Fundamentals of Manufacturing Processes
Dr. D. K. Dwivedi
Department of Mechanical & Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture – 04
Materials and Manufacturing Processes

Welcome participants to this lecture. This presentation is based on the Materials and Manufacturing Process, related with the subject fundamentals of the manufacturing process.

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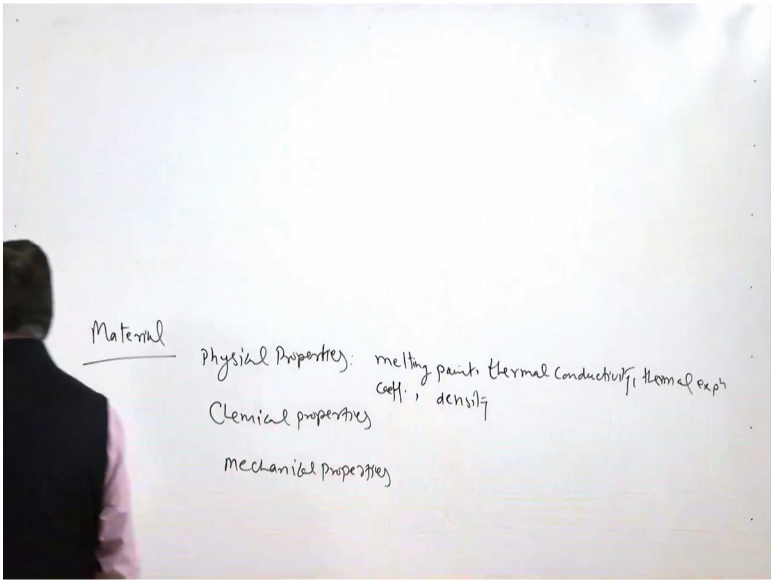

We know that in manufacturing we will be using some kind of the material. So, basically here we will be talking about the metal processing for manufacturing by the different processes. So, the material we know that the material of have possess the different physical properties, there will be different chemical properties, and they will be having the different mechanical properties.

So, these are the properties which are of the important from the manufacturing point of view, any material you take which is to be processed for manufacturing by any of the manufacturing processes, we need to consider certain the properties of the material, and these properties need to be seen to see that which process will work better for given material. So, among the physical properties like the melting point; melting point, temperature of the material, like thermal conductivity, thermal expansion coefficient, density.

So, these are the some of the properties which are related with the manufacturing and if it is anything else, then I will let you know - here like say thermal conductivity, expansion coefficient, melting point and the solidification temperature range.

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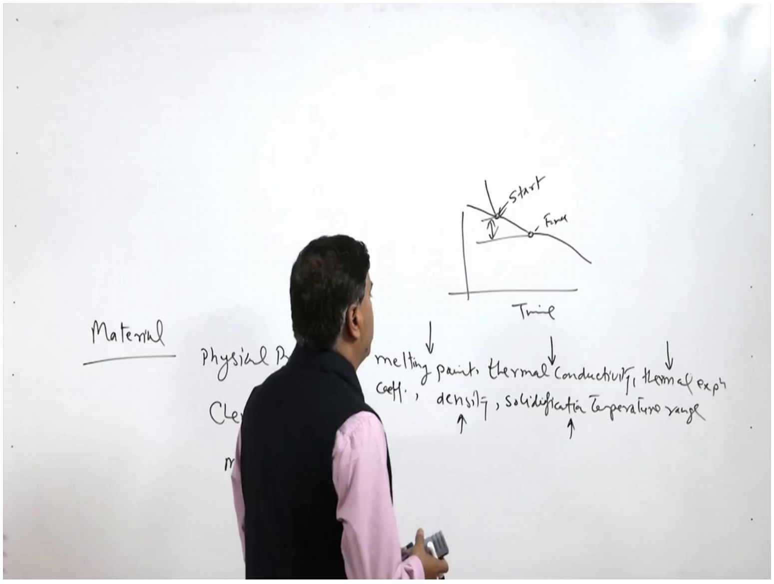

Melting point is the temperature at which the material is brought to the complete molten state, thermal conductivity determines the ability of the material to transfer the heat, thermal expansion is about the change in dimension for unit degree of the change in temperature, and the density is the mass per unit volume, and the solidification temperature range is for the alloys wherein solidification is start at one temperature and then ends at another temperature.

So, like if we draw the two cooling curve as a function of time, so we will notice that that whether this is the temperature at which solidification is starts, this is how the solidification then temperature slows down slowly and then it decreases slowly. So, here the start of the solidification and here solidification and, so this temperature difference is known as solidification temperature range, and this happens mostly in case of the alloys. Pure metals solidify at a one temperature, and similarly eutectic alloys also solidify at one temperature, but the normal other alloys solidify over, so other alloys solidify over a range of the temperature. So, that is called solidification temperature range.

