Manufacturing Guidelines for Product Design

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Lecture-07
Properties of Materials

Namaskar friends, welcome to session 7 of our course on manufacturing guidelines for product design. If we have a quick review of what we have covered toll today, we have covered the basic aspects of manufacturing processes, the classification of manufacturing processes, the applications of manufacturing processes and we have tried to see that what are the process capabilities of the various types of manufacturing processes.

We try to see the application areas of the manufacturing processes, although we have not gone into the details of the manufacturing processes, the manufacturing mechanics of the manufacturing processes or the parameters governing a particular manufacturing process, but we have try to understand from the application point of view that which process can be use under what type of circumstances, under what type of conditions.

And in that we have seen that casting can be used for a very specific application, machining can be used for a specific application and then we have listed a criteria which will help us to decide that which manufacturing process can be used for which type of application. In the 2nd week of our discussion we started the discussion with introduction to the engineering materials in which we have seen what are the various types of engineering materials that we use.

If we see all around us so many types of engineering materials are there. They are polymers, they are plastic, polymers or plastics one of the same thing we have metals, we have wood, we have other types of materials like ceramics. So we have tried to classify the engineering materials into different classes or different families or different groups. Today our target is to see that what are the properties of the engineering materials which a product designer must know.

Every product designer must have a basic idea about the material, otherwise how the designer will be able to specify that this particular material can be used for this specific application.

Again I am taking the example of a chair, in chair if you see the chair can be made with metal, it can be made with wood, it can be made with plastic. Now we have different types of chairs, now depending upon the specific application the product designer has to find out, has to suggest that which material must be used for this particular type of a chair. So the properties of the engineering materials must be known to the product designer prior to finishing for prior to finalising his or her product design.

So we will today try to revise what are the various mechanical, physical, chemical properties as well as a thermal properties which are important from the product design point of view. So whenever we are designing a product we must have a look at these properties from the material suggestion point of view or from the material choice point of view. Because whenever we finalize the product we have to see that which material is going to be used for designing or for after designing for fabrication of this product.

One example that are usually takes in the class is the example of a toothbrush, in toothbrush we see what are the basic requirements it must be light in weight, it must be cost effective, it must not be too costly than the bristles have to be they have to be light on the gums, or they have to be soft on the gums or they have to be harsh on the gums, most of the time we see bleeding from the gums if you brush your teeth too vigorously.

So we have to ensure that the material of the bristles must be soft on our gums. So we cannot use a metallic bristles in case of brushing of our teeth, whereas we can use the metallic bristles for some other application where we want to do hard rubbing on any surface or we want to do cleaning of some very hard surface there we may go for metallic bristle. But in case of toothbrush we will definitely suggest soft bristles only.

And then the material that we select must be soft on our gums. So this is just one example of selection of a material for a specific product and how we will be able to suggest the materials for product if we have complete information about the materials, the types of materials available as well as the properties of the materials and then we must also know that how to select the materials.

What can be the selection criteria based on which we can select the material for a specific application and that is the objective or the aim or we can say the goal of this particular

discussion that we are having during this week, that is the 2nd week of our course on manufacturing guidelines for product design. So let us start our discussion with the properties of materials.

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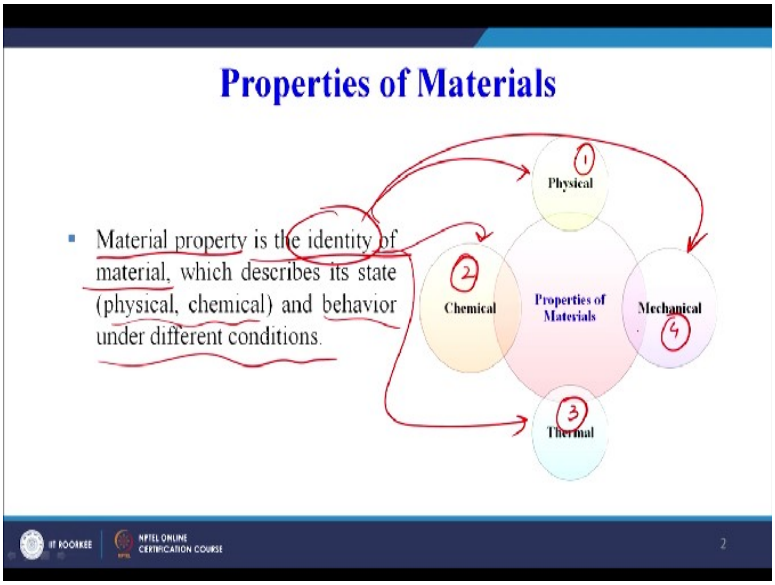

Now what are the properties of materials, you can see a material property is the identity of the material. So identity it will identify the materials, now how it will be identified it will be identified based on the physical, based on the chemical, as well as based on the thermal and the mechanical properties of material. So the material property is the identity of the material which describes it state physical and chemical state and the behaviour under different conditions.

