Introduction to Machining and Machining Fluids
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Lecture – 26
Advances in Metal Cutting_ Machining Processes

In this class we are going to see advances in metal cutting or machining processes.

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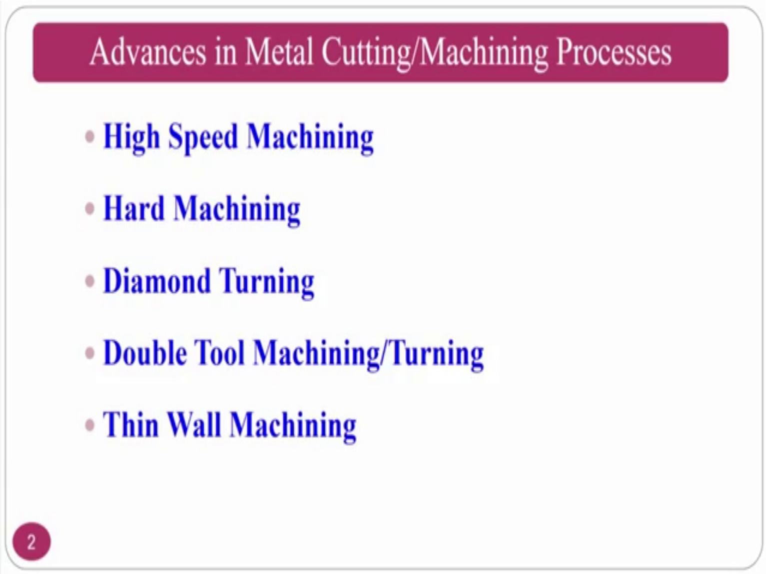

If you see what various processes that are come under the metal cutting or the machining processes which are called as the advanced in particular to the current day is concerned, that as called some of the things; that is high speed machining, hard machining, diamond turning, double tool machining and thin wall machining.

Some of the things are already known to many of the you, at the same time these are also not called as so advanced, but it these are all few of the advancement that are made by the researchers in the arena of conventional machining processes. First we will move on to the high speed machining. So, high speed machining as the word the speed specifies that, it is deals with cutting speed of the machining processes.

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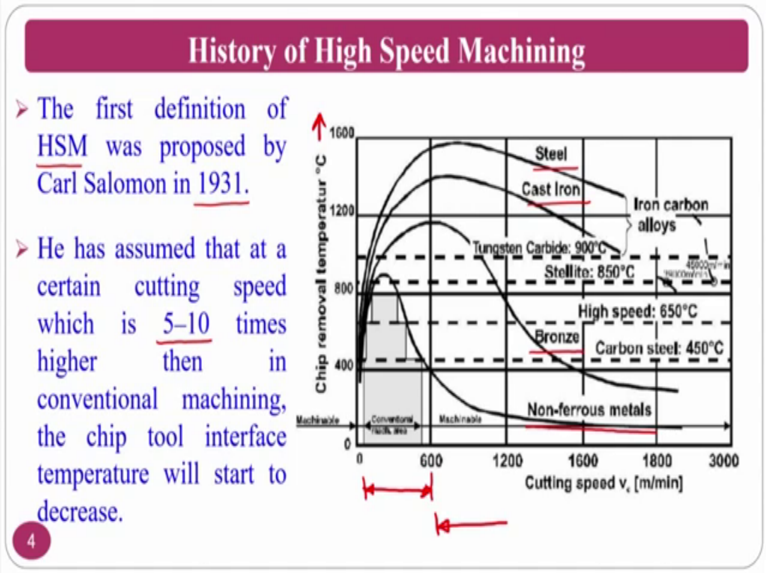

If you see the history the, this is the first definition of high speed machining was proposed by Carl Salomon in 1931. Later on what happen it has the assumed that the certain cutting speed which is 5 to 10 times higher than the conventional machining processes, where the chip tool temperature goes down; that is what the proposed thing and that it was the some of the people they have invented.

So, if you see this particular diagram, where the conventional machining processes will go up to 600 normally. This is the range where the conventional machining processes will take care and the machinable materials and other things. If you go beyond this, this is called as a high speed machining or you can, you can see that what is happening there is the forces; that is conventional temperature which is seeing here is gradually decreasing also. As a speed is increasing the temperature that you can see on the y axis, is gradually decreasing.

So, if the temperature decreases; that means, that the part accuracy goes up, because you know the difference between cold holding and hot holding. The part accuracy the component accuracy in the cold holding is much better than hot holding process. Similarly if the temperatures are lower; that means, that the process will become much safer from the point of machining. If you see the different different materials; like a steel, cast iron and bronze which is comes under the nonferrous materials, all these things the temperature goes down.

So, there are some advantages about this one; that is why we proceed towards the high speed machining.

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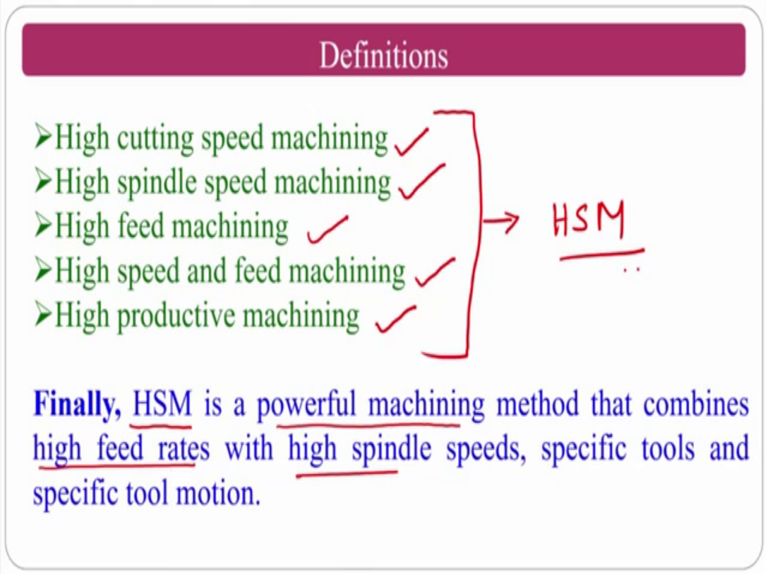

The high speed machining, normally there are many varieties are there, some of the people they say high cutting speed machining, some people they say high spindle speed machining, some they say high speed machining, I and people they clubbed both and they termed it as a high speed and feed machining and the high productive machining. So, these are that the synonyms are some of the variance in the high speed machining or allied processes.

Finally high speed machining is termed as, it is a powerful machining method that combines the high feed rates with high spindle speed and the specific cutting tools and the specific tool motion. If you are clubbing most of the things which are specified above, these all lead to a common word called high speed machining ok.

So, this is about the high speed machining. This contains high feed rates as well as high speeds that are there, used by specially made cutting tools. So, what are the cutting tools, what are the materials and all those things we will see in the upcoming slides.

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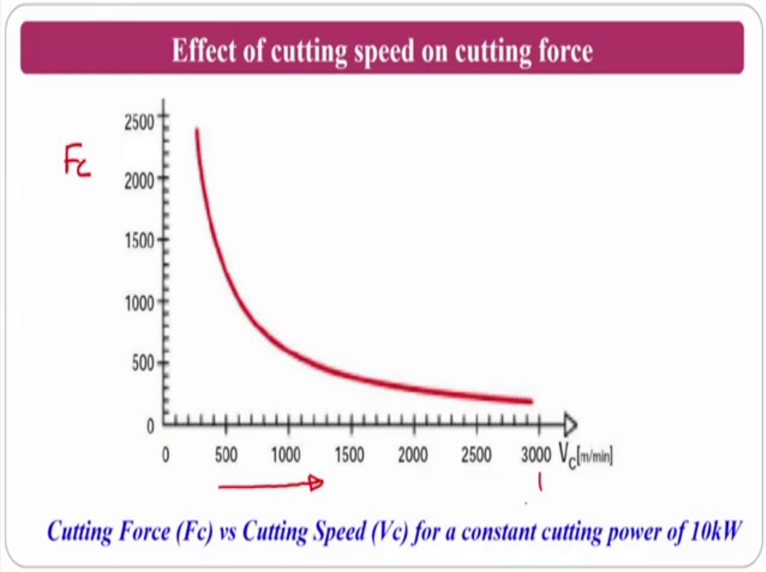

If you see particularly about the cutting force versus cutting speed, e as the speed is increasing what is happening? The cutting force basically Fc is gradually decreasing, but this is up to certain velocity. Whatever you have seen the previous graph is beyond the range that inner zone.

The basic mechanism here is, whenever you are going to cut the workpiece material if the temperature is high the basically problem is the workpiece becomes thermally softened, if the workpiece become thermally softened up to particular temperature only. I am not talking about 16,000 meter per minute and all those things up to certain, what will happen this will work as a preheating for the upcoming material; that is why the cutting forces will decrease.

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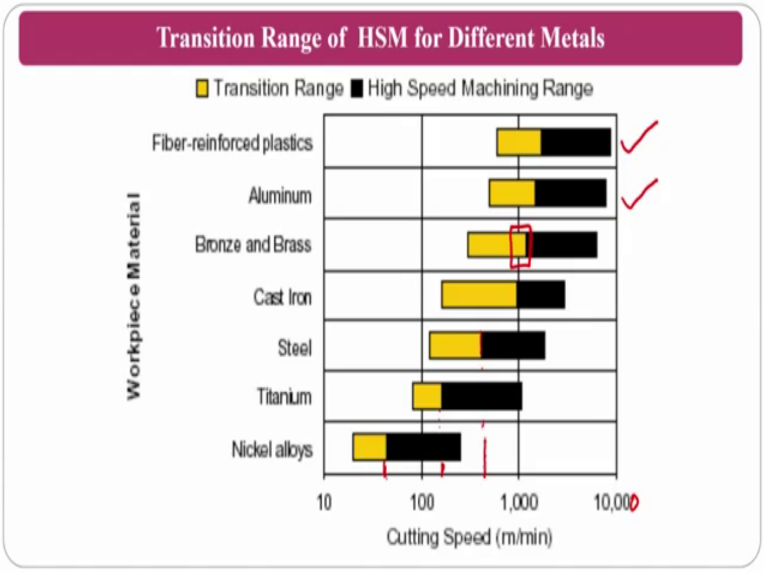

So, various materials will have various transition ranges of high speed machining, because if you take a aluminium, if you take the hard steel, both assume that if I am rotating for that same RPM tool with help of head stock. You cannot say the same is considered as a hard machining. In steels, hard steels you may consider as hard, high speed machining, but not in case of the aluminium, because there is a hardness variation ok

The hardness variation also plays a major role, whenever you are deciding particular process as a high speed. So, for that every material there is a transition range, when you call it as a high speed machining, when you call it as a conventional machining. If you see particularly reinforced plastics are the polymer based materials, if the range is approximately 1000 metres per minute, still you can call it is a conventional machining. If you are crossing some more then only you can call it as a high speed machining.

If you see the aluminium at 1,000 degrees still you can call it as a conventional machining beyond which slightly ahead like 1,300 meters per minute, 1400 4 meters per minute, then you can call it as the high speed machining. Bronze and brass on the edge it is exclusively on the edge it is there.

So, you can call it beyond 1100 degrees and 1200 1100 degrees around, you can call it is a high speed machining cast iron, 1,000 degrees itself cast can be named as a high-speed machining and the steel, titanium, nickel based alloys which are called the high-temperature alloys and all those things, have very less speeds. If you see the steels approximately the temperature is around 700 degrees or something you can say it is a high-speed machining; that is the transition from the conventional machining to the high-speed machining.

