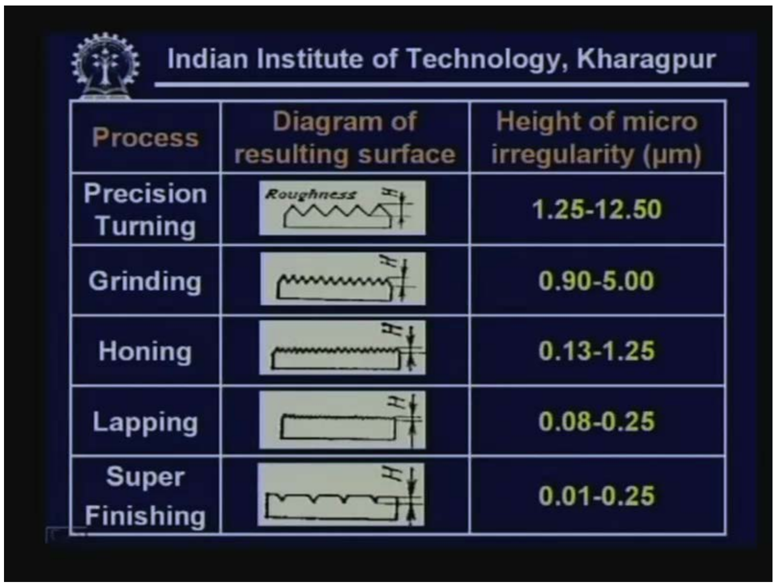

Process	Diagram of resulting surface	Height of micro irregularity (μm)
Precision Turning	Roughness	1.25-12.50
Grinding		0.90-5.00
Honing		0.13-1.25
Lapping		0.08-0.25
Super Finishing		0.01-0.25

Now here we find one illustration which shows the various processes and against each processes, what could be the surface roughness which can be attended? Even if we consider a precision turning, although we get a regular surface profile by using proper geometry of the cutting tool, right kind of machine environment. But still, the roughness is quite sizeable. We can say that in that microscopic scale, this irregularity that means the height of the roughness is also deviation from the ideal surface. What we mean to say here that, this irregularity also causes some deviation from the actual dimension.

From precision turning, we can go to grinding. Of course, what can be seen that these micro irregularities can be markedly reduced. But still, in that microscopic scale, still it is the deviation from the desired dimension what one like to achieve. Here we can see gradually, the roughness value has been brought down. But what has been all ready said that the surface finish what can be achieved in this range that cannot satisfy the need. So that, in order that the component can work in a very reliable manner for that we need further improvement not only on the surface finish but also on the surface accuracy and also on the surface integrity. Now to have that, we have here first comes the honing process.

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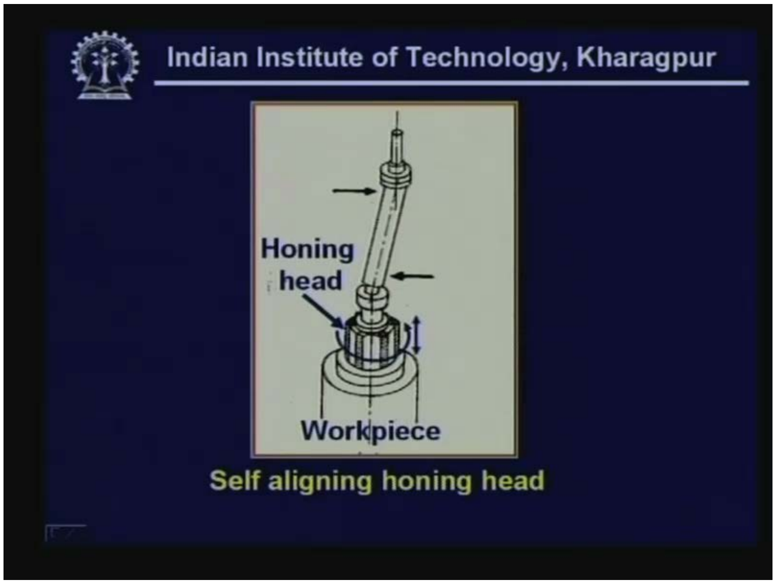

This is the schematic representation of a honing process. As we know, in any material removal process. There should be an interaction between the work piece and the cutting tool. In this case, what we see that we use a work piece and we are interested to have improvement on the surface quality of the internal surface and for that a tool is preferred in the form of a honing head and this honing head consist of a number of abrasive sticks fixed to this honing head. Now this abrasive sticks comes in the form of bonded abrasive. Now here, we have various motions to perform the honing action. What are those motions? Primarily the honing head should rotate. In addition to that, it should also reciprocate along the axis of the hole. As a result the desired surface is obtained.

Now one thing can be noted here that, this honing head is not guided by the machine honing machine, but it is guided by the hole which is originally made on the work piece. So to have proper alignment of this honing head, we have to provide some flexibility here and which is nothing but to universal joints. So according to the orientation of the hole, the head will guide itself and it will move along the axis of the hole in the form of an oscillatory movement. Now what are those characteristics of the honing?

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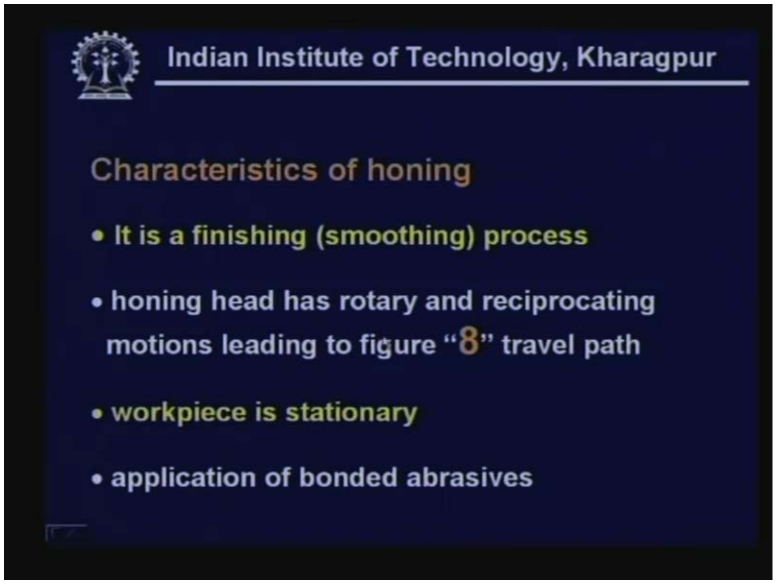

It is basically a finishing or a smoothing process. Honing head has both rotary and reciprocating motion. This rotary motion is a unidirectional motion. As a result, we can see that the track which is followed by this abrasive cutting points. It almost looks like the figure eight, that means the travel path is almost like a figure eight. It is a closed loop than the work piece is remained stationary. It does not have any movement and we can use bonded abrasive in this honing process.

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Although we use abrasive grit, it is an abrasive action but it is not similar to grinding. It is quite different from grinding. How let us look in to this? At least if we consider the grit density at least 100 to 1000 types more grits are participating in this abrasive action in this honing head. Cutting speed is fairly low in this honing operation. It is about one fiftieth to one hundredth of the grinding speed. It is fairly low then if we consider the grinding pressure or the cutting pressure a pressure is required for the cutting action for the formation of the chip and in that respect, it is also one six to one tenth that of grinding and if we consider these three characteristics that makes its quite different from grinding operation.

Now if we consider application, in this application what we find? It is basically meant to improve the surface finish of a hole and the size of the hole can go from 3 millimeter which is quite low to as high as 1000 millimeter. Now so far as work material is concerned, we can have it covers a wide range starting from very soft material to very hard material. Soft material for example: silver, brass can be quite effectively honed by this technique. Now if we go to the other end, we have hardened alloy steel, hardened carbide and ceramic. Those can be also handled by this honing process. Then, we have also some attainable tolerance. Of course that is in production honing, it can be regularly attainable in the order of 2 to 3 micron.

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Now the types of abrasive material which plays the most important role in this cutting action: These are the actually abrasive materials. We have just like grinding, conventional abrasive and super abrasive which can be readily used in making or in bringing up this abrasive stick which constitutes the very vital element of the honing stone. We have on the conventional side, aluminum oxide and silicon carbide and the super abrasive family diamond and cBN. cBN is the new addition to this family, just like grinding aluminum oxide is recommended for honing steel and ferrous material and when it comes to non-ferrous material or nonmetals in the softer ranger less hard silicon carbide can be recommended. Diamond is used for handling non-ferrous very hard material where silicon carbide cannot be a very good performing element and cBN has been all read said it is a new addition and with this cBN, what can be done? Hardened steel like various material which are used for making components, alloy steels, those can be very easily tackled with this cBN. Now here we see how the honing stick works within the hole.