So the property basically will define the behaviour of a material under different conditions, how it is going to behave, when it is subjected to different types of conditions. For example if we have a surface and we rub on the surface, we will try to see that what is one of the properties that may come to our mind may be the hardness of the material. If it is hard it will wear out less, if it is soft it will be wear out quickly. So that we have to see that how the material will behave under different types of conditions.

So that is going to and that will be dictated by the various properties of a material. So steel may have a different wear resistance properties, whereas plastics may have a different wear resistance properties and from application point of view this example if we can talk about the floor so **so** many people are working on the floor, so we must know that how this flooring is going to behave when maybe 100s of people are going to walk on this floor.

It must not wear out, it must not decolour, it must not be chipping of material may not take place from the floor. So how we will decide that which material must be selected for our floor, it must be tiles, it must be a carpet or what type of flooring we must provide when so many number of number of people or x number of people are going to go walk on this floor on a daily basis, on weekly basis and on yearly basis.

So that selection of material will depend upon the properties of the material, that yes this material posesses these specific properties and therefore it can be used for this specific application for making the floor. So that is why the importance of material properties cannot be ignored from the product design point of view and every product designers must have little information or we can say a basic information about the material properties and the focus primarily has to be on these 4 properties that we are listed here.

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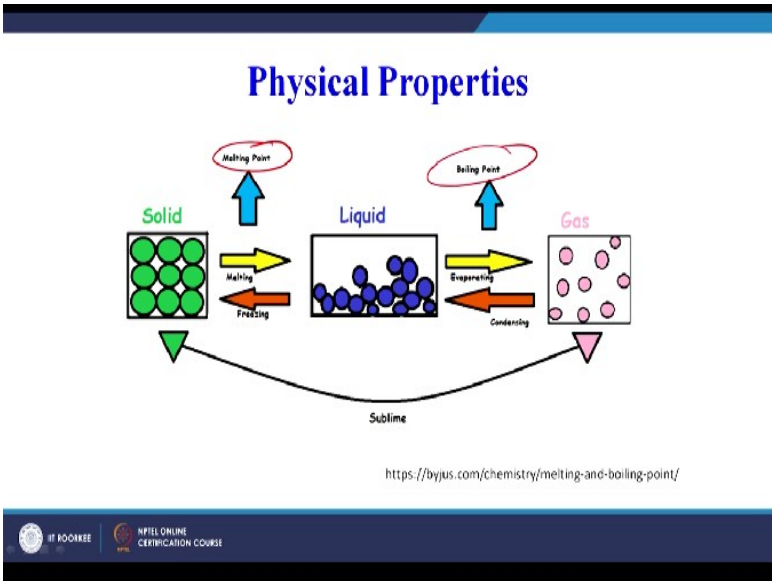

So first one can be the physical properties, the chemical properties, the thermal properties and the mechanical properties. So we will see each one of these in today's session. Now what are the physical properties, a physical properties are maybe it is mentioned here the melting point, the boiling point of the material we must know and the phase change may be sublimation, characteristics of the material must be known to us how it will change from solid to liquid at what temperature the transformation will change take place.

From liquid to gas at what temperature this is going to take place, what is the boiling point of the materials, what is the freezing point of the material, what is the melting point of the

material. All these properties must be known to the product designer when he or she is designing the product. So what are the physical properties.