If you take a around the titanium, normally titanium will be around 200 to 300 degrees, the 300 meters per minute. And if you see about nickel alloys, the transition will come below 100 metres per minute. This is about the transition where particular material if you are using as a workpiece material, heat properties strength, its hardness and all the properties will also matter, will also can decide whether you are in the high speed region or the conventional region.

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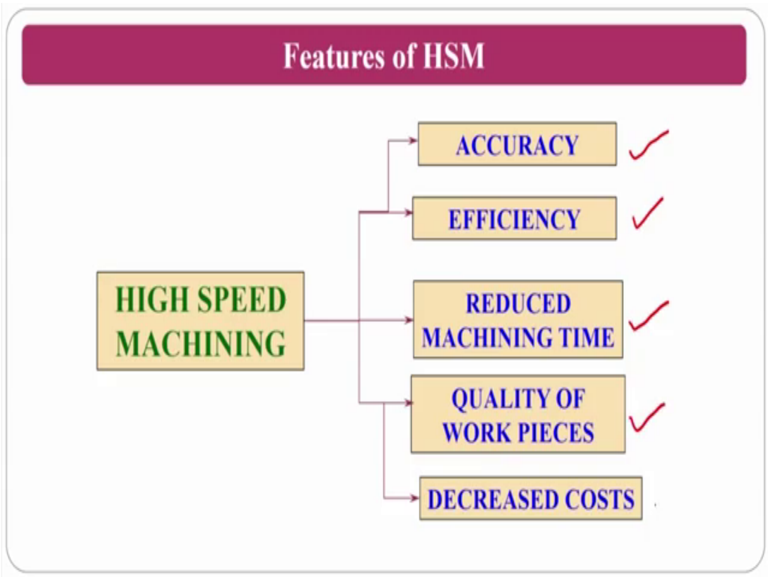

If you see the features of high-speed machining, the high-speed machining, the features you will get is good accuracy and the efficiency, because you are going to machine many parts in less time, because your speed is very high; that means, that you are efficiency or the performance is very high, reduced machining time, because you are machining at very high speed, so the part to be manufactured will take very less time.

Assume that you have two components one is machine conventionally, another one is machine using high-speed machining. You are going to complete the second part in less time; that means, that the time is reduced, time is money. So, you can sell the particular component at less price.

The quality of the work pieces is very good and decreased cost. These are all on an average the final destiny for any company is, how to sell a market competitive price. So, that the buyers or the customers will purchase the product, a quality product at economic price; that is what the motive for the people are going regularly continuously, the research towards the betterment and betterment of the products by reducing the cost of the product.

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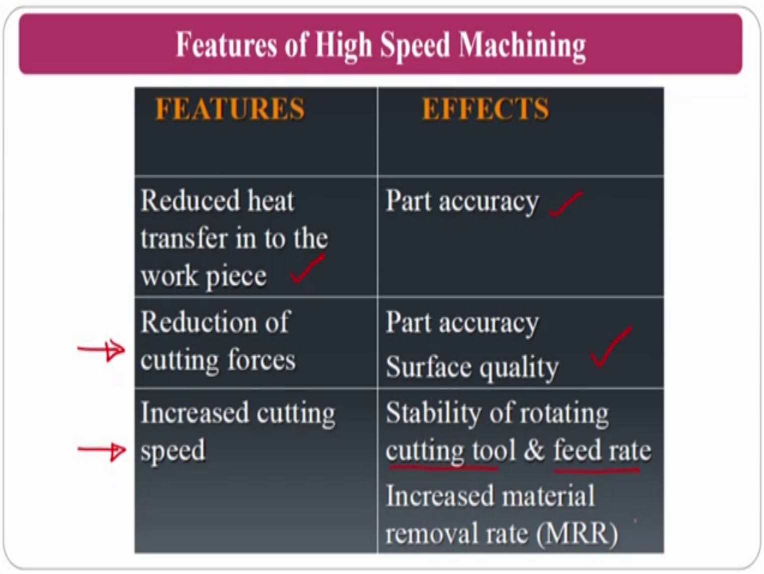

If you see the features and its effects, reduce the heat transfer into the workpiece, because of which you will get the good part accuracy; that means, that tolerances will be good and the surface finish will be good and all those things. Reduction of cutting forces, if the cutting forces are reduced what will happen? The part accuracy and surface quality is good. If the forces are less what will happen? The penetration and all those things will be less, at the same time temperature generation will be less. So, the part accuracy and surface quality will be more.

Increased cutting speed, if you increase the cutting speed what will happen? The stability of rotating tool will be good and feed rate of the material will be increased and material removal all and average. What I mean to say is that, if you are going to increase the cutting speed your MRR, MRR stands for material removal rate. There is a difference between material removal and there is a difference between material removal rate.

Sometimes B.Tech students may confuse with this respect to these two words; that is material removal is how much material you are removing and material removal rate is how much material you are removing per unit time, so time factor comes in this particular. So, if the speed is very high your time taking is very less ok. For less time I am going to remove more material; since this particular process is a machining process, you are mostly worried about how much material I am removing per unit time, so that the production rate will increase.

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COMPARISON BETWEEN CONVENTIONAL AND HIGH SPEED MACHINING

		Solid Tools (end mills, drills) WC, coated WC, PCD, ceramic		Indexable Tools (shell mills, face mills) WC, ceramic, sialon, CBN, PCD	
Work material		Typical cutting speed [m/min]	High cutting speed [m/min]	Typical cutting speed [m/min]	High cutting speed [m/min]
aluminum		>305 (WC, PCD)	>3050 (WC, PCD)	>610	>3658 (WC, PCD)
cast iron	soft	152	366	366	1219 (sialon, ceramic)
	ductile	107	244	244	914 (ceramic)
steel	free mach. steel	107	366	366	610
	alloy	76	244	213	366
	stainless	107	152	152	274
	hardness HRC65	24	122	30 (WC) 91 (CBN, ceramic)	46 (WC) 183 (CBN, ceramic)
titanium		38	61	46	91
superalloy		46	76	84 (WC) 213 (sialon)	366 (sialon, ceramic)

So, comparison between Conventional and High Speed Machining; If you see the typically cutting speed in the normal machining and high-speed machining. So, aluminium if you seem it is less than 305 and normally it will be multiple times. So, similarly if we, if we can see the cast iron, steel, titanium super alloys and all those things, the speed normally that you will use here is this one. The conventionally normally people will use this much.

Assume that let me take the super alloy. So, 46 will be the normal people using speeds, but if at all you want to use or you want to term, your particular process is a high-speed process then you have to go for the speed above 76; that is what this particular table shows. Similarly, there are two types of tools; one is a solid tools and indexable tools. The for the indexable tools it is slightly different, for the solid tools it will be different. So, you can differentiate between these two for the same materials.

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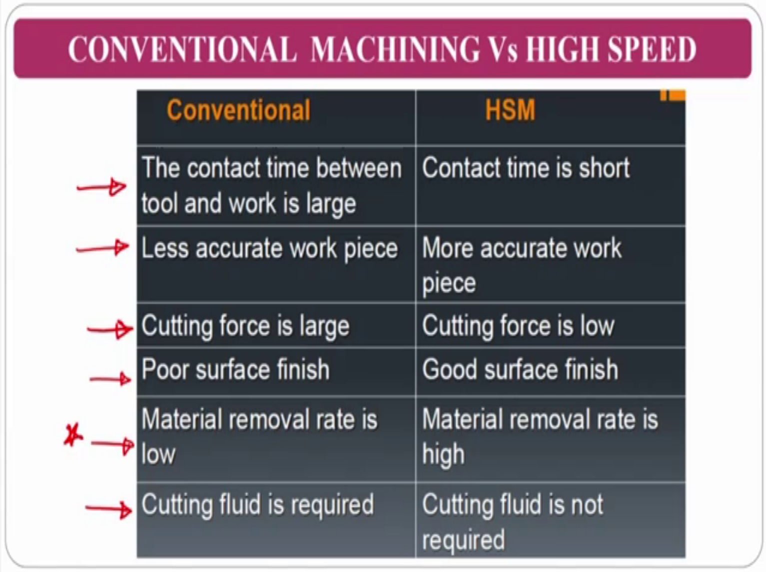

CONVENTIONAL MACHINING Vs HIGH SPEED

Conventional	HSM
The contact time between tool and work is large	Contact time is short
Less accurate work piece	More accurate work piece
Cutting force is large	Cutting force is low
Poor surface finish	Good surface finish
Material removal rate is low	Material removal rate is high
Cutting fluid is required	Cutting fluid is not required

Conventional machining versus high-speed machining, what are the differences? in the contact time between the tool and workpiece will be large in convention, because you are speed is low. If the speed is low for the particular length of a workpiece material what will happen, the contact time will be large, and in high-speed machining contact time will be less; So, less accuracy of the workpiece.

These are the things that are given, but not particularly all are true ok. So, the people should slightly judge sometimes, because these are taken from particular peoples, and we try to acknowledge them at the end. So, what I mean to say is that conventional machining do not give good surface finish, I am not saying, but the thing is you have to play your input parameters, you have to play with your input parameters such a way that you have to get good surface finish.

So, surface finish normally depend on your no tedious as well as your feed. So, if you can play with these two parameters, even in conventional machining processes also you will get good surface finish. The accurate work pieces, I cannot say less accurate if your surface finish and other things are very good; that means, that; obviously, your product will be very good.

So, more accurate part you will get in terms of high-speed machining, the forces are large, because your temperatures in high-speed machining will be very high; that is why the thermal softening of the workpiece takes place, because of if the forces will be slightly lower in terms of high-speed machining.

The poor surface finish, because you have forces, high forces will normally results in bad surface finish; that means, that the surface roughness is very high. The material removal rate is low, it is obvious, this is perfectly fine, because if the speed is very high the material removal rate will be very high; that means, that the conventional machining process the material removal rate is low.

The cutting fluid is required, but cutting fluids is required in both the conditions, but the slide which is shown that it is not required, but it is not true in all sense, it is most of the time you required the cutting fluids in conventional as well as the high speed machining. In high-speed machining you need the dominating characteristics of cooling; that I will come to the point whenever I am going to talk about the cutting fluids and high speed machining, just a point I will raise I do not talk much about that.

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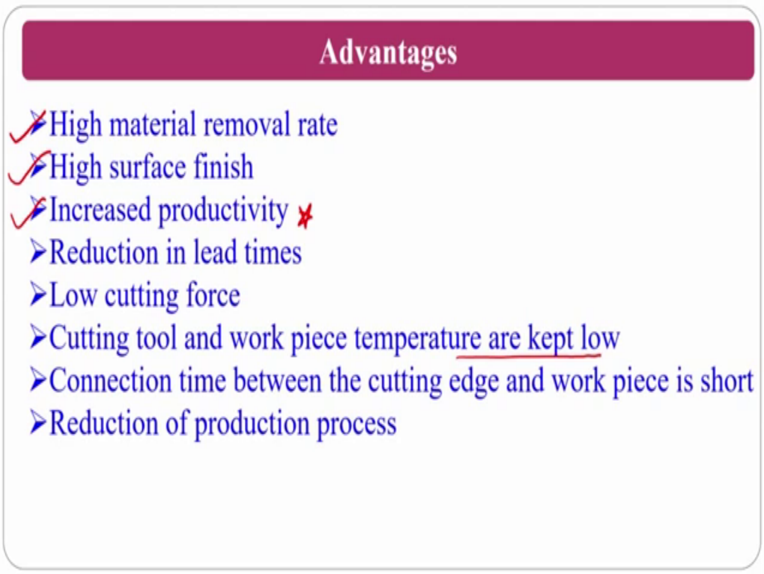

The advantages it is high material removal rate obvious, good surface finish, increase productivity is good, because you are material removal rate is very good. The reduction in lead times; obviously, and the low cutting forces, because the thermal softening of the workpiece will takes place; Cutting tool and workpiece temperatures are kept low.