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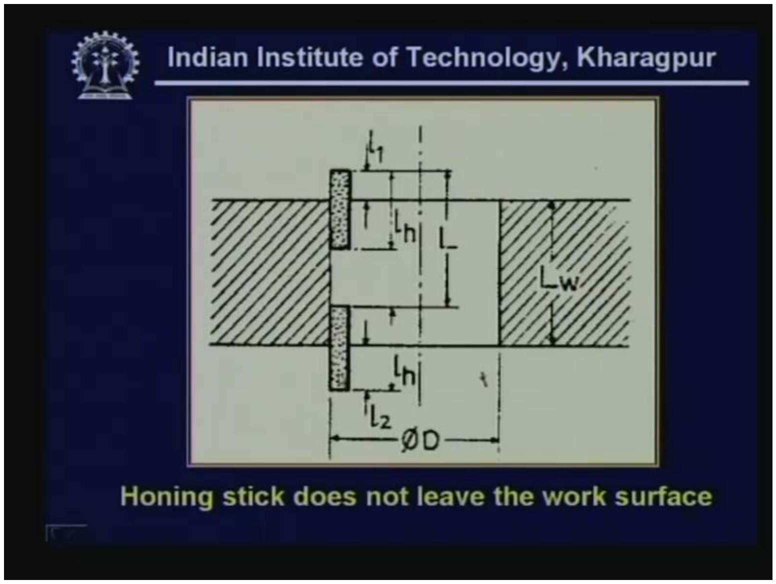

This is the initial position of the honing stick and this is the final position of the honing stick over which it is reciprocating. So here, the stroke length has to be determined correctly. One thing to be noted that the honing stick should never leave the work piece either during the forward stroke or during the reverse stroke or the upward stroke. There should be always some overlapping or contract and to have this properly done, we have to consider the length of the stick, the length of the hole and this overlap what is on the upper side and what is on the lower side considering all these parameters, the stroke length of the honing stick is determined.

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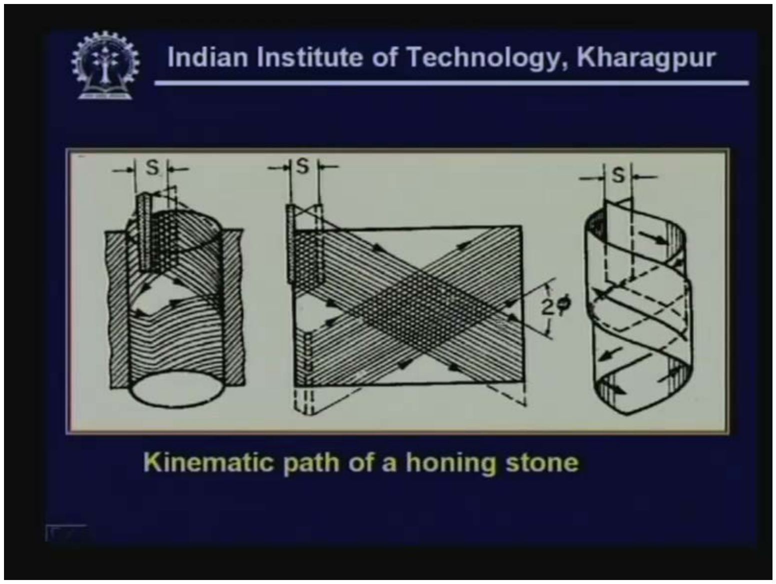

Here we see clearly, the path followed by this honing stone. It has a unidirectional rotation of the honing stone, but it has a continuous reciprocating motion and we can see it gets a eight like figure originated on this hole made by some other previous processes and we get cross hatch mark and these steps determine this determine by this upset and by this overlapping cards. This improved surface finish can be effectively obtained in this honing process. Now we got to the operational parameters of honing.

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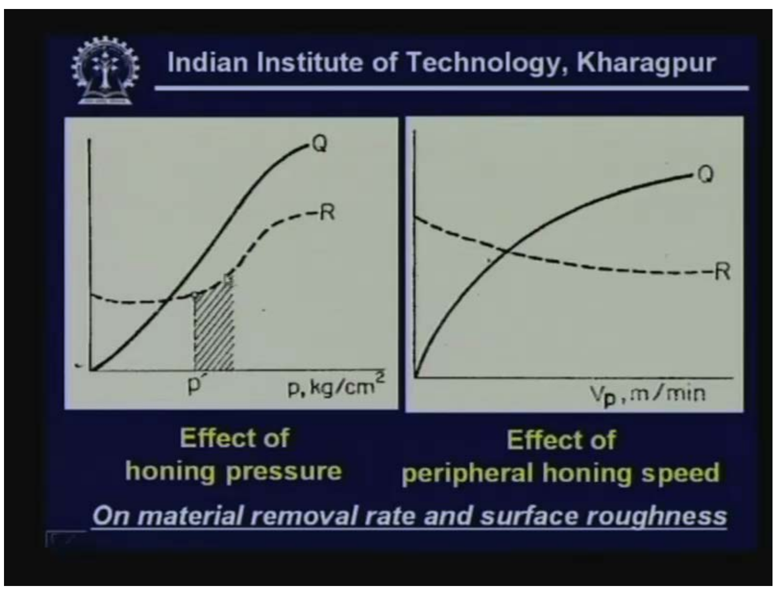

We find, at least there are two parameters in honing. One is the peripheral honing speed of the honing stone. Another is the unit pressure, which is exerted on the surface to be honed.

So these are the two important parameters deciding and now what is our goal? Atleast we have two goals: One is the material removal rate, another is more important that what is the level of surface quality, what we can achieve out of this honing process and here we have to see the very influence of this unit pressure and this peripheral velocity of the honing stick. Let us look in to this graph. Pressure along this axis, and we have material removal rate and also the surface roughness which develops because of this honing action.

What we see? With the increase of pressure, we can increase the material removal rate. But what we see here, over a certain range of pressure, the surface roughness is almost steady and after that it takes a rise. It is a rising curve like this. Now, where we should fix the pressure? Now to choose the right value of pressure we have to see? What is the limiting value of the surface roughness which we can allow or what is our limit? Now here see, this be this limit, then we have to fix the pressure here over say certain range where we do not have any marginal increase. But if we go little bit then perhaps we can gain a lot in terms of material removal rate. But, we cannot go beyond that why because the surface roughness will increase substantially.

So, the hatch mark the zone shown by this hatch mark shows the range of pressure which can be conveniently used to get the desired surface roughness and also a sizeable amount of material removal rate. If we go to the right hand side of this diagram, the variation of material removal rate and this doted line shows the roughness. With increase of this peripheral velocity material removal rate can be increased. We can also reduce the surface roughness. That means this speed, if it is permitted by the machine and its all system, then by just increasing the speed, we can achieve some improvement in surface finish. What does it mean? Lowering of the surface roughness and increase of the material removal rate.

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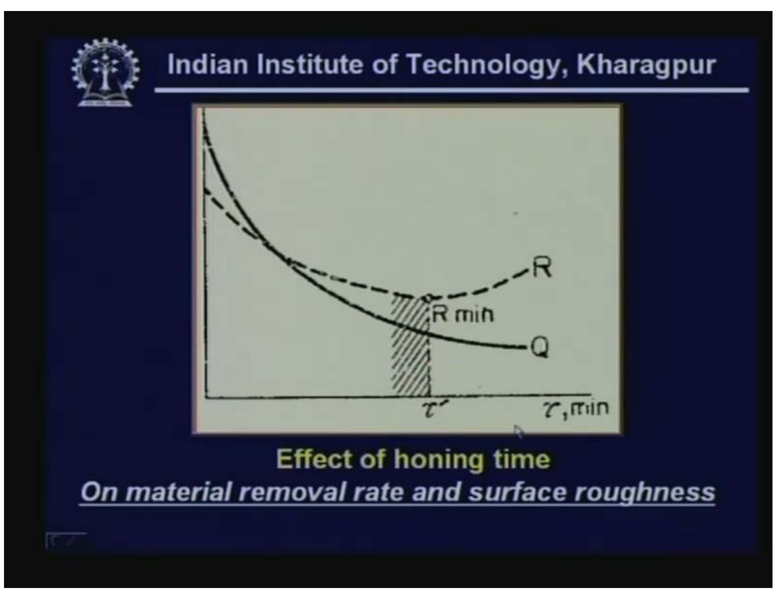

Now we have another which is represented by the tau that means the honing time that is very much connected with the productivity. If we look if we prolong this honing time then the material removal rate decreases, for a constant unit pressure. This may be because of the dulling action of the grits and it gradually losses its cutting capability and that is why it has a falling trend, but here we can find a minimum value of surface roughness and then again it has an increasing trend. So, we can say that our goal is to achieve the desirable surface roughness and we can just leave here this should be the preferred honing time which satisfied the need of achieving the surface roughness.

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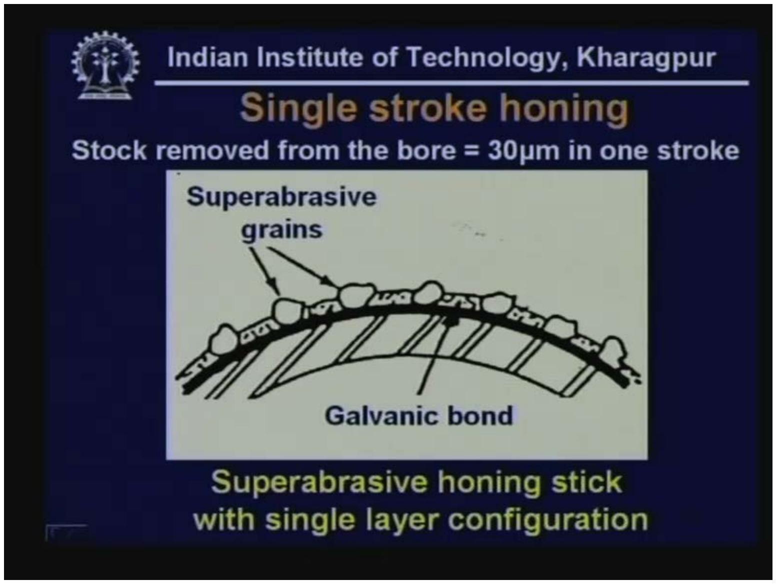

Now the honing; so far we have discussed it is a multi-past honing that means the tool is suppose to reciprocate for a quite a number of times, but here what we see a quite new type of honing stick. What we have discussed so for that is a bonded abrasive, but this is a composite structured bonded abrasive that means, the abrasive grain and the bonding material they make a composite structure. But, the figure what we can see here that is a special type of honing stick. It is very similar to a single layer grinding wheel. Here, the grits are formed in the configuration of a single layer which is bonded or embedded in a galvanic layer. Now what we achieved here that larger chip clearance space and this honing stick can be safely used with increased material removal rate, which is not just possible with a bonded stick having a composite structure.