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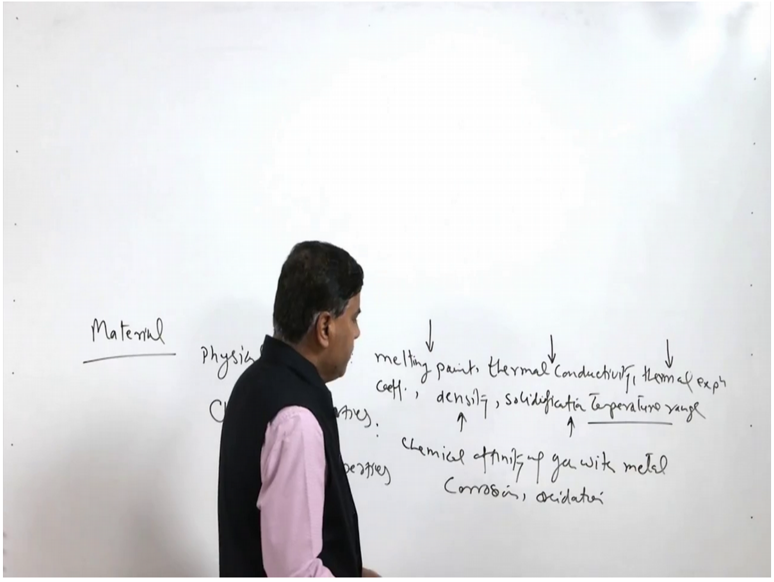

And it affects the soundness and the cracking tendency of the material which is being made by either welding or the casting processes, chemical properties of the material which includes like affinity chemical affinity corrosion, chemical affinity of the gases with the metal which is being processed corrosion tendency or oxidation tendency, since during the processing like the welding and the machining as well as during the forming processes at high temperature. There is a tendency of the oxidation of the metal, and in the molten state during the casting the affinity high affinity of the molten metal of the metal with the gases leads to the increased tendency for inclusions and the gas porosity formation tendency.

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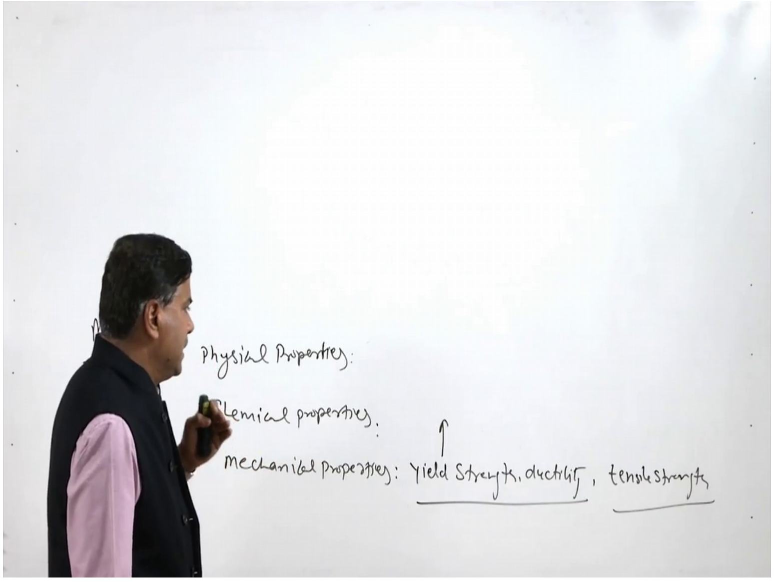

Then coming to the mechanical properties like, yield strength ductility, these are the 2 important properties, and maybe sometimes tensile strength or ultimate tensile strength, also affects the manufacturing aspects. So, here yield strength is the stress level where the plastic deformation starts the elongation is the extent of the deformation or the strain which a material can sustain prior to the fracture, and it is measured in terms of the percentage elongation, and also the percentage reduction in area is and as the is a another parameter, which is used for as a measure of the ductility, and the tensile strength is its a maximum stress that material can take is a defined as the tensile strength or a ultimate tensile strength, beyond which the failure of the material will be occurring.

So, how are these properties relevant to the manufacturing that is what we will try to see the process wise.