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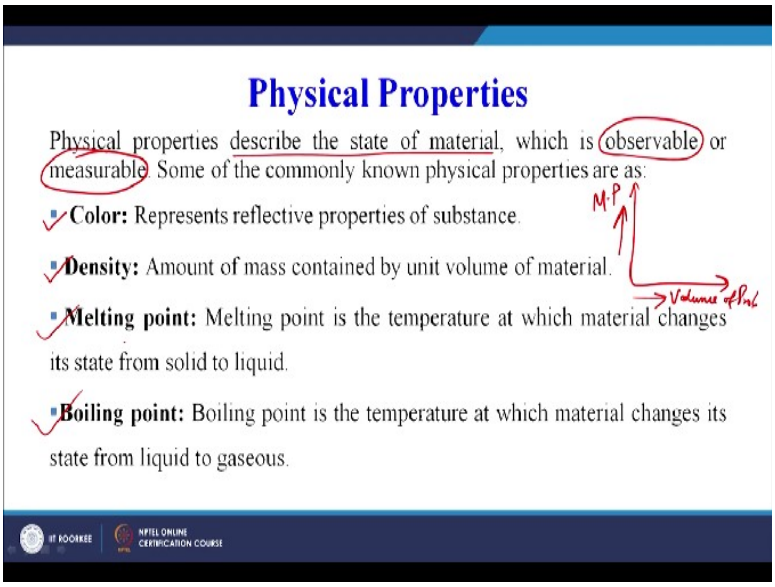

Now physical properties describe the state of materials, so these describe the state of material which is observable or measurable, so these are the 2 key characteristics observable, and measurable. Some of the commonly used physical properties are we can go one by one. So we have to see that the properties which we call the physical properties are observable as well as measurable.

So we can see colour is one property represents the reflective properties of the substance. So we can easily grade the material based on the colour and if you see some of the advertisements they show the different colours where before this is the colour, after this is the colour. So that is measurable, that before the treatment, this is the colour, after the treatment this is the colour.

So that is one physical property, then density amount of mass contained by unit volume of material. So this is another physical property which we must know and this is very very important when we design the product, when we are designing the product and we wanted to be very very light in weight. So we have to understand that which material can provide us this light weight product.

So we will definitely compare the densities of the different materials and try to see that wherever it is possible for us to save some weight, we will select the material which will have

density accordingly. Similarly the melting point of the material, the melting point is the temperature at which the material changes its state from solid to liquid. So that melting point if you remember we have seen in the first session when we were discussing the manufacturing processes.

We have seen one graph on y-axis we had the melting temperature if you remember for the various manufacturing processes we have seen this type of graph, on y-axis we had the melting temperature of the melting point and on x-axis we had the volume of production, and then we have put different processes there. So melting point is an important parameter from the material selection point of view.

And subsequently it will affect that which process can be used for making the product. So if we are selecting the material which is having a very high melting point we may not be able to make it by casting process. So therefore we may have to suggest a different process where the melting point is not going to play an important role. But the melting point high material that we are selecting for a product may have certain special characteristic.

Thereby we are suggesting that high melting point material must be used for this specific application and if we are suggesting a material for a particular application where the melting point is low we will suggest since the melting point is low we can use casting process for making this product because usually the furnace will be able to convert the raw material from solid to liquid form.

So therefore this knowledge of these properties is going to be helpful for the product designer for appropriate selection of the material for the product being design. Similarly the boiling point also is very very important. So boiling point is the temperature at which material changes its state from liquid to gas as we have seen in the previous slide. So when we are talking about the material properties of the material we have 4 broad categories.

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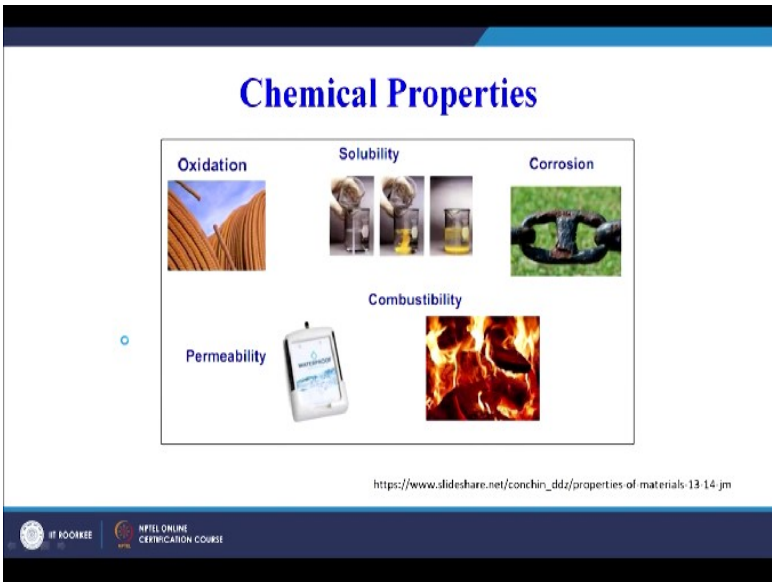

The first one are the physical properties, then we will go to the chemical properties and on your screen you can see this is a property of oxidation, solubility, corrosion, permeability, combustibility. So these are just we can say representative chemical properties, there can be extended list of chemical properties which must be taken into account before finalising the material for a particular product.