Now with such material we can go for higher material removal rate. So following this idea, attempt can also be made to have superabrasive honing stick with a single layer configuration but here we can replace this galvanic bond with a best bond because we already know that, this best bond has a chemical attachment with the grit and this best bond can provide much more chip clearance space which reduces the risk of chip clogging during honing. So as we can see here this honing stone can be used of high stock removal rate. For example a 30 micron stock cannot be removed from a bore in one stock. So these types of sticks are used for single stroke operation. Now we go to lapping process.

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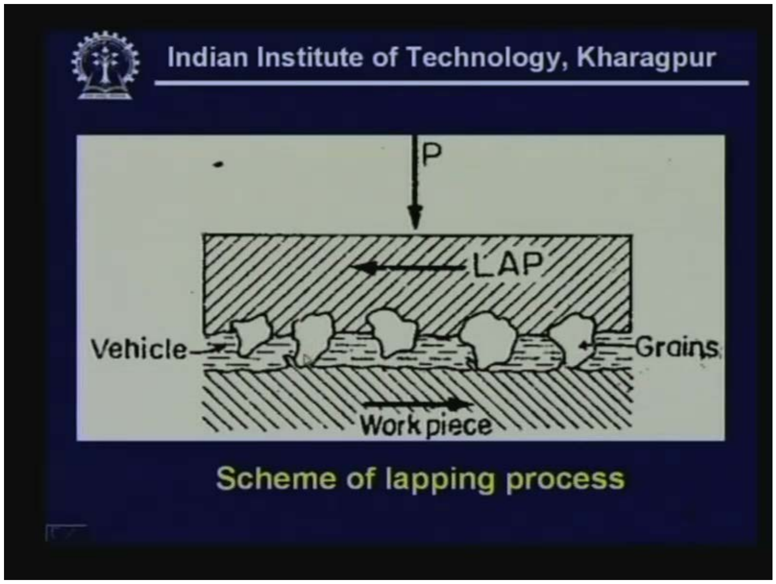

What we see here? Instead of a bonded abrasive the loose abrasives are used in honing we used bonded abrasive but in lapping the loose abrasive. Now these loose abrasives are carried by a vehicle which is in this form of oil or grease. Now they have a momentary support from a top surface which is a piece of metal usually made of a cast iron and this is a cast iron block which provides a necessary support and the necessary pressure. What we see here, the work piece which needs the further improvement so far as the surface quality is concerned. So here, these grains are working like sharp cutting points getting momentary support from the LAP which is the top component and which is a cast iron block. A pressure is excreted and this grits, now they are very very active in formation of the chip tiny chips and getting the right surface finish on this work piece. So if we can summarize the characteristics of the lapping process.

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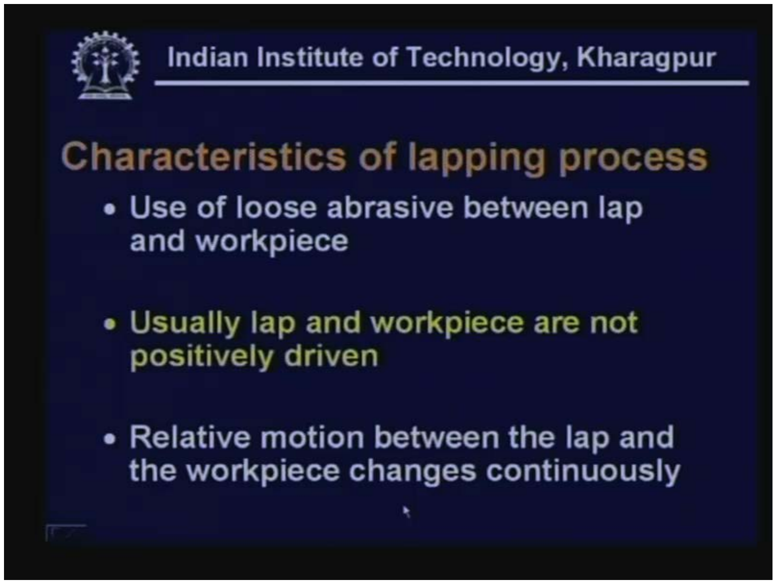

Number one the use of loose abrasive between the lap and the work piece then lap and work piece are not positively driven. They are not positively driven, then the relative motion between the lap and the work piece changes continuously because they are not positively driven. So we have reviewed the characteristics of the lapping process, then comes the abrasive which are used in this lapping operation. It is also abrasive process using loose abrasive material.

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Here we can see aluminum oxide and silicon carbide. These are the two commonly used lapping materials then, what is added? Chromium oxide for with finer grit size that can be also used boron carbide which cannot be used in any grinding operation or grinding wheel that can be effectively used in this lapping operation, the grain size is little higher. Finely, we can also use diamond with a very fine grain size. So aluminum oxide, silicon carbide, chromium oxide boron carbide and diamond. These are the usually used grit material than the vehicle materials machine oil rapeseed oil and grease. These are the three materials which acts like a transport or the carrier of these abrasive materials. Here some illustrations are given how lapping is conducted.

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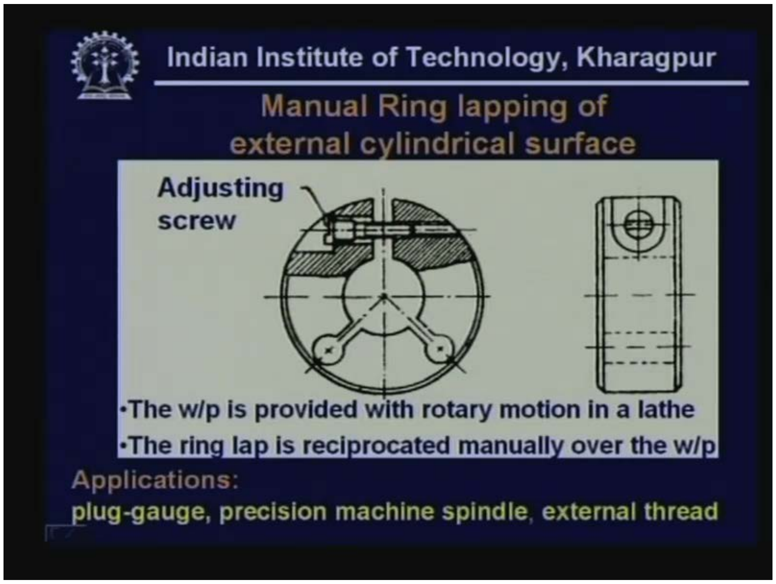

There are actually two types of lapping. One is called manual lapping, another is called machine lapping. In manual lapping, what we can see? It is an example of external lapping external cylindrical surface external cylindrical surface like a shaft. So, this shaft can be held in lathe and it it is provided with a necessary rotary motion then a piece in the form of a bush comes and it is fitted with this rotating cylindrical piece which needs this lapping. In between this cylindrical ring, and the solid piece to be lapped is added the lapping material. Now the pressure can be adjusted that means what is known as the lapping pressure to have the proper lapping action.

There is an adjusting screw which can be tightened to have proper lapping pressure around the cylindrical surface. So the cylindrical surface required to be lapped has an automatic rotary motion provided by the machine. However, this ring which is the lap it has to be reciprocated along the axis of the job manually and that is why it is called manual lapping. So this ring lapping finds use in plug-gauge lapping machine spindle which needs much precision and also lapping of external threads. This is an important operation which can improve the surface quality of the thread surface markedly and obviously it can be understood that the internal ring the ring internal surface of the ring should have an internal thread profile just like a nut which will participate in this lapping action.