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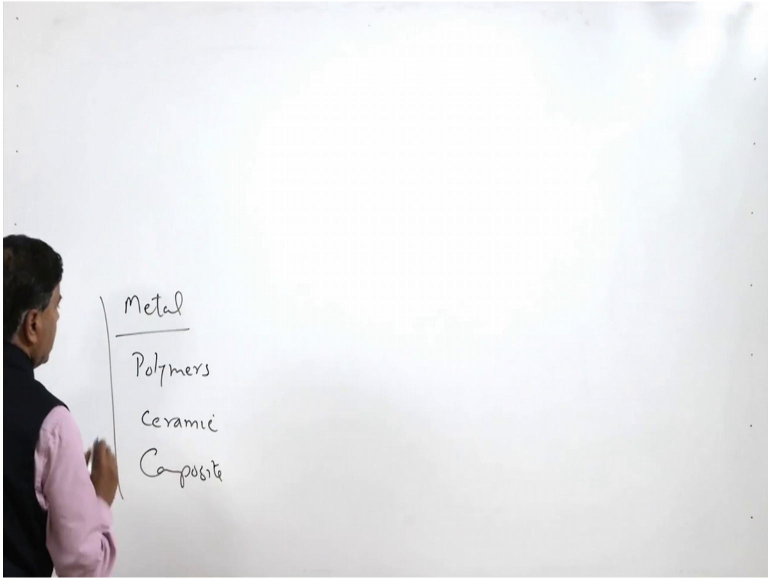

So, we know that there is very wide variety of the materials, like we have the metals, we have like polymers, we have ceramic, and we have like composite materials, which are mix of so, in the metals also we have very wide variety of the materials like, the ferrous metals, and non ferrous metals, in this subject mostly we will talk about the metals and they are manufacturing.

So, in metals we have like a wrought a ferrous metals, we have wrought iron a steels or in the steels although there are different categories steels then cast iron, and in the steels which are extremely common like, medium low, medium and high, carbon steels, and the stainless steels, and there are a number of categories in each of the category of the steels, and among the non ferrous metals, what we have like magnesium alloys, aluminum alloy, titanium alloys, nickel or super alloys.

So, since there is very wide range of the metal systems and this limit is this list is very long, and in each category there are number of the alloys. So, since each metal system will be of a particular composition which will be having particular kind of a structure, it will have its own melting point, it will have its own mechanical properties, it will have its own like say all the physical and chemical properties. So, since the systems are very wide having the different compositions structures melting point mechanical physical and chemical properties so, each of these metals cannot be processed equally well using a given process.

So, what we need to look into to see the way by which a particular metal can be processed. So, we need to definitely see the physical chemical and mechanical properties of these metal systems, in order to find the way by which it can be by which process it can be manufactured effectively, like polymers are of the low melting point system ceramics are the high hardness high melting temperature materials and composites are of like, the mix of a the 2 constituents like, we can have the system A, is the metal matrix and B particle is reinforced of the ceramic, in order to have a combination of the properties.

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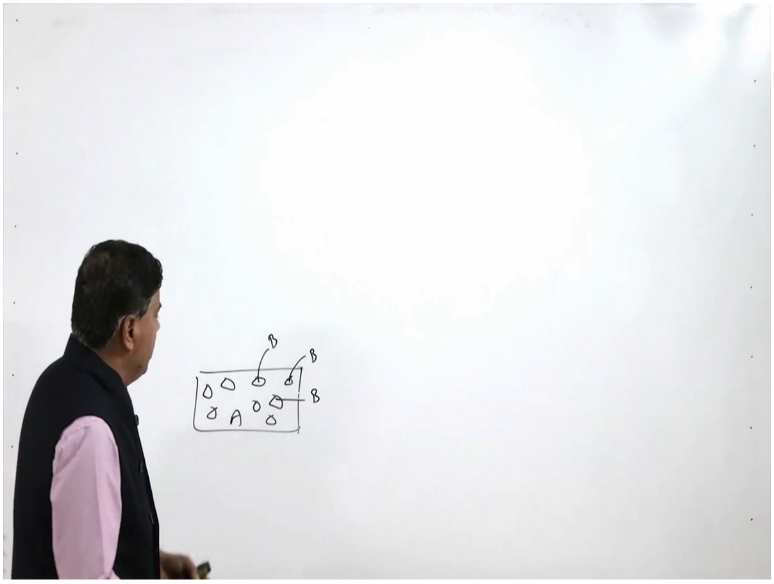

So, it will have the where in each of them will be maintaining its identity its properties so, means ceramic particles are reinforced in the metallic matrix, so it will have the properties of both so, the these are made using a special category of the processes. So, now, we will be seeing the properties that matters a lot for a processing using a particular process for making using a particular process starting with the casting.