So, if you can use proper cooling and lubrication, I mean to say better cooling properties you can keep your temperatures low. Connection time between the workpiece and the cutting tool will be short. So, the machining is very fast, reduction of the production process.

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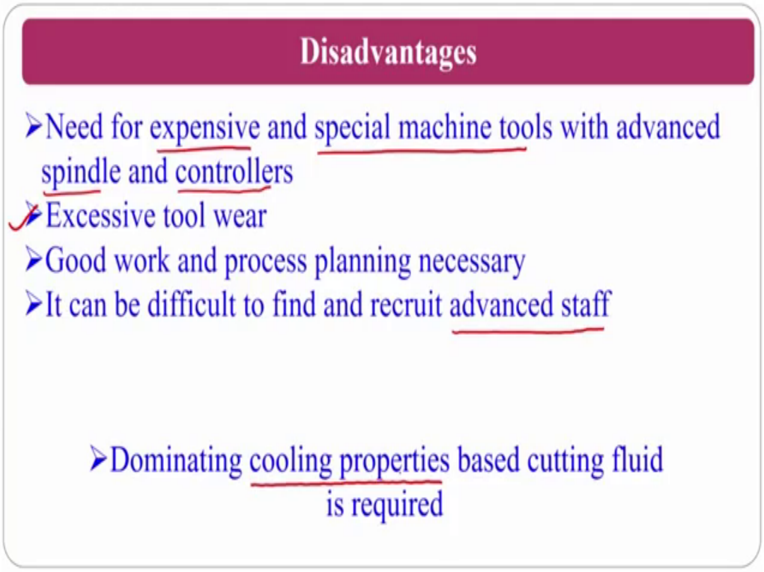

See there are some disadvantages of high-speed machining also. So, you need an expensive and the special type of machine tools, because whenever you operate very high speeds the chances of that machine is that it can vibrate. So, you need a precise machine tool, for that purpose you need to have the advanced spindles and controller. At the same time if you take care about your machine tool dynamics and all those things.

So, these machines are specially designed, so the cost of these machines will go up enormously goes up, excessive tool wear, because you are operating at very high speeds though temperatures will be very high, this temperatures will transfer to the cutting tool. In that circumstances the tool wear will be very high, because of the thermal softening of the cutting tool.

Good work and process planning is necessary, because whenever you are going to use the sophisticated equipment, you need to plan your things accordingly, because the using of this particular machines is slightly expensive from that point you should be well planned, from that point you should be well planned.

So, it can be difficult to find the recruit advanced staff, because these are the costly equipment, at the same time there is advanced controls and sophisticated staff is required to do this type of advanced control systems and all those things, that is why you need to have a staff who can operate or who is well trained in the industry.

So, the cost of the operator will also go up ok. These are all will add to the product cost. The point that I want to say at this particular moment of time is, here high-speed machining whenever you talk what will happen the speed is a most biggest culprit in terms of producing the high heat; that is why you need always the most of the time the cutting fluids with cooling properties.

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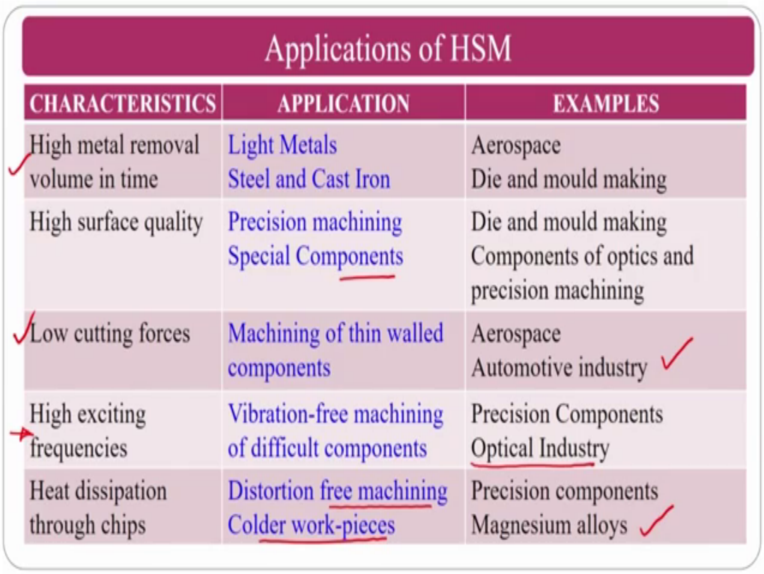

Applications of HSM

CHARACTERISTICS	APPLICATION	EXAMPLES
High metal removal volume in time	Light Metals Steel and Cast Iron	Aerospace Die and mould making
High surface quality	Precision machining Special Components	Die and mould making Components of optics and precision machining
Low cutting forces	Machining of thin walled components	Aerospace Automotive industry
High exciting frequencies	Vibration-free machining of difficult components	Precision Components Optical Industry
Heat dissipation through chips	Distortion free machining Colder work-pieces	Precision components Magnesium alloys

So, applications of high-speed machining; Normally this high material removal rate if you see, then the light metals steel cast iron which are normally used in aerospace, die and mould applications, high quality surface roughness are the low surface roughness, precision machining and special components like die mould and all those things, because you need to have the precise components to be fabricated.

Low cutting forces, the machining of thin walled components because if you are going to put more force on the thin walled components; the thin wall may try to bend on one side. These are exclusively used in aerospace industries, and I particularly come to you the applications and the introduction about the thin wall machining in upcoming slides. Those thin wall machines have a huge applications in the aerospace and automotive industry.

High exciting frequencies; where vibration free machining of difficult materials. Normally these are all used in optical industries. Heat dissipation through the chips, distortion free machining of colder workpiece materials, precise components in magnesium alloys. Magnesium alloys are one of the advanced materials, people nowadays talking about, because the magnesium there are multiple varieties and there are the advanced materials like biodegradable magnesium, which normally people are using in the orthopaedic applications in the biomedical devices

Coming to the second part; that is called hard machining so, hard machining, the word stays, the word says hard; that means, that the workpiece is hard. The workpiece hardness is very high if you are going to machine that material, then you could call it as a hard machining. Now, we will see what is the range of that hardness.

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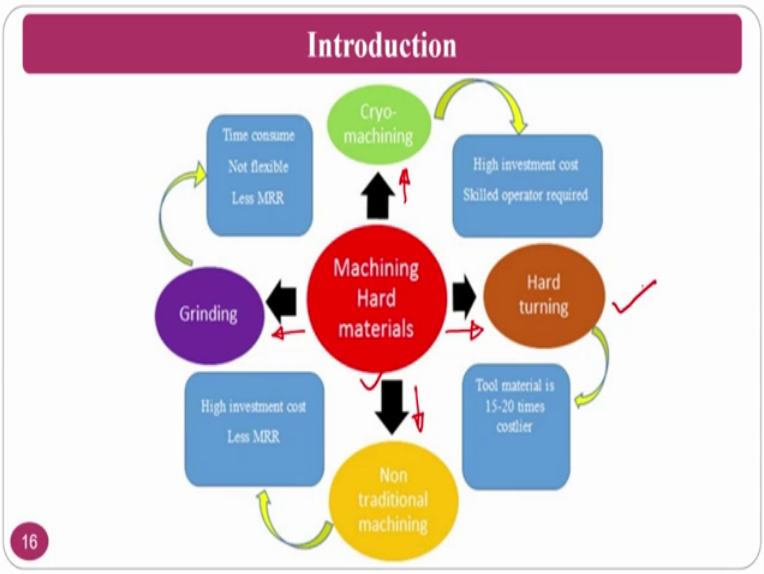

Introduction to the high-speed, introduction to the hard machining; So, machining of hard materials, people can go for many things; that is one of the options you have is a hard machining, another option is a non-traditional machining that is advanced manufacturing processes, another one is the grinding process and there is a option for cryogenic also. So, these are varieties there, among which particularly we talk about hard machining.

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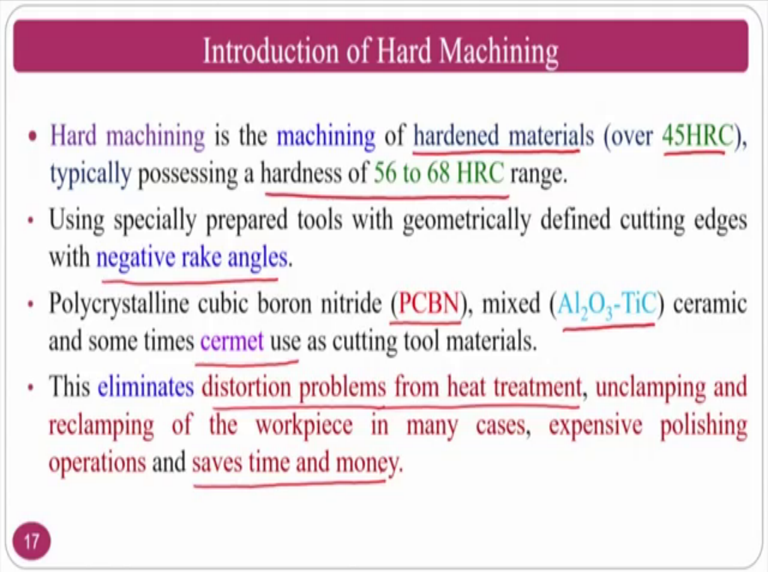

So introduction to hard machining; So, hard machining is the machining of hardened materials, over 45 HRC, workpiece material which have the rock well hardness scale see above 45, then typically you can call it as the hard machining process, but the hardness if it is in the range of 56 to 68 you can easily call. Some of the people they do not call even the HRC is 45, but there is a slight contradictory is there, some people they call it as a hard machining with 45 also some people they do not call it as.

So, it is a time dependent, because if you see the old papers other time they do not have most sophisticated cutting tools, from that point they called it as a hard turning or hard machining process. As the world grows or the time passes what is happening is, that the hardness is going to increase in terms of work pieces, at the same time the people are inventing new and new cutting tools, it is raising the bar.

Continuously the bar is raising, because the tools which are sophisticated are coming into the market; that is why the hardness is, as you know the nanotechnology peoples stay. People say about once upon a time they say that below one micron is a nano, but nowadays people say about below 10 nanometre is a nano. So, there is, because the world is progressing. If the world is progressing, the world become advanced and advanced and the values are going to increase ok.

From this point of view for hardness values for the hard machining is increasing gradually. Tomorrow this particular 56 to 68 may also increase; there is a chance, because the world grows. When you students will become faculty you may teach to your student saying that if you are going to use the hardness of your workpiece above 70 called as hard machine, there is a chance, I am not saying that is going to be true, but there is a chance or there is a probability, using this specially prepared tools with geometrically defined cutting edges with a negative rake angle, normally uses in the hard machining process. Polycrystalline cubic boron nitride that is called PCBN and mixed ceramics; Al2O3, titanium carbide and sometimes ceramics also used as a cutting tool materials for machining of this hard workpiece materials.