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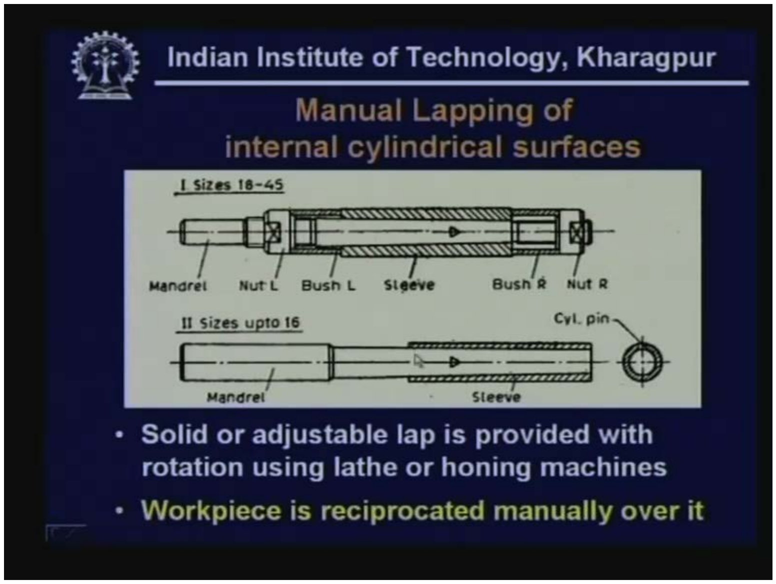

Now we go to the internal cylindrical surface like a bush or a liner, it also need lapping. So in this case, what is done? A mandrel is taken which serves like a lap. This is the lap which is a solid piece which is allowed to rotate, so it is held in a lathe and provided with the necessary rotation and this tube or a sleeve which needs lapping on the internal surface that is reciprocated manually over this mandrel along the axis, and in between the lapping material or the lapping medium is provided and this is how this manual lapping of internal surface is conducted. We also have machine lapping:

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Now when we have more number of work pieces or large amount of material to be removed during relatively what I mean then this manual lapping become say tedious job, then one has to go machining machine lapping with the help of a machine and this machine lapping obviously facilitates economic production of the material by lapping. Now here, what we can use? Either loose abrasive has been all ready illustrated with suitable vehicle or a bonded abrasive which is bonded in a suitable plate in the form of a plate or in certain other form that can be also used. Now in this lapping machine family we have a classification. Now machines which uses a cast iron or a bonded abrasive circular plate, it can be a cast iron block which can use loose abrasive or it can be a bonded abrasive circular plate which is used for either lapping a flat surface or a cylindrical surface.

This is one category of the machine. Now for lapping cylindrical surface, we can use another type of machine which does not need any centre support and this is centreless lapping very similar to centreless grinding and it is specifically meant for lapping of cylindrical surfaces. We have the third type which is meant for lapping internal surface very similar to honing machines. So, these are the three types of machines used in lapping. This is an illustration where a lapping machine is used for production of either flat surface or cylindrical surface.

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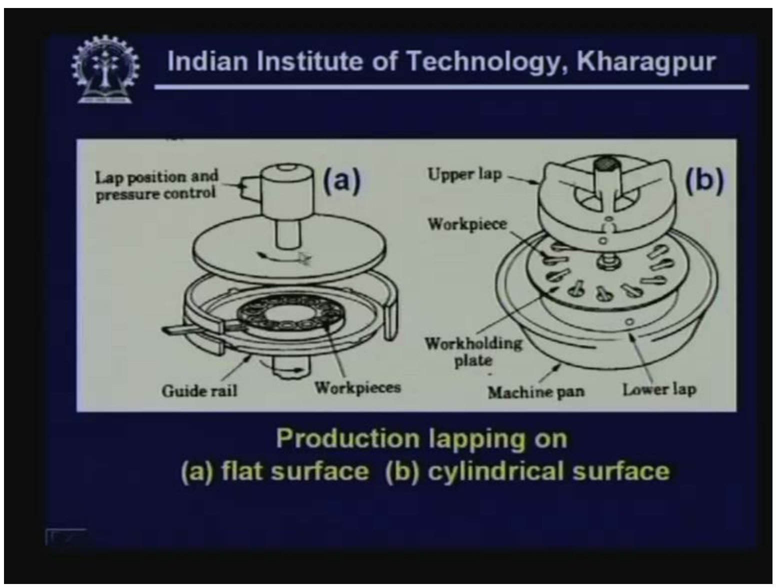

The work pieces are put on this table support which is rotating the lap which is provided at the top. It can be a provided with bonded abrasive it is also rotating. Now this should be correctly positioned to give the required pressure and this pressure can be precisely controlled to have the proper lapping action. So this is how flat surfaces can be lapped. So, similar principle can be also used in another machine which is dedicated for lapping of cylindrical pieces. Here to we have the work holding plate it is the lower lap the machine pan where this will be collected the upper lap which is doing the necessary lapping. Here also, a bonded abrasive can be in the form of a plate just at the bottom can be used to have lapping on the cylindrical surface. Now this is one example of centreless roll lapping.

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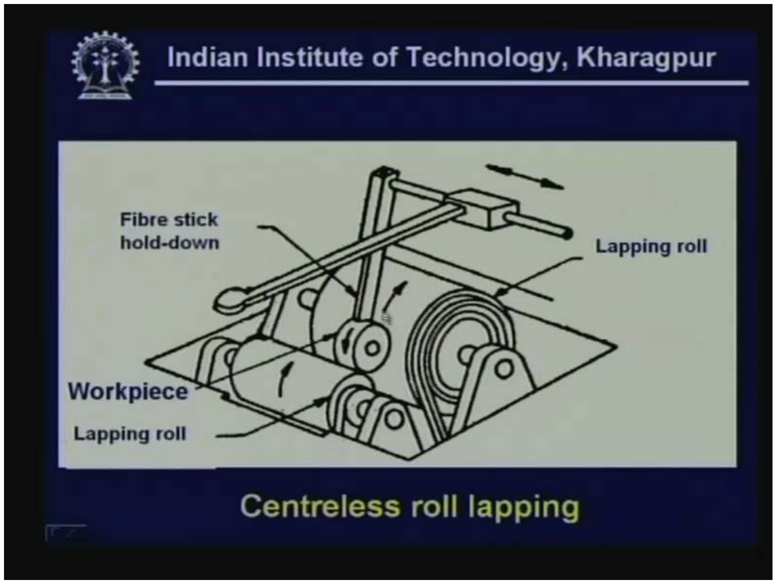

Here we do not have any centre support. This is the work piece; now these are the two rolls lapping rolls differing in their sizes. Now this work piece is almost supported between this two rolls and then there is a fibre stick, plastic fibre which is giving the support so that, it should not displaced during the rotation and the rotary motion is provided by this rolling action and the required pressure is provided by this hold down stick. So with this rotation and this reciprocation and this exertion of the pressure, necessary lapping action is effectively conducted on this circular or cylindrical surface of this work piece and this is how centreless roll lapping is possible. Now, we have to also look in to those technical parameters which are affecting the lapping processes.

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Here at least we can identify the unit pressure just like the unit pressure which is very much role process parameter in honing, then the grain size of the abrasives which are participating in this lapping action. Concentration of the abrasive in the vehicle as for example, in a unit volume, how much is the volume occupation by this abrasive grit and ultimately the lapping speed. So these are the four process parameters which are controlling the lapping processes.

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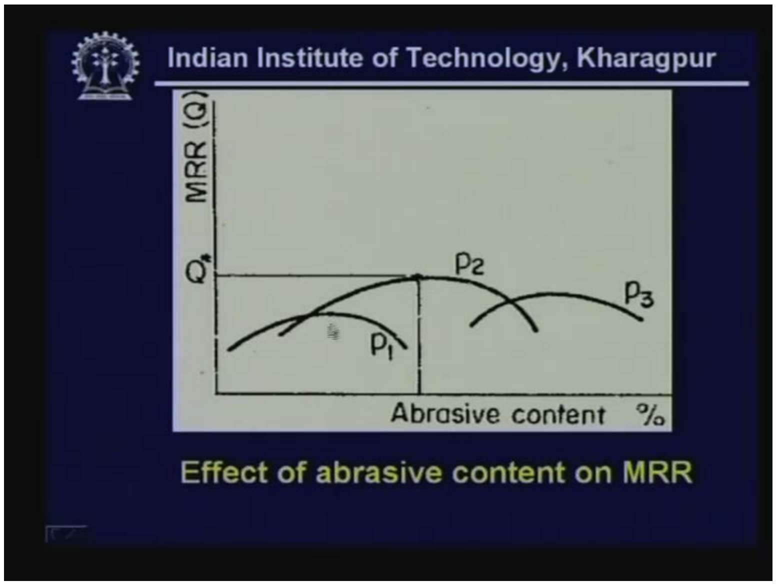

So, at least we can find there is some effect of this abrasive content in the vehicle which is put in the form of percentage, that means so much of the abrasive material content in the vehicle and on the axis, we have material removal rate which is also of interest. We have seen three pressures P 1 P 2 P 3 and suppose it's P 1, with this P 1 value for a constant P 1 value with the change in abrasive content, we can easily see that material removal rate is gradually increasing and then it has a falling trend. Now, if we change the pressure then the whole curve can shift its change its position. If we go to another pressure we can see that it has also certain variation. What is quite interesting to look that for each pressure, we can have a maximum material removal rate and which is not constant for all the pressures. So for P 1 here we have the peak. For P 3, here we have the peak and for P 3 the peak is indicated here. Now if we consider all the three pressures, then we can find P 2 is the best one. The pressure which should be chosen and this also corresponds to a particular abrasive content and which is not same for a unit pressure P 3 or P 1. So what we can see the effect of abrasive content on the material removal rate which starts with a rising trend and that it attends a peak and then again it has a falling trend.