And these are representative list only. So have seen suppose we have to understand we want to mix 2 different solvents together for a particular application we must know the property of solubility of each one of them. Similarly if we are suggesting the material which has to be outdoor or it has to be under water for all of its life or throughout its life, it is a underwater installation.

We have to be very very sure about the corrosion properties, sometimes we try to improve the corrosion behaviour of any substrate by putting lot of coatings on the substrate. So the coating improves the corrosion behaviour of the material, it reduces the corrosion rate. So this type of coatings can be given on the substrate to avoid the corrosion or the problem caused by corrosion.

So this must be known when we are suggesting the material which has to be constantly in contact with water or constantly in contact with some chemical reagent we need to understand that how it the life of the product will be affected, whether the corrosion will take place or not or what is the corrosion behaviour of this material and therefore we need to understand these properties from the product design point of view.

Because many times from the suppose we make a product the product is put into service and then during the service we have to suggest that this has to be maintained this has to be serviced after so many hours or so many weeks or so many months or so many years. So regular maintenance has also to be suggested many times we have maintenance in terms of you have to paint the surface every year or every 18 months.

So why that painting is required because sometimes the corrosion may start at the surface of the material. So for that particular material when we have suggesting it for a particular product or a structure or a bridge we must know that how it is going to behave under the various service conditions and therefore we must know the corrosion behaviour for each properties I am taking one example.

In the last I have taken an example for physical properties for the melting point I have tried to explain the importance of melting point. In chemical properties I am trying to explain the importance of corrosion. Similarly the combustibility, solubility, oxidation, permeability, all these properties we can take example of each one of these and try to understand that what is their importance from the product design point of view.

So from the combustibility we can say that wherever we have suggesting polymers, so we have to have clear idea about the flame retardant behaviour of these materials and if we know that there are chances of fire we must add fire retardant regions or fire retardant additives into our polymer product. Therefore we must know that what is the combustibility or flame retardant behaviour our or the flammability behaviour of our polymers that we are suggesting for particular applications.

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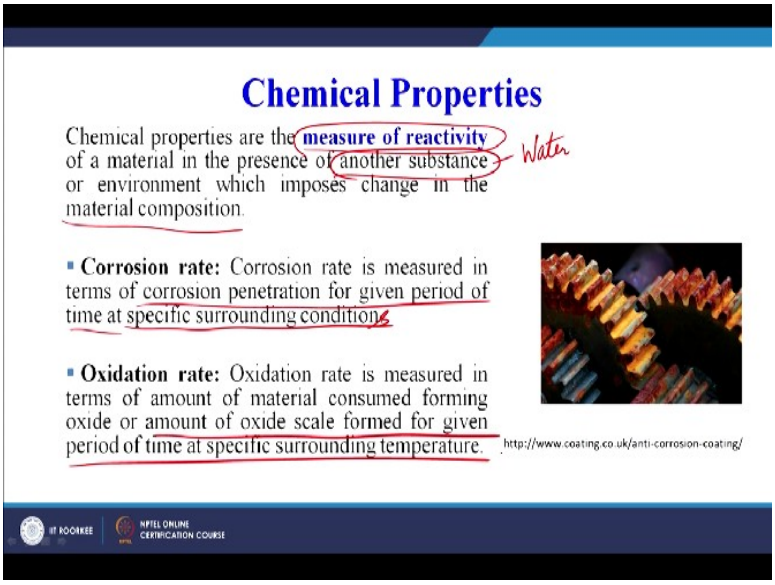

So that has to be taken into account, so similarly let us now have a basic idea of the various properties, we are not going to discuss each and every property in detail because this is a very very exhaustive topic and even on materials as well as metallurgy as well as materials engineering there are number of other courses which focused in detail only on the aspects various aspects of materials and their applications.

Our focus is primarily limited to the understanding of the basic idea about the material from the product design point of view. So our focus is on designing a product and what parameters we must keep in mind while we are finalising the process as well as we are finalising material for our product. So the chemical properties are the measure of reactivity, very very important because in corrosion we see how the material is going to react to the environment during the service period.

So that is the measure of reactivity of material in the presence of another substance, so in my example if you remember the another substance I have taken was water, underwater application I have taken for corrosion or the environment which imposes change in the material composition. So the micro structural changes may also take place when the material is exposed to different types of environment or it comes in contact with different substances.