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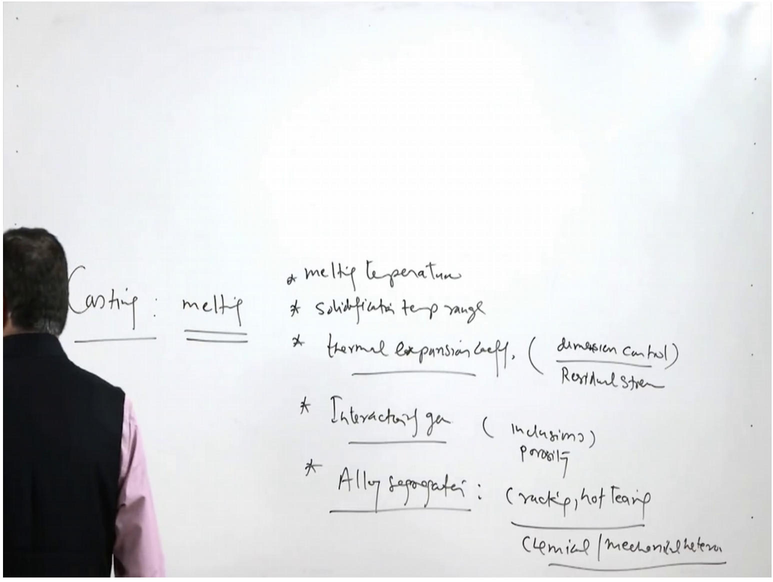

We know for the casting what is important the melting of the material, and when metal is brought to the molten state it will be interacting with the gases it will be solidifying so, shrinkage will be taking place, and so these are the things which and after the solidification we will be getting the product. So, the things which matters for the casting process is like melting temperature of the material being processed higher is the melting temperature greater will be the difficulty in bringing it to the molten state, So, more will be the casting difficulties. So, low melting point temperatures like aluminum magnesium are easier to process cast iron is easier to process has compared to the steels.

Now coming to the solidification temperature range, like the metal systems having wider solidification temperature range they will be showing the greater tendency for the alloy element segregation. So, increased segregation tendency will be leading to the increased solidification cracking tendency, increased hot tearing tendency, and therefore the metal systems having the narrow solidification temperature range, they will offer the limited problems related with the solidification; like solidification cracking, or the hot tearing.

Next is the thermal expansion coefficient; thermal expansion coefficient, is the important in the costing also, because during the after the solidification the casting will be cooling down to the room temperature. So, if the expansion coefficient is too high then excessive shrinkage will lead to the control lead to the problems related with the dimensional control, high solidification the high thermal expansion coefficient will cause the problem of the dimensional control due to the shrinkage dimensional control, due to the shrinkage this is one and excessive shrinkage will lead to the under certain conditions will lead to the development of the residual stresses also, so increased residual stresses will be creating the problem of the distortion as well as cracking tendency.

Then we have the interaction of the gases with the molten metal. So, if the like reactive metals like aluminum and magnesium are very and titanium are very reactive to the atmospheric gases, so they will reforming their oxides nitrides easily and leading to the development of the defects in form of inclusions in the casting, or they will be leading to the presence of the gas post so, porosity in the casting.

So, the interaction of the gases with the molten metal is the problem, so affinity of the gases or this is the chemical property where affinity of the molten metal to the surrounding gases is limited solubility difference is less, in the liquid and solid state that will be leading to the reduced porosity. And then alloys segregation tendency, this will be more actually in the systems having the wider solidification temperature range at the same time the like if the alloying elements have the larger difference in terms of the physical properties, then they will have either tendency to segregate at the top or segregate at the bottom.

So, like the density is too high density differences is a, difference in density of the solvent and the solute is too high then alloying elements will tend to settle down, or they will tend to float over the surface so, that the differential physical properties will be leading to the increased segregation tendency of the certain alloying elements, at the same time increased solidification temperature range also increases the alloy segregation tendency.

So, if the alloying is if the metal being process is having the higher alloys alloying element segregation tendency, then it will be leading to the increased cracking, hot tearing, or tendency as well as chemical heterogeneity, chemical and mechanical heterogeneity. So, this is not good if we consider the alloy segregation tendency. So, these are the properties that need to be seen for assessing the suitability of particular a particular material for the casting process, coming to the forming processes.

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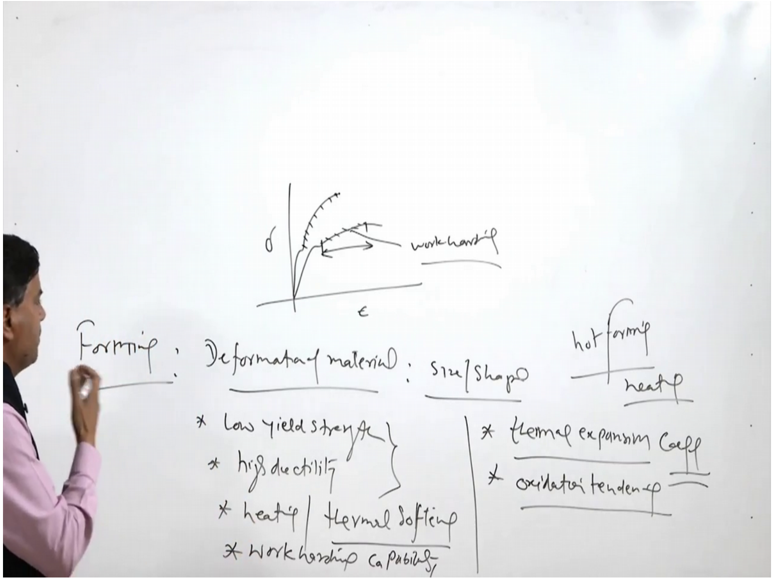