You can also see it eliminates the distortion problems from the heat treatment and unclamping and reclamping of the workpiece in many cases, expensive polishing operations and save the time and money, because the hard machining is one of the advanced process, where you can go for slightly higher sites.

This machine tools are specially prepared for the special application, so you can even go for slightly higher depth of cuts and feeds; that is why your time and money saved, because you may not required to operate the post processing like polishing and all those things. You can do instead of grinding, here itself you can do the turning operation or the milling operation the, whatever the operations that you can do for the particular component to make it as a final product.

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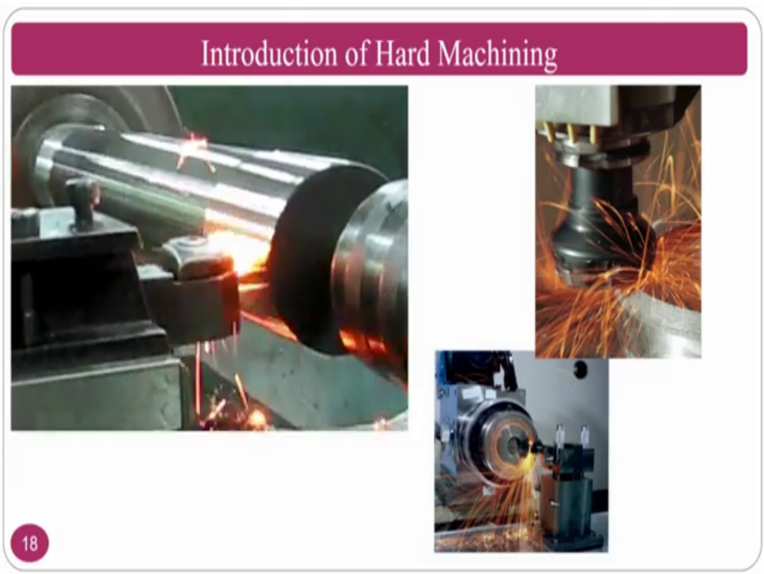

If you see here the turning operation or the milling operation, whenever you are operating against the workpiece material, the lot of fire type of things spark will come into picture. If you see this particular video, you can clearly visualise what is hot turning. In particular this is taken at our laboratory, but this is not that much hard workpiece material to show you how the spark or the fire that will going to generate at the machining region, for that purpose we are showing this particular video.

You can clearly see the hardness of this particular material is around 48 to 50, which is still called in the range of hard only. The spark at the fire that you are going to see is purely because of the interaction forces. If you are interaction forces at the same time speed plays a major role, if the interaction forces is very high and severe what will happen? The fire type of spark will generate.

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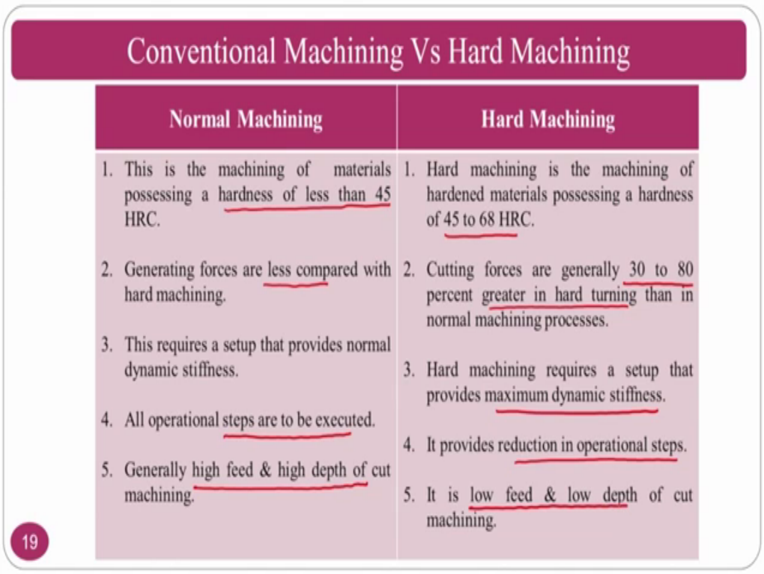

The difference between normal machining or the conventional machining and the hard machining; This is machining of material possess the hardness less than 45 HRC normally, this is above 45 to 68 HRC, this may still may increase with respect to time. Generative forces are less compare to the hard machining. Here the cutting forces are generally 30 to 80 percent greater than the hard turning, normal turning process. It requires setup that providers normal dynamic stiffness, but it requires maximum dynamic stiffness.

All operation steps are to be executed, it provides a reduction in the operational steps; that means, that if the people are using a post processing techniques, you may not requires those post processing techniques in terms of hard machining; that is what. Some of the papers if you go through, they say that there is no requirement of post processing such as a grinding operation and all those things are not required, because the surface finish that you got is a very good surface finish.

Generally, high feed and high depth of cut will be done in terms of normal machining process or the conventional machining process, but in hard machining process, low feed and low depth of cut is normally preferred; otherwise what will happen, your tool may fail at the very less time.

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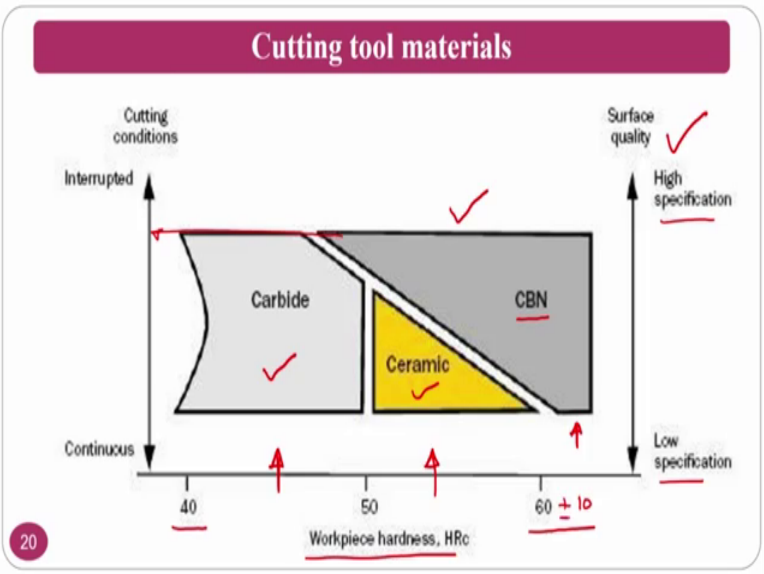

The tool materials if you see, normally there are three varieties of tools are multiple varieties are there. So, commonly people use is carbide, ceramic tools and CBN ceramic tools and the CBN tools people will be using, depend on their application basically. If the workpiece hardness is less like 40 to 50, normally you can go for carbide type of a tool material. If it is 50 to 60 normally you can even go for ceramic or the mixed ceramic tools and if you are rich enough you can also go for the CBN type of tools. CBN type of tools will have more strengthen more hardness.

Normally these particular things are used for interrupted paper cutting rather than the continuous one. At the same time low specification and high specification, because the specification of the surface quality if it is required very high; that means, that I need a very good surface finish, your tool sharpness should be maintained for that particular purpose, people normally go for CBN based cutting tools.

So, standardly, if at all you are going to use the cutting tools for the high hard machining, in that circumstances you try to fit for CBN tools; So, that you will get good surface quality. At the same time if you are using intermittent or continuous, still it works at the same time, it do not bother about your hardness well within the range like 60 plus or minus 10 or something.

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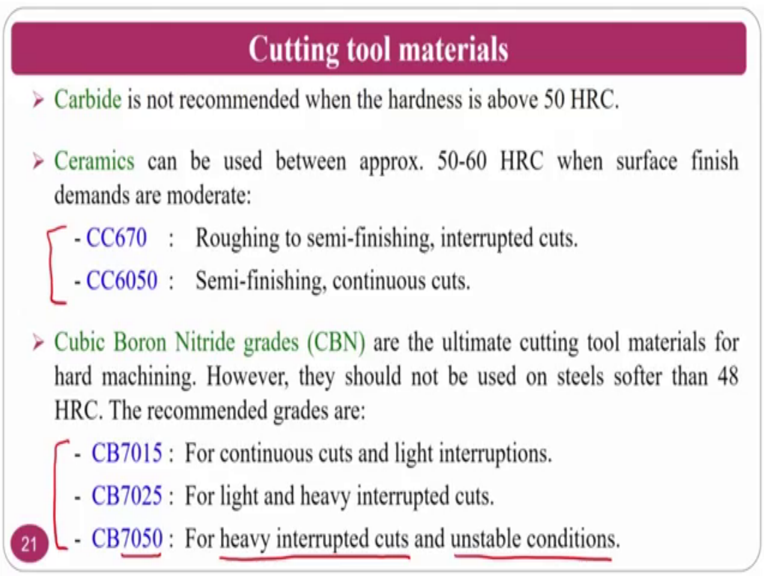

The cutting tool materials carbide is not recommended when the hardness is above 50 HRC. At the same time ceramic tools are preferred. These are the codes of some companies where the people will use for the continuous, discontinuous and all those things. Cubic boron nitride is a mostly preferred one, as I said from the previous one.

For continuous cuts and light interruptions you can go for CB 7015, CB 7025 for light and heavy interrupted cuts, for CB 7050 for heavy interrupted cuts with unstable conditions. Even you have good tools if you go and search for your particular research, but only thing is that the cost of the cutting tools goes higher and higher.

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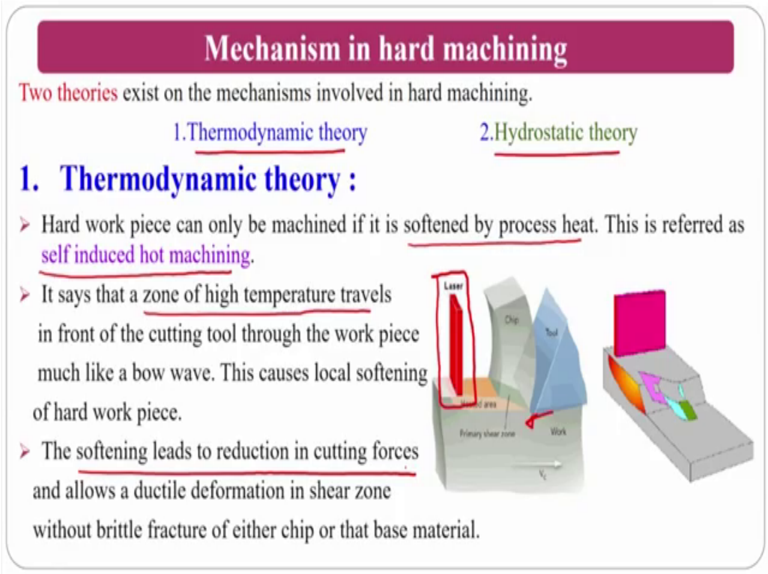

The mechanism in hard machining, there are two mechanisms are involved; one is the thermodynamic theory, another one is hydrostatic theory. In the thermodynamic theory what is happening is, hard work pieces can only be machined if it is softened by the heat; that means, that heat at softened machining or the temperature assisted machining can be applied here; that is what the people says. This is referred as a self induced hard machining process. Normally, where the zone of high-temperature travels in front of the cutting tool through the workpiece, then assume that I have a laser.

Here in this picture particularly you can see a laser is focusing here. So, laser is creating the softening of the workpiece, then you are cutting with the cutting tool this is what happening. So, it is called thermodynamic theory and the softening leads to the reduction of cutting forces.