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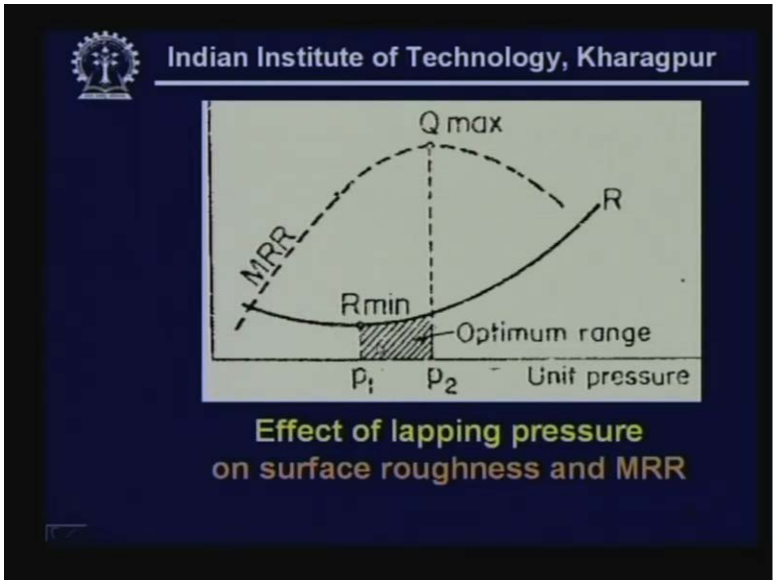

Here we find the variation of unit pressure influence of unit pressure on two criteria like any machining process. Anybody is interested either in material removal rate or the surface finish which is achieved. Now here, what we can see that this roughness value it falls little bit and then it has a rising trend, whereas material removal rate. It continuously rises with increase of unit pressure. It attends a peak value and then it has a falling curve. We have interest for both higher material removal rate and lowest possible surface finish but, however the surface finish is the major goal. So, we cannot sacrifice the surface finish that means we have to look the pressure which gives us the best possible or the lowest possible surface roughness.

Now keeping this in view, keeping this is in mind, we can have the highest value of the material removal rate and then we can see a zone which is shown by this hatch mark. This is a point where the pressure value can be chosen. If we go to the left hand side, we still get a good value of the surface roughness but here we are sacrificing the material removal rate. So still we can push the pressure little towards the right hand side, without any sacrifice on the surface roughness. But gaining something in terms of material removal rate. This is what we can see the influence of grain dimension, the size of the grain or roughness value achievable and the material removal rate with increase of grain size this is continuously increasing just like any abrasive process with increase of grain size this is continuously increasing just like any abrasive process.

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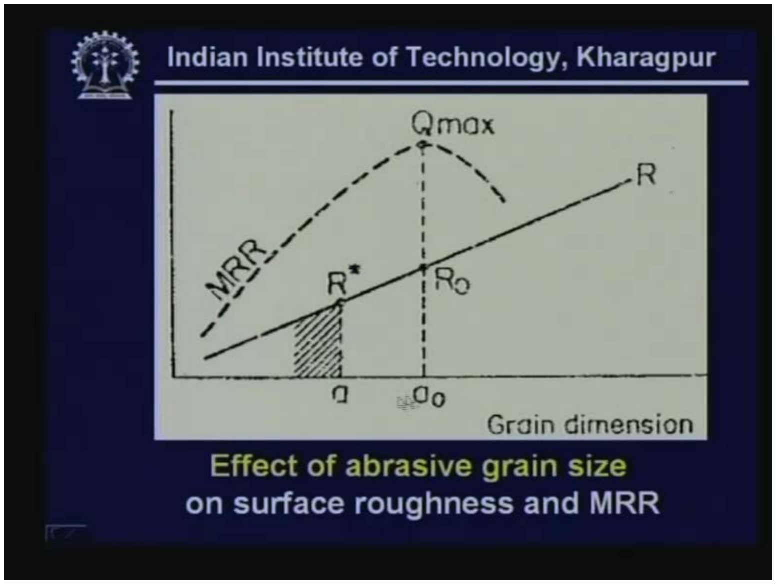

However the material removal rate that has a rising tendency and after attaining a maximum it has a falling trend but from the requirement of achieving the surface roughness which satisfy the very need of the quality of the component to be machined or produced. There is a fixed surface roughness which is fixed which is fixed considering the effective functioning of the component. There we cannot make any compromise. So this is the value which is fixed. So with this value we have to choose the grain size and that is the best possible grain size where we can have the right value of the surface roughness but if there be any adjustment is made if there be any flexibility. So that, we can allow the surface roughness to increase to attend the highest value of surface finish. Sorry, material removal rate then perhaps we can go to higher grain size then comes the lapping time, its influence on material removal rate and the surface roughness.

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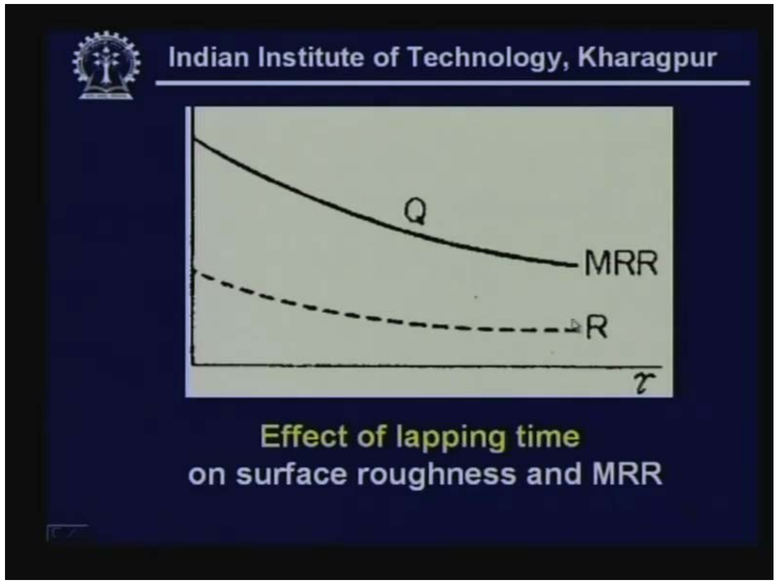

As we know, since it is the abrasive grids which are being used continuously, they will show some dullness, loss of roughness and with the same constant pressure material removal rate will fall because of the loss of cutting capability. But, this also enhances surface finish or reduces the surface roughness. Both, we can achieve by prolonging the lapping action over a period of time. Now we have to choose the lapping time.

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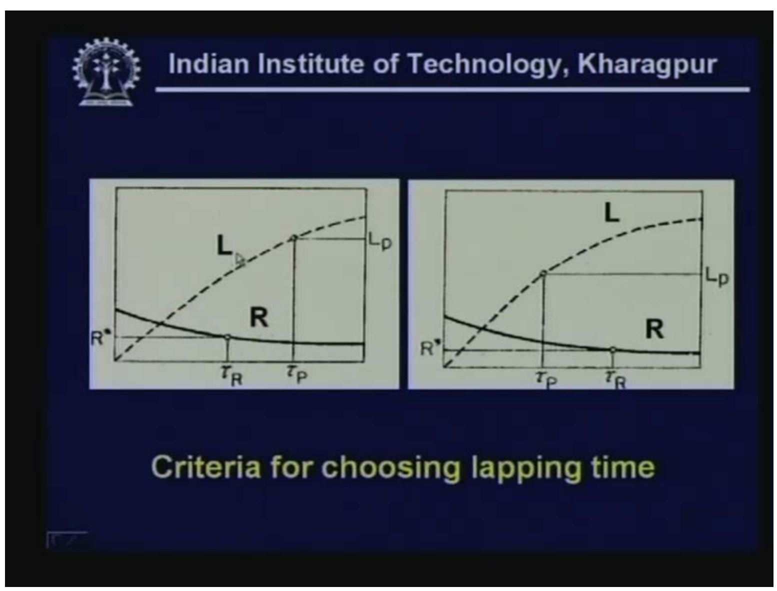

There are two issues; very very important issue. One is L, what is L? L is actually the linear loss of the dimension that means L has also a fixed value. What we can consider as the allowance? So, gradually as the lapping is being continued the material is being removed and there is a loss of material. So this loss has a limited value. We cannot go beyond that. At the same time, we have to achieve the surface roughness as fixed. Now if we can achieve the surface roughness at a time which is tau R much before we go to the limit in terms of the allowance, then we choose tau R as the criteria for choosing the lapping time. It can be the other way. It may so happen that roughness value is chosen it is a very low value and this cannot be achieved over a period of time reasonable period of time and it is quite longer.

We can compare these two curves. Here the lapping time is longer to achieve a lower value of surface roughness but this L p that is permissible limit on the material loss we cannot go beyond that point. So this tau R cannot be allowed so lapping cannot be allowed over this tau R. So what have to be done? All the process parameters have to be readjusted. So that this tau R always becomes lesser or equal to tau p tau R cannot be greater than this tau P. We have another graph showing the effect of lapping speed on achievable surface roughness and linear loss of the material.

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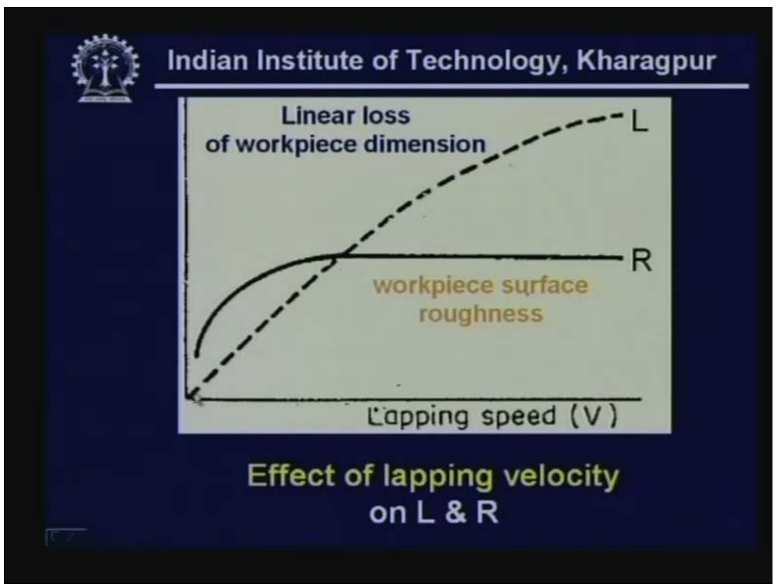

What can be seen here? The effect of lapping speed that increases this linear loss at a faster rate that means if we increase the lapping speed, this loss will also increase over a given period of time but work piece surface finish that increases and that also becomes steady after a certain value of this lapping speed. These are the two influence of lapping speed on linear loss of work piece dimension and also the work piece surface roughness. Now we go to the super-finishing operation.