A forming processes we know that are the based on the deformation of the material, using external forces to get the desired size, and shape, so to facilitate the deformation by the forming processes, it is necessary that the material has the low yield strength. So, that the deformation is facilitated, at the same time whenever material is deformed it should get deformed without developing any cracks, and for that it is necessary that it has a high ductility or the percentage elongation is high.

So, these are the two very important requirements for the material to be processed by the forming process, if material is having limited ductility and the high yield strength, then heating becomes mandatory, so that these properties can be attained and for that purpose the thermal softening of the material should show the good thermal softening, there are many metal systems which do not soften even after heating to the high temperature, and they still offer the of a offer the problem in deformation even at elevated temperature.

So, material should show the thermal softening behavior of the material will also be affecting the success of this process, if the material is getting soft and easily then its good otherwise it will be a problem. The problem then there is like a thermal expansion, we know the hot forming processes, involves the heating at high temperature. So, increase in temperature will be leading to the expansion thermal expansion of the material and an expanded condition material will be deformed.

So, after the deformation it will be shrinking during the cooling to the room temperature, and that will be leading to the problems associated with the poor control over the dimensions, so thermal expansion coefficient of the material becomes important for having the control over the dimensions, if the material is of having very high thermal expansion coefficient, then the control over the dimensions will be poor. Similarly the chemical affinity or the oxidation tendency of the material, during the heating the material gets oxidized, then it will be leading to the poor surface finish after the deformation.

And then the work hardening capability is the another important factor, like work, hardening, capability, to understand this what we need to see the simple diagram, we know that this is the engineering stress strain diagram, and you know the one metal system may respond like this so, this is the region of the plastic deformation, where in the deformation occurs from the end point to the it point ultimate point load.

So during this deformation, we know that during this plastic deformation, we can see that for causing further deformation it requires the higher and higher level of the stresses. So, the means during this increasing stress requirement to cause further deformation, this attributed to the work hardening of the material. So, this is getting work harden work harden at one particular there may be at another metal system, which we may work harden like this.

So, here this is work hardening at much faster rate than another material, so for the same kind of a strain for the same magnitude of the strain, it may be harden it is getting hardened at much faster rate. So, during the deformation in the for a deformation based processes, if the material gets hardened very rapidly, then it makes the deformation difficult, and that is why it is always good that materials work hardening a capacity or work hardening behavior is limited.

So, like the metal systems like aluminum they do not work harden, so rapidly and work hardening the extent of work hardening which takes place in the aluminum is very limited as compared to that which will be taking place in case of like say stainless steel, or the other austenitic stainless steel. So, they will be making the job difficult, like super alloys also get work harden very rapidly during the deformation, and due to the deformation that they make the process difficult.

So, work hardening capability of the work hardening ability of or work hardening behavior of the material, also affects the success of the manufacturing process by the forming processes.

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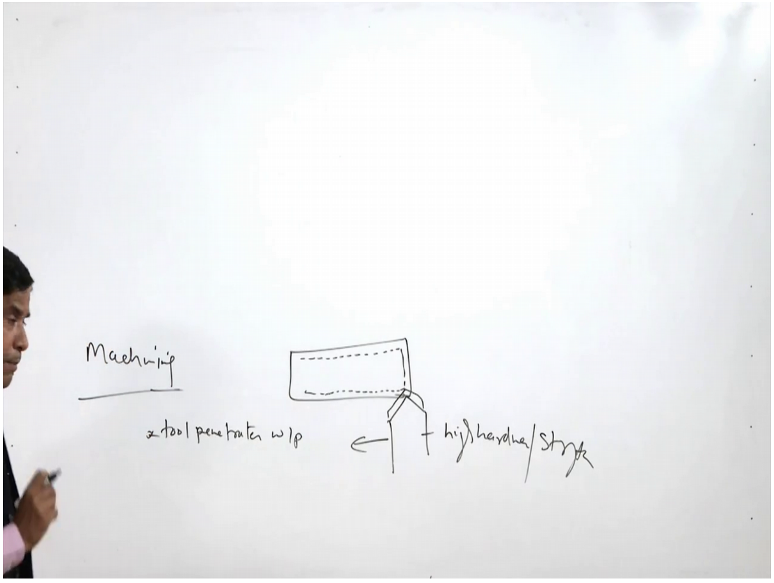

Next is the machining; in case of the machining, what we use basically for machining purpose, we use the tool which is of the high hardness, and strength then the workpiece. So, it penetrates basically it penetrates into the workpiece up to some distance, and then the transverse movement removes the material all along the circumference, so this is the extra metal which is removed through the machining process. So, what is important for this that, the tool penetrates the workpiece, and for this the workpiece material means work hardness of the tool material must be greater than the hardness of the workpiece material.