If the softening is there are the workpiece you are going to soften using the thermal source or extra source that generates the heat, what will happen? This workpiece material will become soft and its machining is easy.

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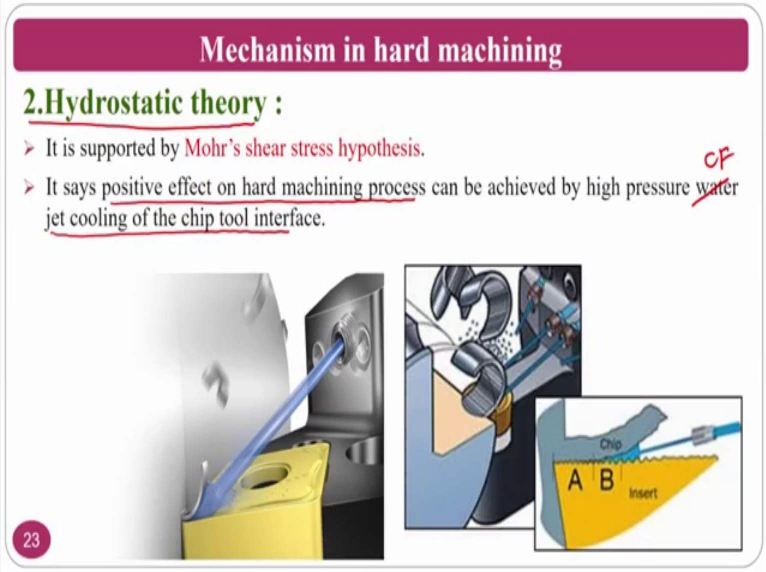

The another one is a hydrostatic theory. In the hydrostatic theory which it is supported by the Mohr's shear stress hypothesis, says positive effect on hard machining process can be achieved by high pressure water jet cooling and or high pressure cutting fluid, you can say jet cooling of the chip at the interface. If you have a cooling at the tool chip interface you can use this particular, instead of going to the hot type of assisted machining ok. These are the two methodologies or the two mechanisms that are proposed to machine the hard materials.

But in the next class normally what we are going to see is, there is called a laser assisted machining or heat assisted machining or hot assisted machining, we will see for the brittle materials ok. There is a slight variation between hard materials and brittle materials. There also brittle materials, you try to heat with external laser or external heat source to make it ductile.

So, brittle material you change it to ductile material then you do the machining operation. Even the same methodologies applicable in hard machining also, you just apply the heat reduce the hardness and do the machining operation

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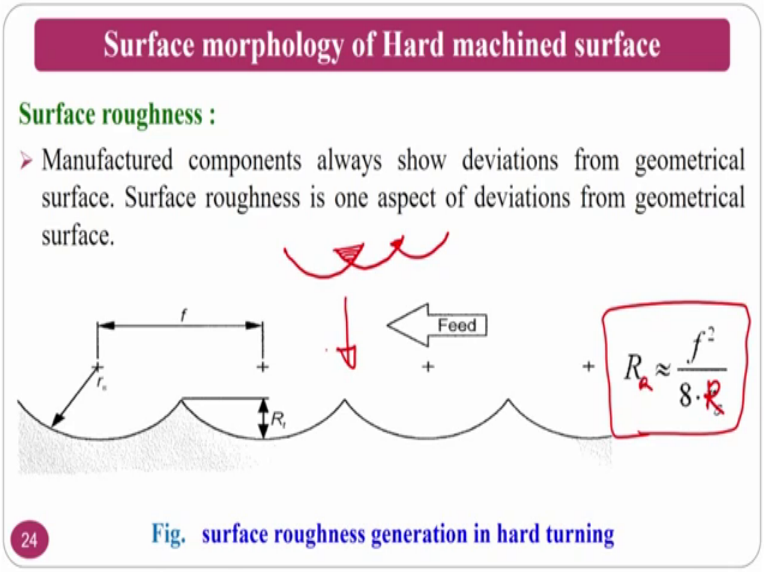

The surface roughness follows the same electorate; that is called the R a is equal to f square by 8 R, where R here Ra you can say f square by 8 R. So, it also depend on the feed as well as no tedious. Normally, if your no tedious is very high you will get, you will goes, these things will goes off that is what shown here and you will get a good surface finish.

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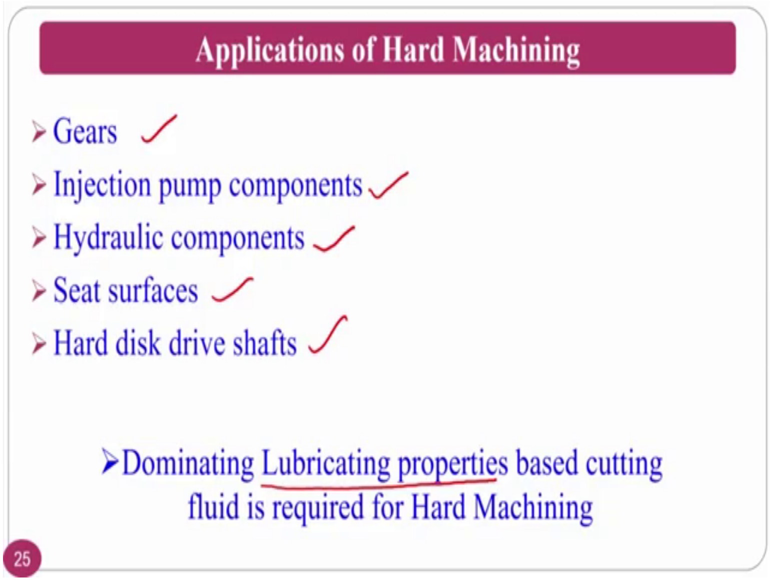

So, applications of the hard machining, normally these are all used for the gears application, injection pump application, hydraulic components, seat surfaces, hard disk drive shafts, so many applications are there. And most important thing here is as a part of machining conditioning fluids. Here lubricating properties based cuttings fluids are used, because a hard machining you will have more amount of abrasion rather than temperature.

Temperature also will play, but whenever you go for high feed and high depth of cut. Normally preferred is low feed low depth of cut. In that, circumstances the lubrication is required, because you need to prevent the abrasion. In high speed machining you need cooling property based cutting fluid; in hard machining you require the lubricating type of cutting fluids.

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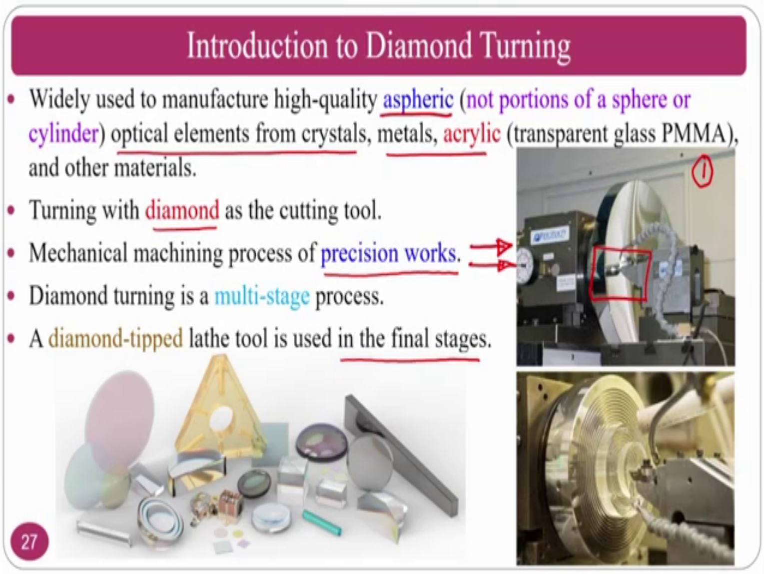

Now, we move on to the diamond turning. So, how the diamond tools are fabricated and all those things we do not see, but if you see particularly, the mirrors. If you see the figure 1 the mirrors are finished by using the diamond turning operation and these are the components, super quality finish. Normally, these diamond turning is costly process, because you are tool itself in this particular process is a diamond one.

So, widely used for manufacturing of high quality aspheric; that is called non pore, aspheric optical elements from the crystals metals and acrylics. Acrylics such as PMMA and all those things; Turning with diamond tool, so you are going to use the diamond as a cutting tool here. There are many varieties of diamonds, artificial diamond and a natural diamond. In this particular thing people mostly use artificial diamond, mechanical machining process for the precise works, whenever you require the precise work in that circumstances, normally you go for the diamond turning operation.

You can see here what is happening? The mirrors are finished. If I want to make a mirror; that means, that the image should be clear; that means, the surface quality that you are going to get on the particular components should be so high. The diamond turning is a multistage process and the diamond tipped lathe tool is used to in the final stages, you will use a diamond tip, assume that here what is happening here is diamond tip is there and you can even see the mirror image inside the workpiece also. So, that much super quality products are to be fabricated.

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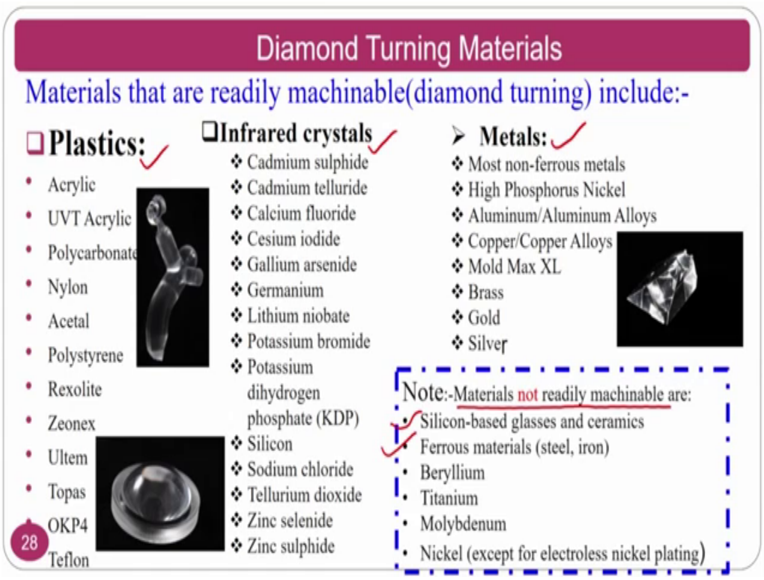

These are the materials, normally plastics, infrared crystals, metals. These are the materials which are readily machinable and you can see the plastics, how the people have used it and the materials not readily machinable or like a silicon based, ferrous based. Ferrous based normally do not use for the diamond, you need to take some of the precautions.

So, silicon based also glasses and all those things you need to take some precautions before you are going to use this particular diamond turning process.