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Now what is mean by this superfinishing? This superfinishing is somewhat very similar to honing. However, there are certain differences with respect to honing. Number one in case of honing, we have a longer stroke which covers the entire length of the work piece but in this case, we have a short stroke. Its not a longer stroke, it is a very short stroke and its very rapid that means the frequency of oscillation is very high compared to honing. Then compared to honing, this has a low cutting speed and a low cutting pressure and as a result rise of temperature during the superfinishing process is well within the limit and that protects the quality of the job because of this high frequency operation the abrasive bonded abrasive stick which is engaged in the super finishing operation that is that does not suffer from chip clogging because chip is produced and that may accommodate within the chip ah within the intergrit spacing but because of this rapid oscillation, the chips are thrown out or evacuated from that chip evacuation space.

What is the advantage of this superfinishing? What we can see here? It removes effectively chatter marks vibration marks which may develop during cutting, feed marks or the scallop marks which arises out because of the tool geometry and the feed that can be also successfully removed. If there be any mark by some grinding action, which comes out as imperfection, those can be also effectively and fairly removed by this super finishing operation. This is one example of superfinishing operation carried out on an external cylindrical surface like a shaft or a spindle.

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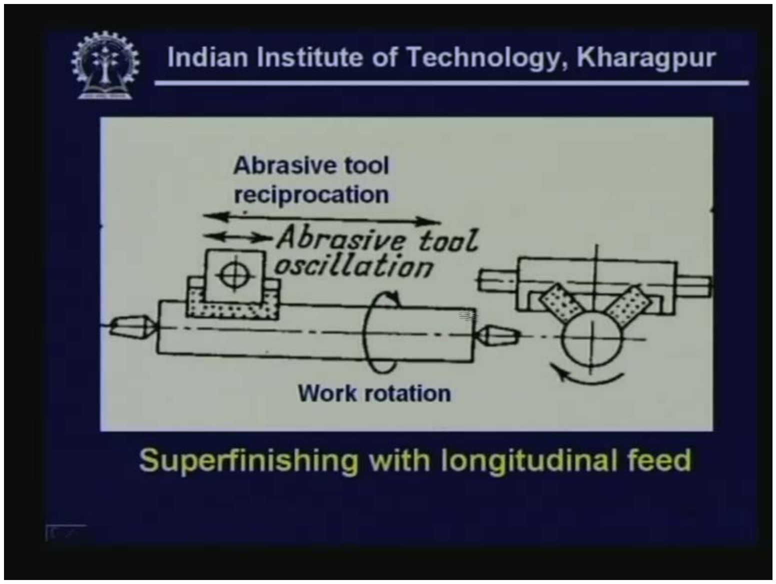

What we can see that the work piece is held between a centre and it is provided with a rotary motion. Now here, we can see that superfinishing stick which is engaged in this abrasive action. What we can see that abrasive tool will reciprocate over the entire length of the work piece. Additionally, what is the special feature? This abrasive tool also oscillates that means it starts its oscillating action, slow oscillation at the same time is moving along this axis over a period of time. So that is why we get this abrasive action. We have another example where this superfinishing can be conducted in the plunge cut mode.

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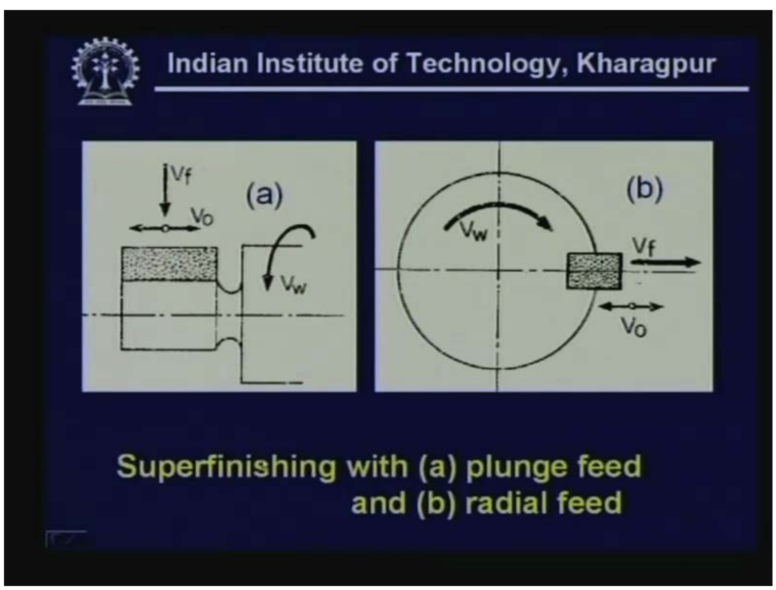

Here this abrasive stick has an oscillation, but it does not have any reciprocation only a feeding is given in this radial directing and it is doing the necessary super finishing operation. This illustration shows, how this superfinishing can be extended over the end phase of a circular plate. This oscillation is carried out in the radial direction while the surface plate is also rotating and a feed is given in the radial direction. This is another example of superfinishing operation where the work piece is stationary.

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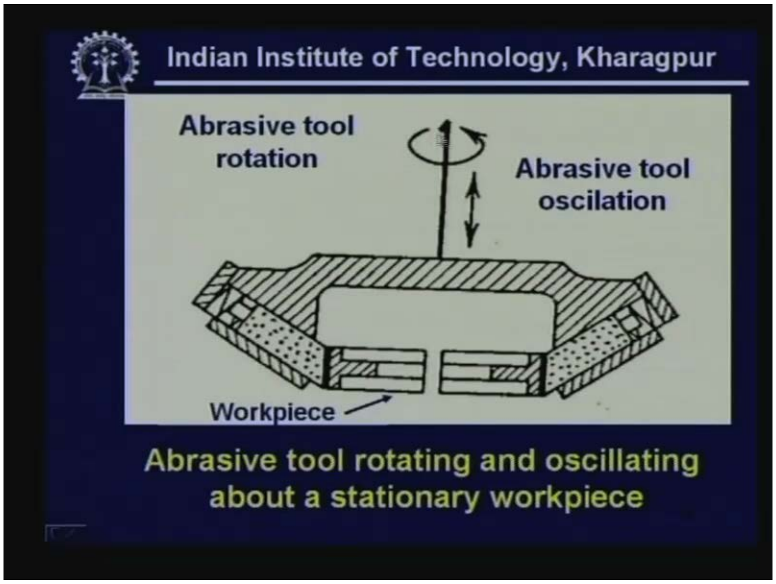

This work piece so far what we have seen that is rotating in nature. But, here the work piece is stationary and this outer surface that is the abrasive tool which is continuously rotating and at the same time an oscillatory motion is provided. So we can see this is the abrasive section of this abrasive stick which is arranged over this head and over this peripheral surface. The necessary oscillation actually produces this superfinishing superfinshed surface by this rotation of the abrasive tool and by the oscillation of the abrasive tool two. This two are combined over a stationary work piece. This is one example where we have oscillatory motion of this abrasive tool and which can be carried out to have the superfinishing action on an internal surface.

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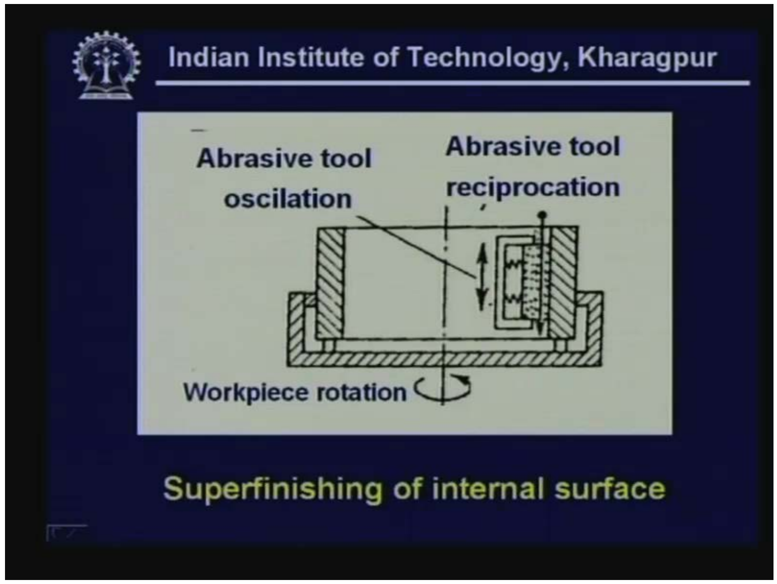

We have oscillatory action, on the abrasive tool. Rotation of the job and the reciprocation over the entire length and when these three motions are combined, we get this superfinishing action on the internal surface. This is abrasive tool which is in action superfinishing action over a flat surface.