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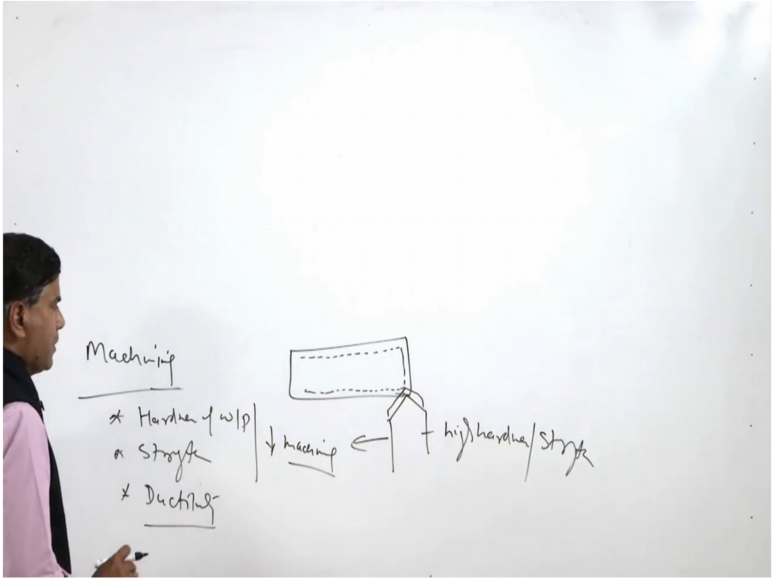

So what is important for this process is that the among the mechanical part is hardness, of the workpiece is one strength of the workpiece material because material has to be sheared off from the raw stock material, so if the higher is the resistant it will take the greater power for removal of the material power consumption for a machining will be more, so it will make the job of the machining difficult. So, higher is the hardness, higher is the strength, both these will be reducing the ease of machining of a given material.

Then the ductility; ductility, also affects you like if the material is having too high ductility, then it will be forming very long curly chips which will make the machining zone very clumsy as well as the chips, will be rubbing to the surface of the machined component machine surface of the component, so which will be adversely affecting the surface roughness.

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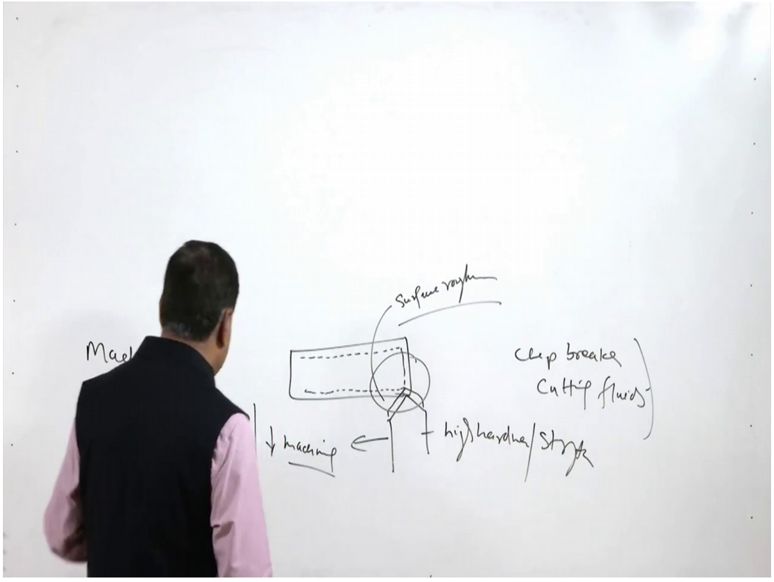

So, what is good that the ductility of the material is limited otherwise it will be forming very it will be forming very long curly chips, and which needs to be taken care of although there are methods like the chip breakers are used or the coolant or the cutting fluid will be helping to clear the chips being formed from the machining zone, but ductility certainly affects the ease of machining in the way by which chips are getting cleared from the machining zone.