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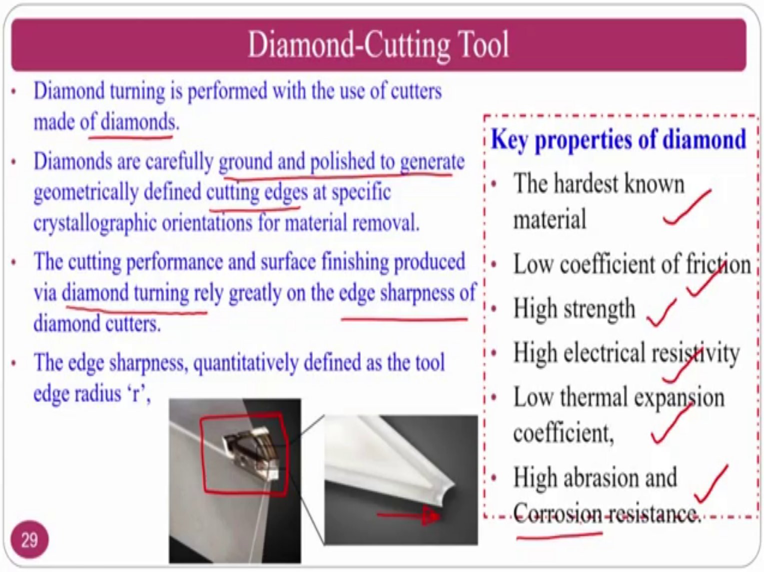

Diamond tools which are used for the cutting operation. This turning is performed with the use of cutters made of diamond; that is we have already shown in the previous slides. Diamond are carefully ground and polished to generate the geometrically defined cutting edges, at the specific crystallographic orientation, you cannot do the grinding of the or the polishing of this diamond as you wish. You need to follow certain procedures, you need to follow certain metallographic or the crystallographic access only.

Otherwise you cannot do the process. The cutting performance and surface finishing produced using the diamond turning is great and edge sharpness of the diamond is greatly depend on the cutting edges; that means, that if you can maintain the cutting edge sharper and sharper, you are going to get a very good quality of the surface finish on the particular component.

You can see here, this is the diamond tip that is there and if you see the exaggerated view, how sharp is the cutting tool. The edge sharpness and quantitatively defined as the tool edge radius. So, this edge radius is most important, key properties of the diamond, you also know that this is the hardest and coefficient of friction is very low and the strength is also high, electrical resistivity is very high.

So, thermal coefficients of expansion is low and high abrasion and corrosion resistance. This is one of the stable materials that is why the corrosion and all those things are very minimal. That is why diamond is mostly preferred cutting tool whenever somebody want to use for high tech applications; like aerospace applications, biomedical applications, where you require the high precision and all those things.

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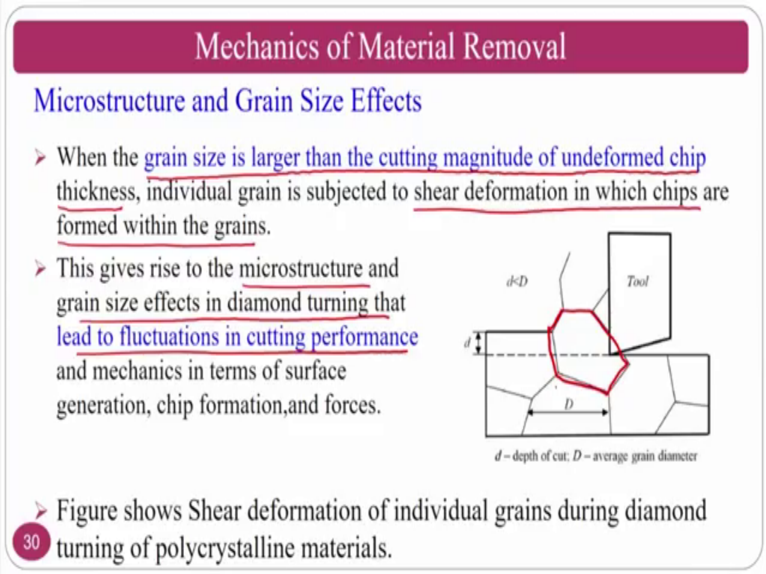

The mechanics of material removal; Here the grain normally the sharpness of the cutting tool is too sharp, if it is less than the grain size, then the cutting magnitude is normally undeformed chips. So, when the grain size is larger than the cutting magnitude of the chip; that is the chip thickness, individual grain is subjected to shear deformation which chips are formed with the grains. What I mean to say is, this is a particular grain, and I am cutting through. In a conventional machining process, the chips will go by through the grain boundaries.

Here it can cut across the grain also. It gives raise the microstructure and the grain size effects in the diamond turning that leads to the fluctuations of the cutting performance. If there, if you are going to cut across the grain in that circumstances, the there will be a chances of coming the fluctuations.

This figure shows the cutting across the grain. You can clearly see now the cutting tool is cutting across the grain. So, there is a chances of slight fluctuations, because of many reasons, cuts the. Whenever the cutting tool cuts across the grain, normally there is a chances of slight forces fluctuation. Applications this spherical and aspherical molds for ophthalmic applications is there.

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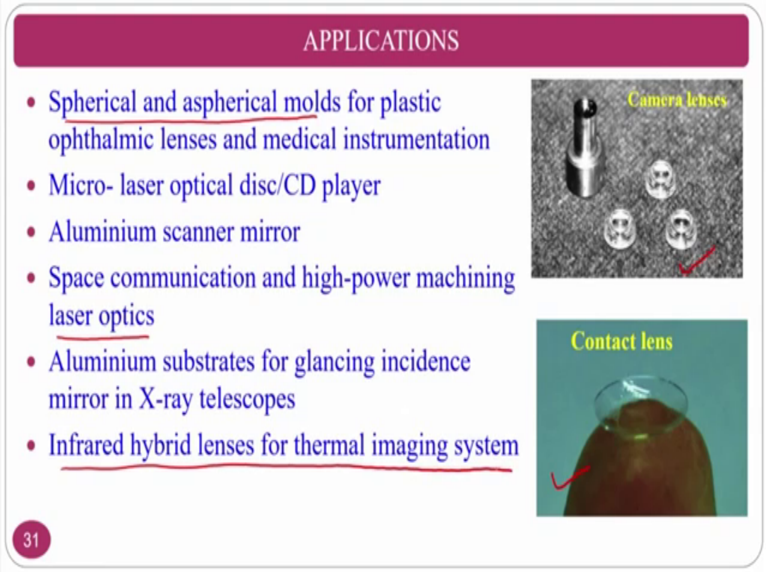

The applications, if you see the applications normally the contact lenses, moulds, the camera lenses moulds, these are the things can be manufactured by this particular process; spherical and aspherical molds of this particular ophthalmic lens and medical instruments can be prepared micro-laser optical disc, CD players will be and aluminium scanner mirrors.

These are the another high power machining laser optics and all those things can be developed using this particular process, infrared hybrid lenses for thermal imaging system and all those things will be used ok; that means, that most of the things wherever you required high precision, high surface roughness is required. In that circumstances you are going to use the this particular process. So, double tool turning process. Normally, this particular process where you will use the two tools on both sides of the turning process.

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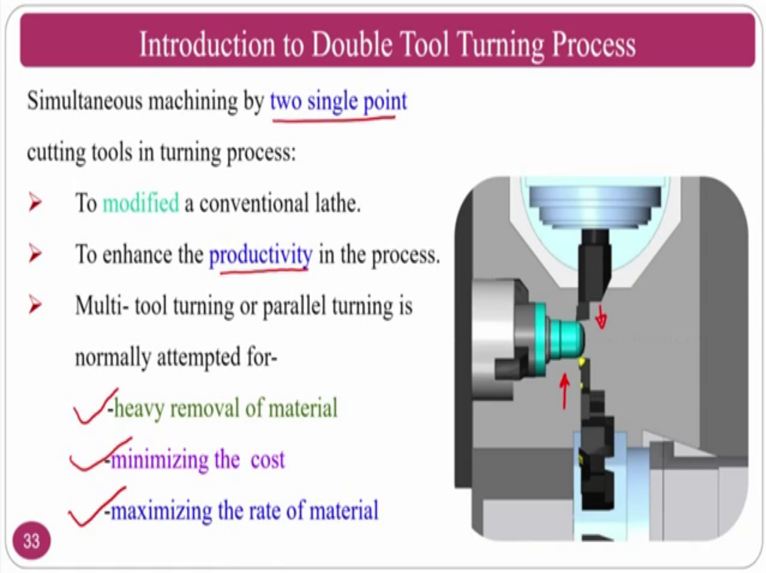

Like you can see here; one tool is from this side, another tool you are feeding from this side. So, there should be some offset, so that we can do the process safely. Simultaneous machining by two single point cutting tools in the turning process: so to modify a conventional lathe and to enhance the productivity. Basically, if at all I want to give the depth of cut heavily in a single guided is not possible, for that purpose you can divide that particular depth of cut into two and you can give on the both sides.

So, normally multi-tool turning or the parallel turning is normally attempted for heavy material removal, minimising the cost and maximising the rate of material removal. In this particular circumstances you can go for double tool turning process.

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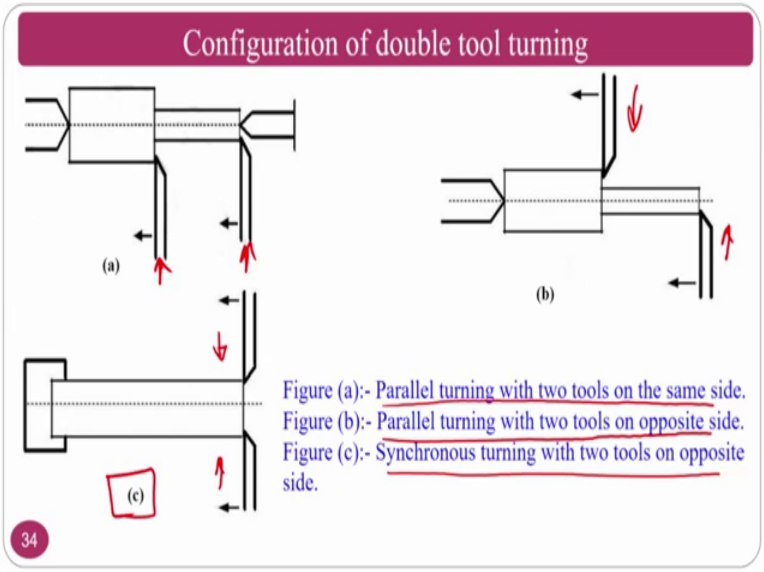

So there are three varieties; one is a parallel turning with two cutting tools on the same side, one is here, another one is here. This is the one. The second is parallel turning with two tools on the opposite direction; one is here another one is here.

The synchronous turning process two tools on opposite direction; one is here another one is here. Whatever we are going to see in the next slides is the variety c, but slight offset is required. In the schematic it is not shown properly, but you required slight offset, so that you can do the machining process with safe.

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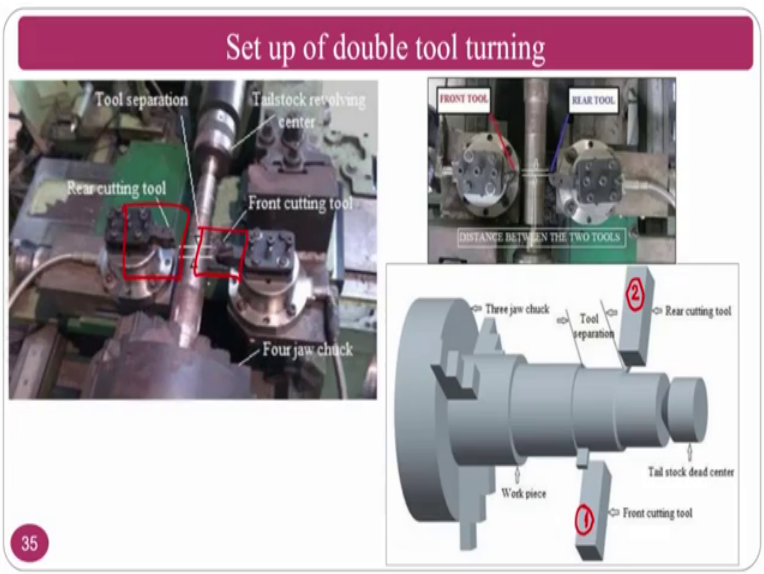

You can see here one tool is mount on this side, another tool is mount on this side, so that the machining process is taking place. The schematic image, if you see here, the tool one is here and tool two is here, so that the machining is taking place. At the same time you are dividing the depth of cut, you are not wearing any other parameter, for the same thing you are doing what you are doing is, you are dividing your depth of cut into two segments and you are giving to one tool some depth of cut another tool some depth of cut

The advantage of this one you are going to use the rotational speed same; that means, that the power that you are going to feed to the lathe machine is same ok. For the same revolution or the for the same workpiece rotation, the two tools are operating simultaneously by dividing the depth of cut or if at all I want to remove more and more material, you can go for the single rotational speed requirement power for particular lathe using this particular process.