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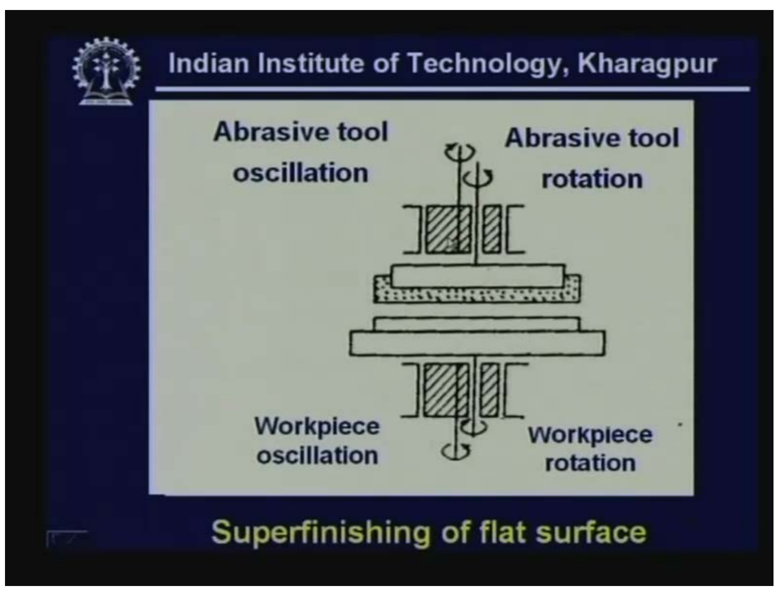

Here oscillatory motion is provided both on the work piece and also on the abrasive tool by some eccentric rotation. It has one axis which gives the rotation and the oscillation is provided by some eccentricity.

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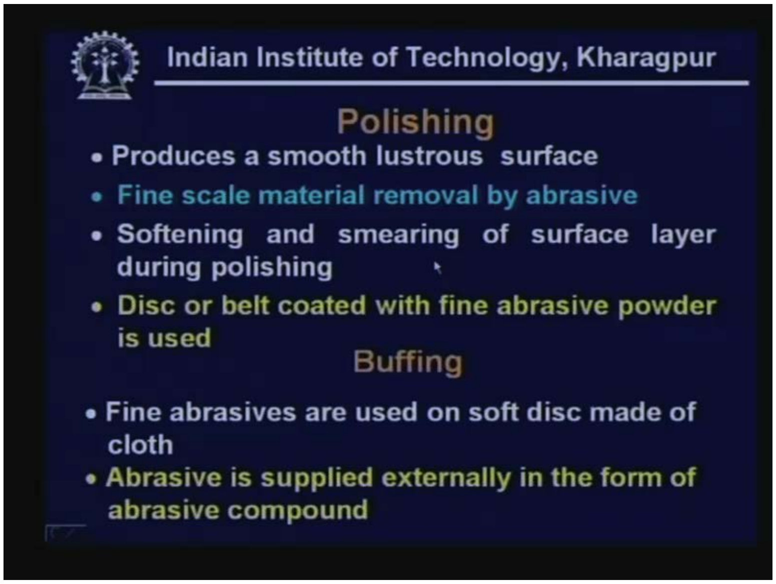

We have mechanical polishing which uses a polishing cloth and it is by this mechanical rubbing. This polishing is done by softening and smearing of the surface. Buffing is just and extension of polishing where we have still finer cloth this made of cloth and here we have finer grit. So, these two are actually mechanical action.

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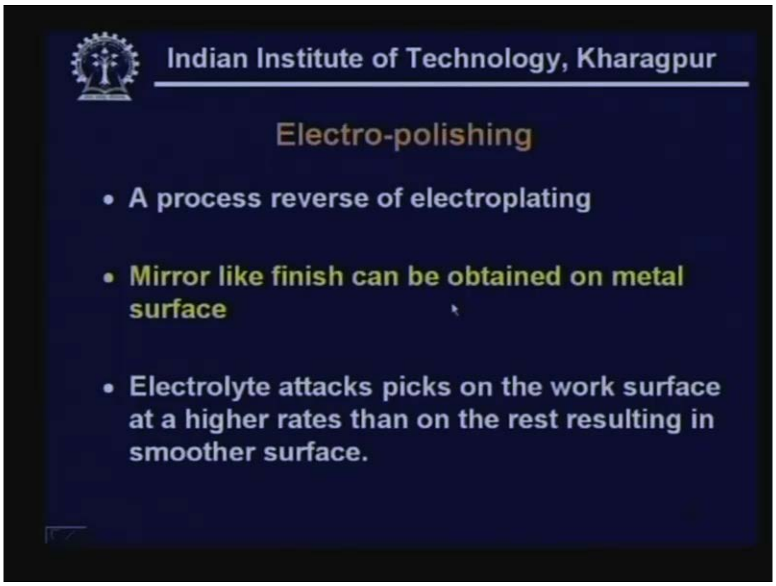

This is electro-polishing, quite different from the mechanical action. It is just reverse of electroplating. Just by having the electrochemical dissolution, by having the electrochemical dissolution over the work piece, a mirror finish can be obtained on the metal surface. It is advantages in that, the high points are preferentially attired by this electrochemical action and there by a smother surface can be obtained rather quickly.

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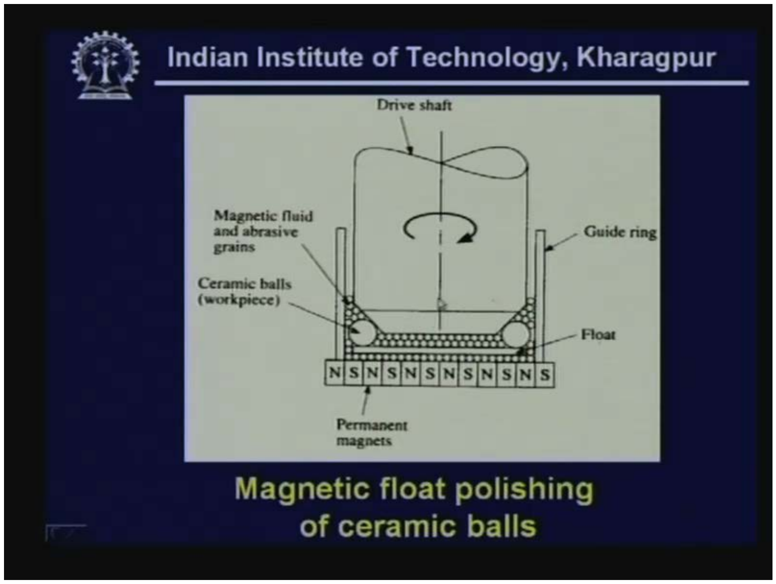

This is called magnetic float polishing of ceramic balls. Here what we can see? This ceramic balls need some superfinishing and within this chamber, we have a magnetic fluid and abrasive grains. Now these are supported by this magnetic force. So these balls are actually held between the float on one side and the rotating shaft on the other side. These two are actually rotating and by this ceramic float, this ceramic balls are being abraded by this abrasive grains.

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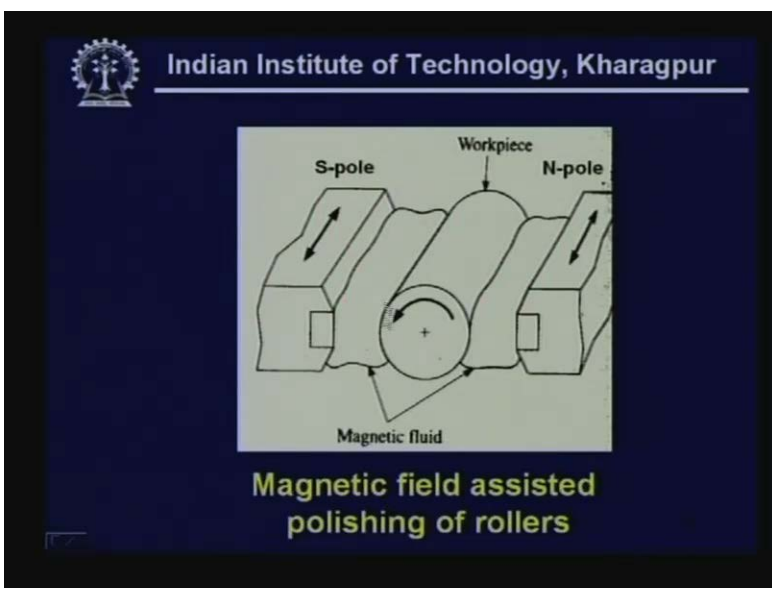

Here we have magnetic field assisted polishing. Here also, we use this magnetic fluid along with the abrasive material and here these poles are little oscillated there by creating some vibratory motion in the magnetic fluid which is also containing the abrasive material. There by some polishing action is obtained and the work piece in the form of cylindrical surface can be polished. Now we go to ball burnishing process.