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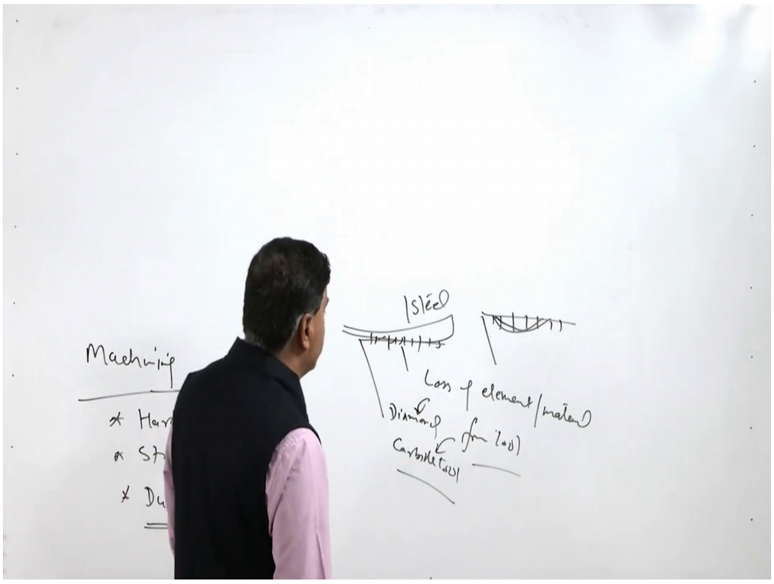

Another other properties related with the machining like the interaction of the workpiece material with the tool. So, here it is important like, that the say this is the tool and the chips will be flowing after the getting removed from the workpiece, so interaction between the 2 if it is taking place, then this will be leading to the loss of the elements or materials selectively from tool. So, this will be weakening the tool actually, like if the diamond or carbide tools are used, then the steel interacts with the tool material and carries away some and this interaction leads to the loss of the elements in form of the carbon or in form of these the carbides which are there in the tool.

So, the loss of these elements will be leading to the reduced or weakened zone of the flank of sorry face of the tool and, this in turn leads to the formation of the crater on the face of the tool, so that in turn will be reducing the life of the tool.

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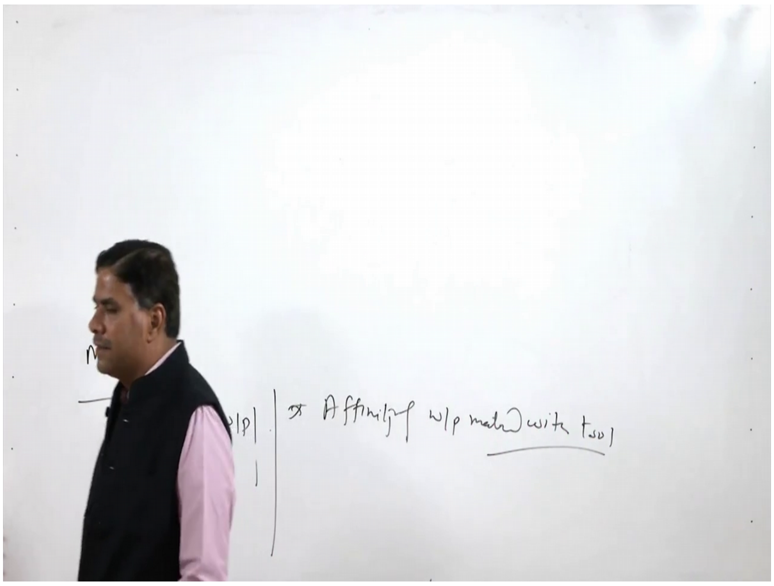

Therefore interaction or affinity, we can say affinity of the workpiece material with the tool, this is also important and thermal conductivity is important in the sense that whatever heat is generated from the heat is generated in the cutting zone, that will be effectively carried away by the workpiece, otherwise heat will start getting localized in the cutting zone tool temperature will rise and that will adversely affect the tool life so, the ease of the machining will be adversely affectedah. From the welding point of view the properties which are important that will be talking, we know that there are various variants of the welding like, the solid state welding process where the things remain in the solid state, so for that the important is the yield strength of the material, because the flow of the metal is important for establishing the metallic continuity.