In a single tool what will happen if you are going to use the RPM, certain RPM, you have to give some power to the lathe machine, but you are able to remove only certain material. If at all I am using two tools I can go for the higher material removal rate; that means, that my production rates are very high.

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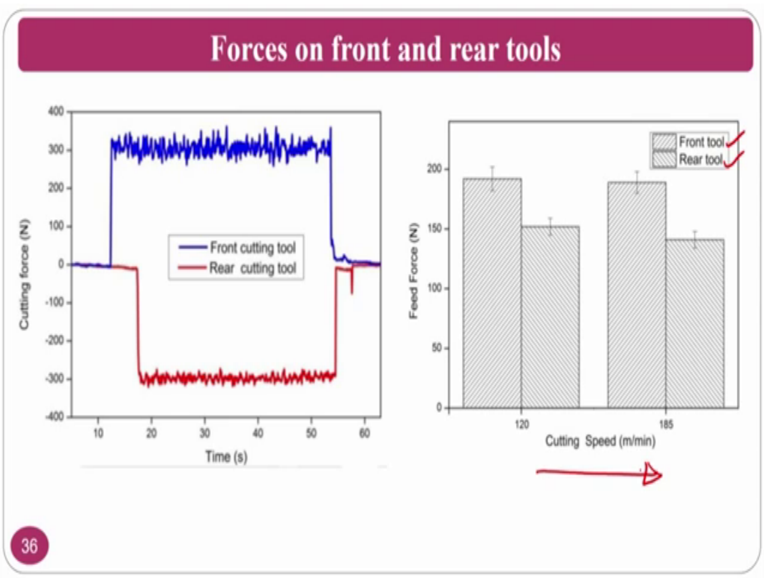

But your tools are mounted on the opposite direction, because of which one will experience positive; another will experience the negative forces. The tool one that is called the front tool and rear tools; The front tool will experience higher and the rear tool experience the lower, because of the thermal softening of the workpiece; that is done by the first tool, the forces experienced in the second tool will be normally low; that is why as you increase the speed the feed forces are slightly low.

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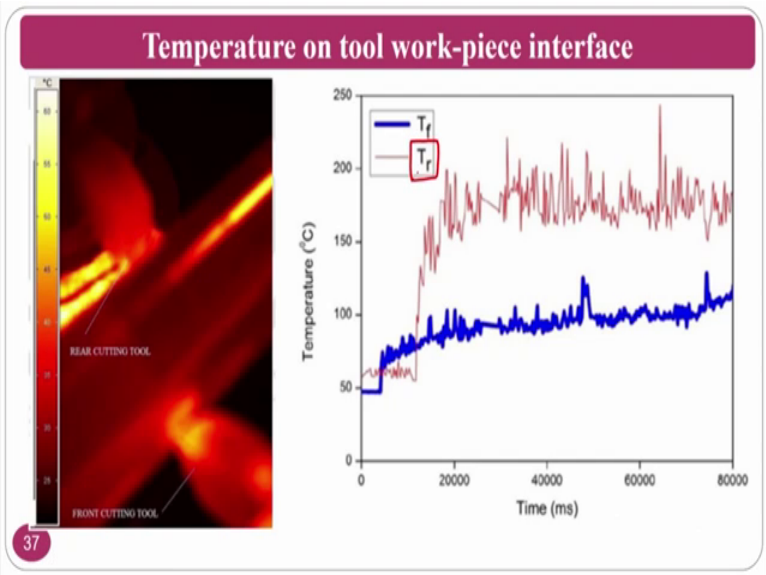

You can see the temperature on the tool workpiece interface. If the temperatures also the rear tool as well as the first tool. So, the temperatures normally will be very high, because already the temperature is there in the workpiece that will be imparting to the tool; that is why the temperatures in the rear tool will be slightly higher compared to the first tool.

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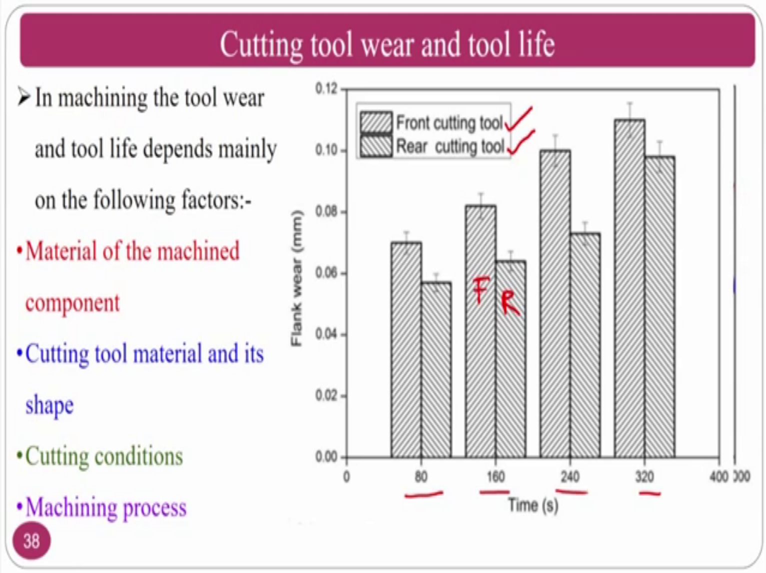

The cutting tool wear life and all those things. Normally the tool wear if you talk in terms of the front and the rear tool. Rear tool; obviously, the flank wear will be very less, because the workpiece is getting thermal softened and all those things. In the machining the, if you talk about the tool wear in the front cutting tool and the rear cutting tool, the tool wears normally if you talk. The front tool wear will be slightly higher, because you are removing the original material.

In the rear what is happening is, the workpiece is getting pre-temperature; that means, that the heating is taking place that is why the thermal softening of the workpiece is there, because you are offset is too less between the two cutting tools. Assume that my cutting tool is here another cutting tool is here, there is a slight offset because the time travel is very less that mean that the first tool cuts and goes off second tool come into action; that means, that there is no much is sufficient time to cool down.

In that particular case what will happen, the thermal softening of the workpiece takes place, so that the rear cutting tool experiences very less temperature. Rear tool experiences the thermal softened workpiece material; that is why the flank wear is less. If you see all the speed, if you see all the cutting times, for every condition, normally front tool as well as rear tool follow the similar trend; that means, that front tool have higher flank wear compared to the rear tool.

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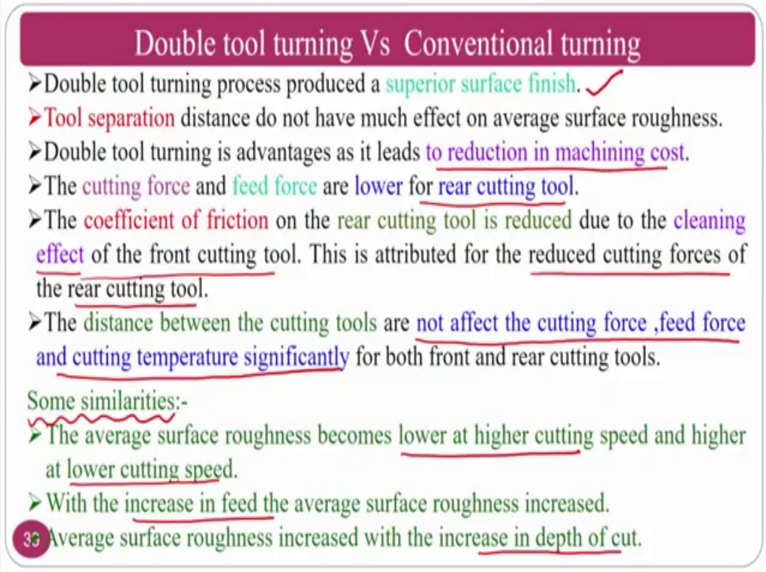

Double tool versus the conventional, double tool process produces the superior surface finish. This is a maybe may not be that is depend on your second tool feed conditions and depth of conditions. If you are going to use less in terms of the second tool; that is the final tool that is coming. In that circumstances you are going to get good surface finish. Tool separation distance do not have much effect on the average surface roughness, but it will have effect on the temperature.

Double tool turning is advantages and it leads to reduction of machining cost, because the same power of the workpiece spindle is you are using in both, same power that you are giving to the spindle; that is head stock, you are using for machining with two tools; that means, that; obviously, the power consumption is less.

The cutting forces and feed forces are lower compare for the rear tool. Basically the thermal softening of the workpiece takes place, because of which rear tool experiences low forces. The coefficient of friction on the rear tool is reduced due to clearing effect, the front of the front tool. This is attributed to the reduction of the forces of the rear cutting tool.

Distance between the cutting tools are not affected, the cutting force, feed force and the temperature significantly, but in practical there will be a some temperature raise, because of the machining of the front tool, because of that there is a slight variation that you have seen in the previous one, where the tool life is or the tool wear is less in the rear tool.

Some similarities in terms of conventional as well as the double tool turning; The average surface roughness becomes lower at higher cutting speed and higher at lower cutting speed. The average surface roughness becomes lower at higher cutting speed; this is holds good for the both double tool as well as single tool, with the increase in the feed, the average surface roughness increases. This is the same in terms of conventional as well as double tool.

Average surface roughness increased with increasing depth of cut. This is not so, but the problem is whenever you decrees that depth of cut what will happen, temperature raises, if the temperature raises there will be a problem with surface roughness also in the nano-scale, not into very big scale, but very minute level.

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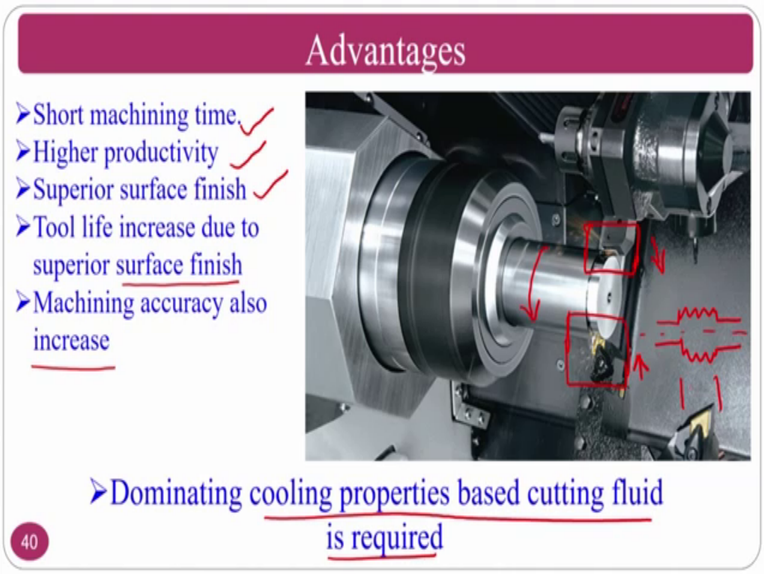

Advantages of this particular process; short machining time, because you are doing with two tools high productivity and superior surface finish subjected to the machining conditions. Tool life increases due to superior surface finish. Tool life normally will be increased in terms of the rear tool, machining accuracy also increases. This is about the advantages.