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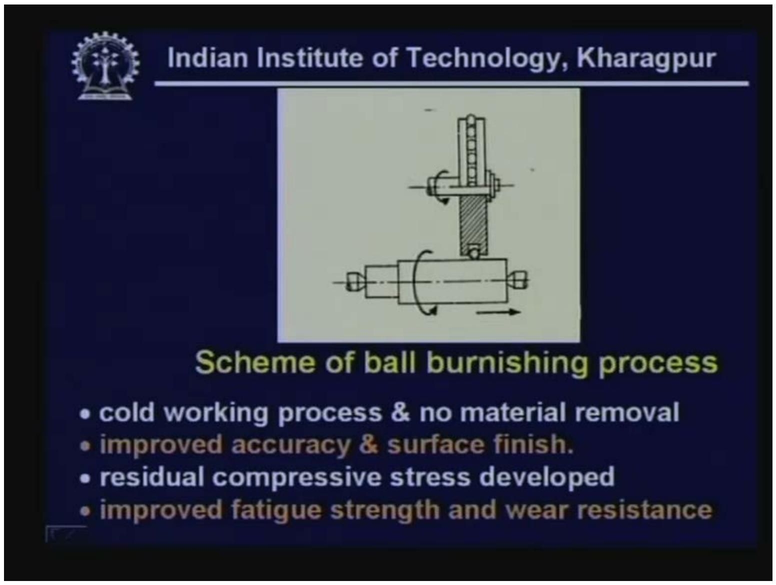

It is actually a smearing operation where by, by this plastic deformation, we create some improvement in surface integrity. Number one we have we can induce residual compressive stress developed. We can have enhancements of the surface hardness, there by increasing the wear resistance, we can improve the fatigue resistance of the material and not only that surface finish can also be fairly improved. There are certain questions.

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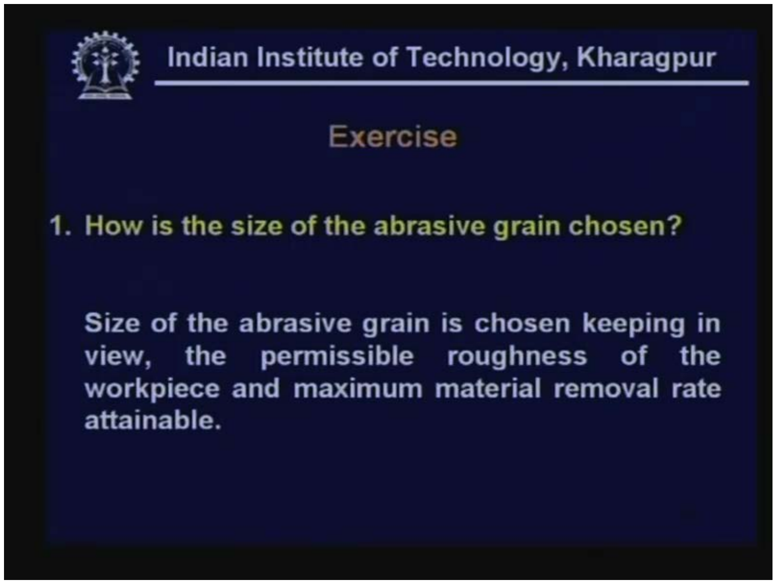

How the size of the abrasive grain is chosen in lapping process? Now in the lapping process the abrasive grain is chosen keeping in view the permissible surface roughness and the maximum material removal rate which can be attended.

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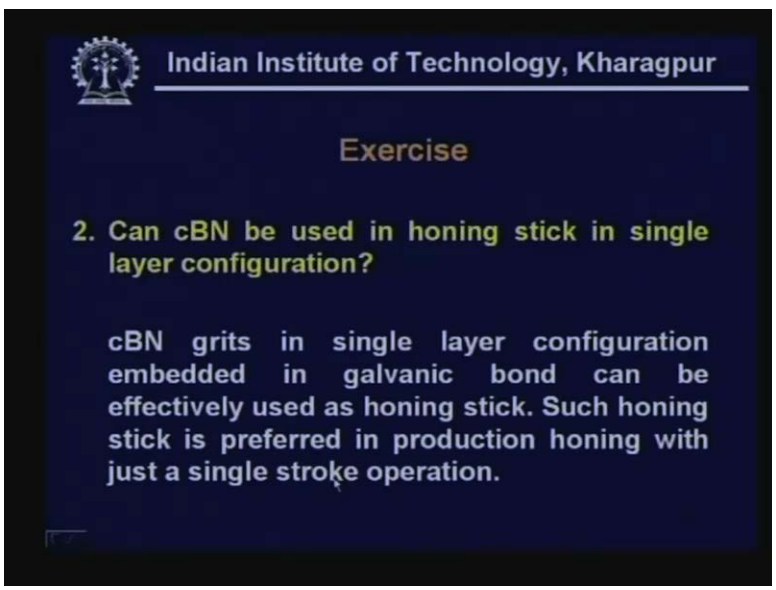

cBN can be also used in honing stick in single layer formation. It can come as a bonded abrasive in the form a galvanically bonded abrasive stick which can be used for this lapping action .It is for honing action.

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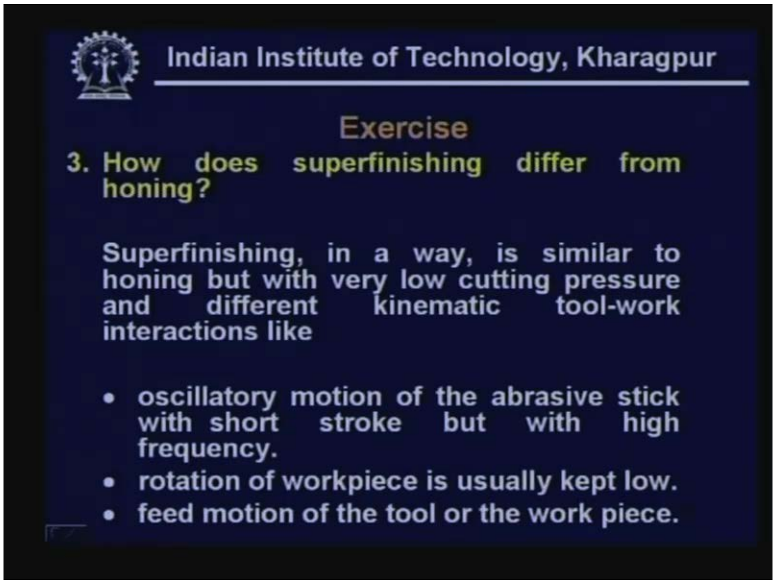

How does the super finishing differ from honing? Super finishing in some way very closer to honing but actually it has oscillation over a short length. It is high frequency oscillation, cutting pressure is much lower and the rotating speed is also much lower compared to honing.

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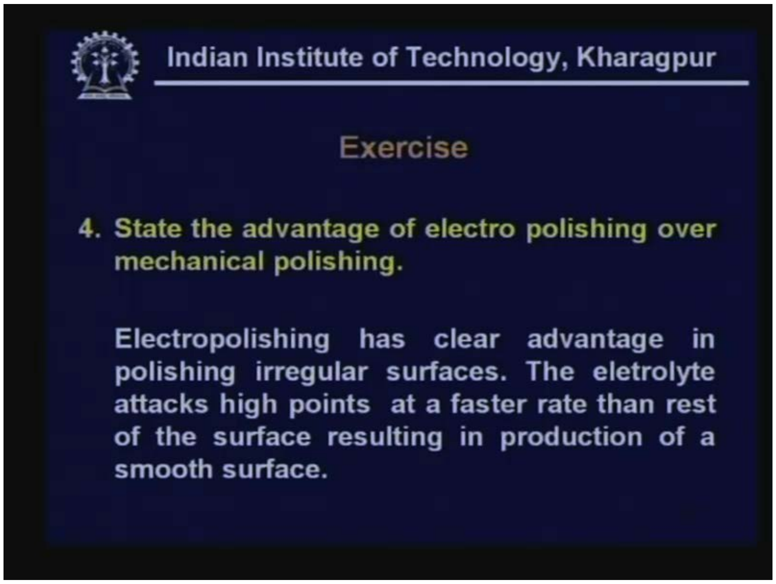

Electro polishing has the advantage over mechanical polishing because the high points can be very easily electro polishing has an advantage over mechanical polishing in that, the high points can be very easily attacked by this anodic action. There by material removal is facilitated and high finish can be obtained rather quickly.

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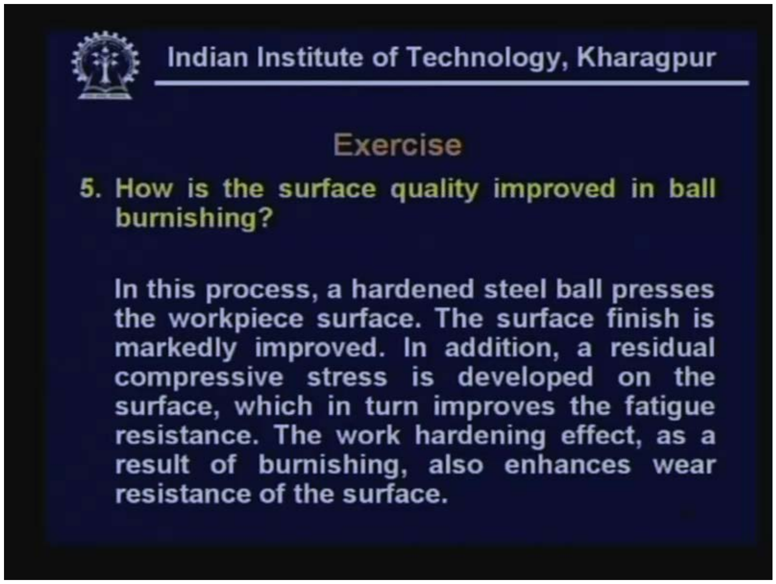

How is the surface quality improved in ball-burnishing? Actually in this case a hardened steel ball is used for improving the surface integrity of the work piece. By this rolling action, actually material is not removed but there is a smearing action, by this smearing action surface finish is sizably improved but what is more we can induce compressive stress on the stress which immediately translated in to enhancement of the resistance to fatigue during some alternating stress.

Thank you for your attention.