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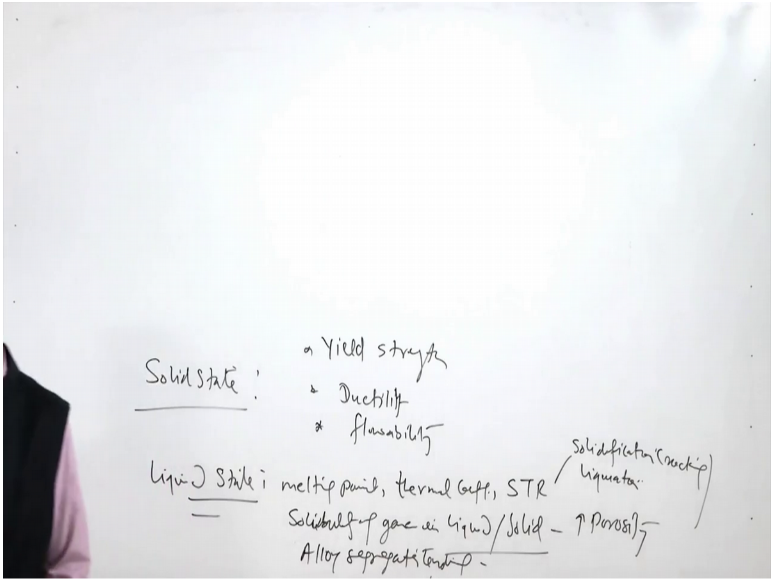

So, yield strength and the ductility these are the two things that are important, at the same time for the solid state welding process, as the same time the flow ability of the material also affects the success of the process.

And then in case of a the liquid based processes where fusion of the faying surfaces is to be achieved, in that case the melting point of the base metal because we need to ensure that the faying surfaces are brought to the molten state. Then thermal expansion coefficient we need to see that the faying surfaces which are being heated, that they do not cause much of the expansion otherwise it will be leading to the higher expansion more increased expansion of the region near the faying surfaces, which have been brought to the molten state, and that will be increasing the increase increasing the tendency for distortion as well as residual stresses.

Then solidification temperature range, in case of the welding it increases the solidification, cracking tendency, and another form of cracking is also the liquation cracking tendency is also observed if the solidification temperature range is high, and the solubility in the liquid state and the, so in case of the liquid state processes, a solubility; solubility, of the gases in liquid, and solid state also important if the difference in the solubility of the gases, in the liquid and solid state is more, then it will be increasing the tendency for the porosity formation.

And similarly the alloy segregation tendency, this is important because it affects the solidification cracking tendency, as well as liquation cracking tendency, in case of the weld joints.

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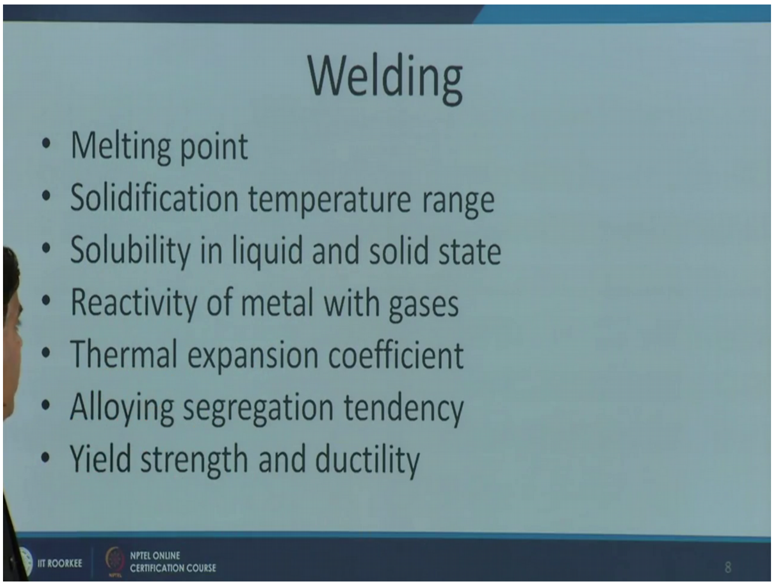

So this is what we have seen in case of the welding the melting point or the certification temperature range, solubility in the liquid and solid state so, melting point effects the ease of fusion solidification temperature range affects the solidification cracking, and the liquation cracking tendency solubility of a solubility of the gases in the liquid and solid state, affects the porosity formation tendency, reactivity of the metal, with the gases determines the cleanliness of the weld metal, because if the metal is very reactive to the gases all around the well zone. Then it will be leading to the increased inclusions, and increased impurities tendency, in the weld metal, a thermal expansion coefficient, we know that as I have explained greater is the thermal expansion coefficient, greater will be the problems related with the residual stresses, greater will be the problems related with the residual stresses, and distortion of the weld joints alloy segregation tendency.

This is more related with the liquation cracking in the solidification cracking tendency, and the strength and the ductility these two are on important for the solid state joining, but these can also be important for the fusion welding processes because, higher is the yield strength greater will be the residual stresses higher is the ductility, reduced there will be reduced cracking tendency of the base metal.

So, here now we will summarize this presentation in this presentation I have talked about the properties that are important for a manufacturing of the material, manufacturing the material by the different processes. So, what are the properties that we need to look into to see that how a given material can be effectively processed using a given set of the manufacturing process. So, it basically it will help us in choosing the right kind of the manufacturing process considering the material which is to be processed.

Thank you for your attention.