The domination cooling properties based cutting fluids will be used for the both the things or you can use if the speed is very high you can go for the cooling based also. The here you can see here; one tool is doing the machining here, another tool is doing machining here, for the rotation is same. If you are rotating like this your tool in this, one condition it will be facing upward, in another condition it will be facing downwards, it will be facing downwards here the tool facing upward; that is why in the previous graphs where you have seen the forces in one condition is like this, another condition it will be like this.

So, you will get negative forces and positive forces, only you need to do the mode. So, you take the mode of that one, so that you can get the forces in a positive spectrum. Now, we move on to the thin wall machining. Thin wall machining as such as a great importance and nowadays people are working. Those people who are interested to work on a for their Masters and PhD or the B.Tech projects, they can take up the thin wall machining thin.

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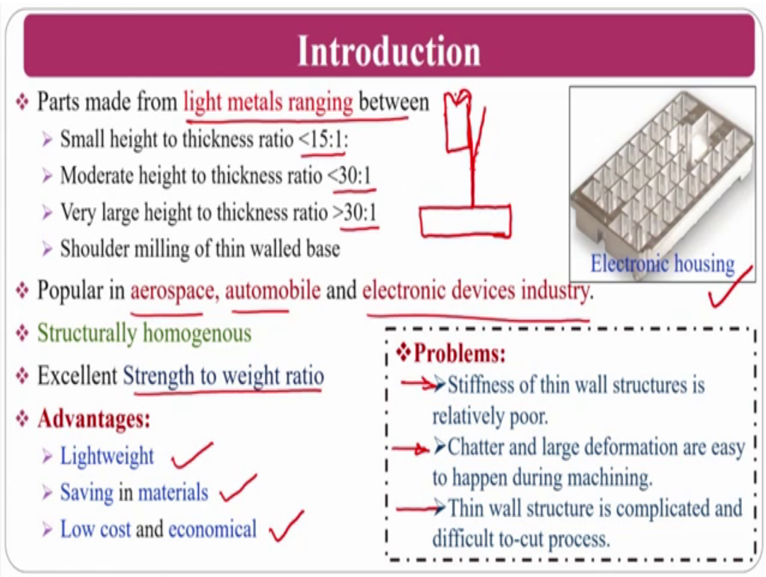

Wall machining has a great applications in various sectors, especially electronics sector. If you open your CPU, basically you will find 2 or 3 thin walled components for taking out the heat dissipation in the CPU. The parts made up of light materials ranging between small height to thickness ratio that is called 15 is to 1, moderate height with thickness ratio 30 is to 1, very large height to thickness ratio 30 is to 1 above 30 is to 1. So, shoulder milling and all those things.

You can see here, you can see here electronic housing, where you can house some of the electronic parts in this particular housing system; that is done by thin wall machining. You can also see some of the examples in the upcoming slides.

This is most popular in aerospace automobile and electronic devices industry. Structural homogeneous is most important in this particular process and excellent strength to weight ratio also can be achieved. And the advantages is, normally this will applied for light weight, saving materials and low cost and economic. If you see the applications in the upcoming slides you can understand more and more.

The problems with respect to this one is stiffness of the thin wall structure is relatively poor and at the same time charter and large deformation are easily happened during the machining process, thin wall structures are complicated and difficult to cut process, because basic problem comes is, if at all I want to cut a thin wall like these on a workpiece material, what will happen? If I start cutting this particular top portion, because it act as a cantilever type, it tries to bend like this.

There is a complications are there, whenever you try to do the machining operation ok. Whenever you try to do this machining operation what will happen? This particular thing try to bend like this. So, there are many people who are working on how to reduce the bending effect and all those things or this.

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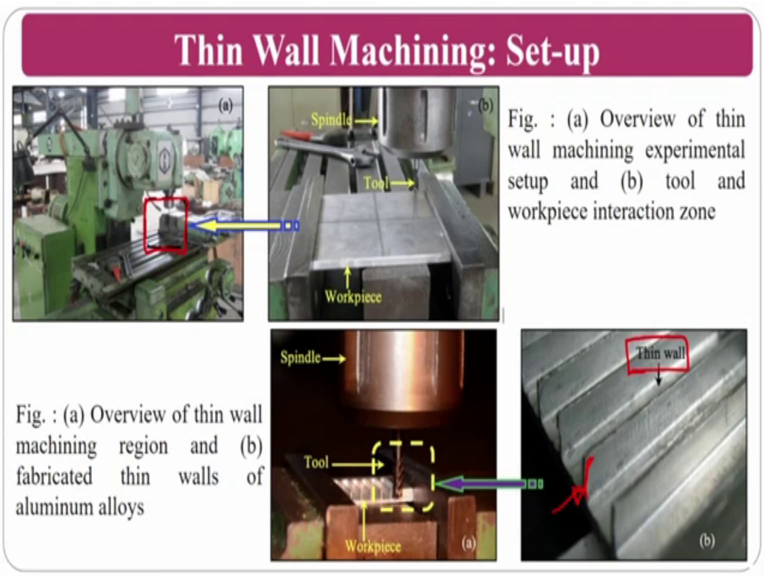

If you see this is a particularly we have tried to take the pictures using aluminium, copper which are the soft materials and you can even see here that the thin walls that are machined here in this particular thing is the aluminium alloy, where the thickness is approximately 1 mm, but I cannot say this is the thin wall machining process, but still we have done in the next step, like whatever you are seeing here in this particular thing, is 0.5 mm. Still as I said know world grows you may be working on micron, some few micron thickness walls and all those thing.

There are so many techniques, like you can go for some of the advanced techniques where you can get thin and thin walls on the material. But at the same time the workpiece material is aluminium, it is soft, the basic problem is somewhat bending nature will come that one has to see.

Normally, in this particular condition what we have done is the milling process, you can see the milling zoomed version you can see here, milling cutter is there and you can also see how it is cutting the thin walls in the aluminium and you can finally, you can see the thin walls in this particular material.

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So, thin wall machining, basically you can do by the milling process, whenever you do the milling process high efficiency reduction cost, pocket milling with the minimum hand finishing or the free form hand finishing you can do, and the rough machining also followed by the fine finish machining, then the hand finishing and these are all the some of the techniques that people are going to use for making the thin walls.

You can see here the milling cutter, how the milling cutter making the pockets, how the milling cutter is making. This is a basic mechanism that people will use for making the thin walls; like here you can see the thin walls, how the thin walls are fabricated.

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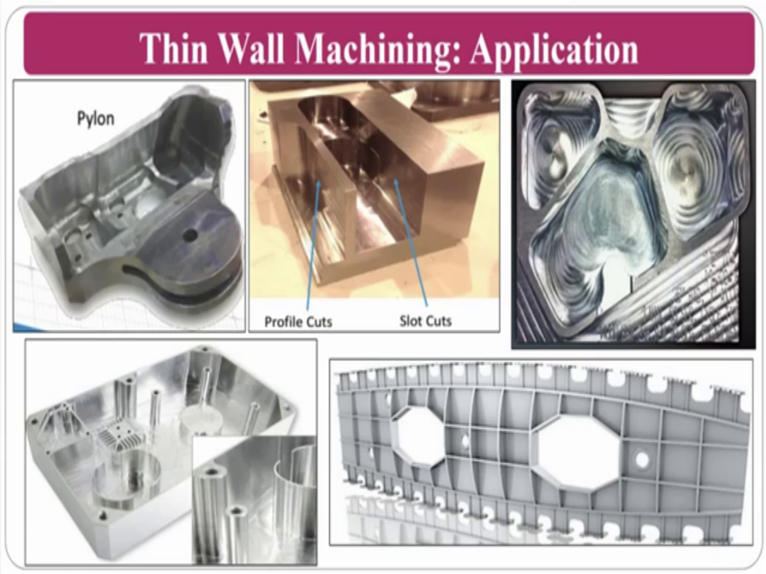

The applications normally pylons, profile cuts and all those things, if you can see normally this is a wing, where the thin walls are there, wherein you can use for filling some of the fuel and all those things.

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Still more if you can see the structures of your laptops, you need to cut very fine, because people are talking about ultra slim laptops and all those things for that purpose, one has to cut very very fine structures on the base material that are fabricated for the laptops.

You need the strength, at the same time you need accuracy, because electronic packaging is most important thing whenever you are packing a mobile, whenever you are packing a laptop and all those things. For that particular purpose the most sophisticated thing that people are going to use is, thin wall machining.

You can also generate some of the cylindrical surfaces, some of the heat exchangers. Normally the people are going to use for heat dissipation. So, thin pins based technologies are there. So, if you going to do the milling operation or if you are going to generate with a thin profiles are very very thin walls what will happen, the surface area increases. Whenever the surface area increases what will happen? The heat dissipation ability will be very very high that, for that purpose normally thin wall machining is applicable.

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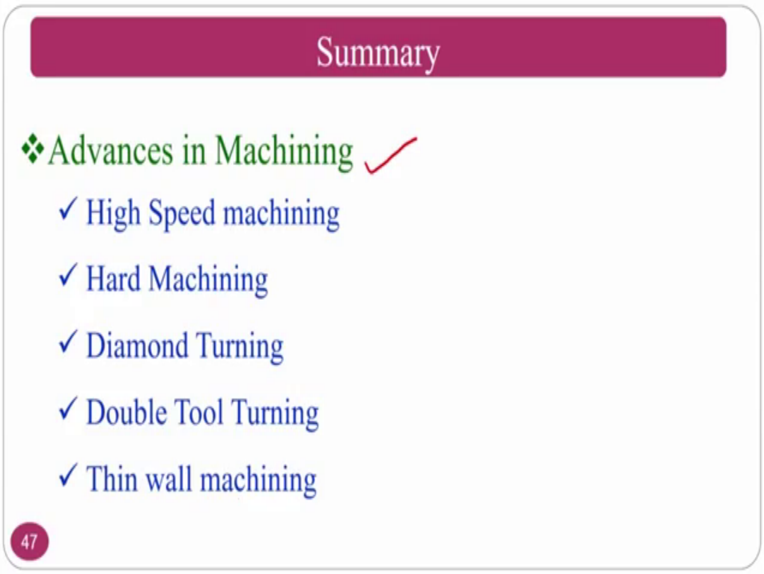

So, summary of today's class we will go by this, we have seen the advances in machining in this particular class, where we talk about the high speed machining, hard machining, diamond turning, double tool turning and thin wall machining process. So, we come up the next class with some other things; like machining of advanced materials and machining of brittle materials, how do machine. Assume that I have a glass if I want to machine it, what will happen if I go and use a milling cutter with high force and all those thing what will happen, brittle fracture will takes place.

For that purpose we need to do some of the technologies like as ductile region machining of brittle materials, how we are going to, some of the things you have seen here, where you are looking at the hard machining process, you need to use some laser source make it soft then do the machining operation, similar type of things we will see for brittle materials, some of the biomaterials and so on, and at last we also see if time permits about the sustainability machining.

Thank you.