So that is the measure of its reactivity, so what is corrosion rate, corrosion rate is measured in terms of corrosion penetration for given period of time at specified surrounding conditions. So at specified conditions with the product is used how it is going to react to the penetration

for the given period of time. So for given period of time may be 6 months, may be 1 year how much corrosion penetration has gone into the material.

That is the indication or the measurable quantity we call as the corrosion rate. Similarly the oxidation rate, oxidation rate is measured in terms of amount of material consumed forming oxide or amount of oxide scale form for a given period of time. We can say the amount of the oxide scale formed for a given period of time at specified surrounding temperature. So we can calculate the oxidation rate, we can calculate the corrosion rate for a material.

And we may not be interested in calculating as a product designer but we may look for the oxidation rate it may be available for material that we are suggesting. So there are 2 different thoughts that are available or that we must keep in mind. If we are suggesting a completely new material for a particular application we must find out we must do research on finding out the oxidation rate or the corrosion rate for that material.

And then specify that what is the corrosion rate if it is beyond a particular value we must suggest the maintenance procedure the service procedure for that material or the product during its service life. But if we are using a standard material which is in use for the last 50, 60, 70 years very easily we can get the data related to the oxidation rate, related to the corrosion rate of that materials.

So if the material is a standard material we can very easily get this date, if we are proposing a new material we must try to do research and find out these properties before suggesting the use of this material for a particular application. For example the underwater installation if we suggesting a standard steel we must look for its corrosion rate and oxidation rate from the standard handbooks.

But if we are suggesting a use of a composite material or underwater application we must try to find out that how it will crowd or how the fibre reinforced plastic or a composite material will react to the water which may be under freezing conditions. So how that reaction will take place and how the material will behave under those specific application area or undergoes specific environmental conditions.

That has to be found out before suggesting a particular materials for the underwater installation. So this is just one example that I have taken. Now the other important properties are the mechanical properties.

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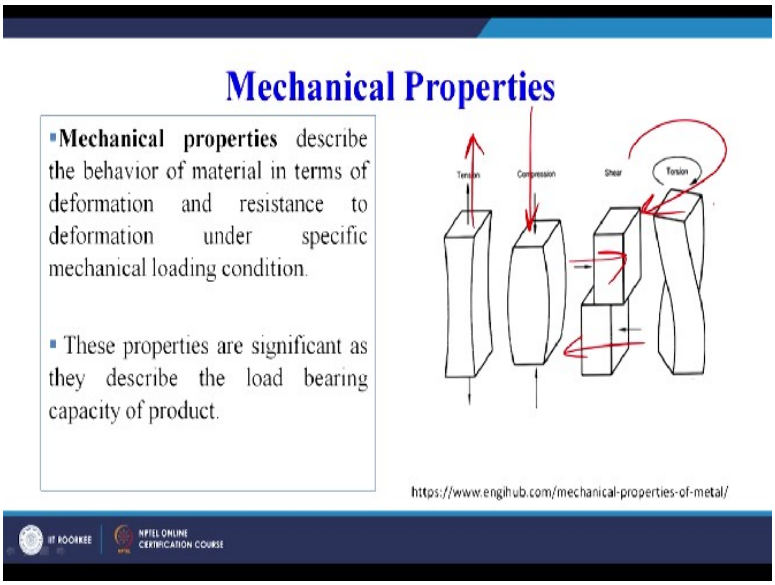

So we can see with the help of example this is the behaviour under the tensile load, the behaviour under the compressive load, the behaviour under the shear load type of loading and the torsional loading. So this is the behaviour of a material under applied loads that how the material is going to behave, one of the most important applications that we can see here is the bulletproof applications or the bullet proof materials.

Suppose we are making the bulletproof helmet or we are making a bulletproof jacket, so there has to be this investigation that when projectile or a bullet is coming and hitting the material how the material will behave, it must have good impact resistance. So that impact resistance is also of mechanical property. Suppose the material is getting stretched maybe we can see the mechanical properties of the rods that we used for RCC structure or another example where we must know that what is the tensile strength.

What is the compressive strength of the materials, there can be number of examples where the mechanical properties play a very very important role or a very very integral role during the product design process, we must know that what type of loads the material can bear before suggesting that material for a specific application and moreover whenever we are making structure or for structural analysis different type of material is being used.

We need to do the standard tests to find out the properties of that material. So that the material passes or surpasses or overcomes or may be it has better properties than the specific requirement. So we have to always keep in mind the factor of safety also while proposing the use of different types of material for a specific application. So let us see the mechanical properties I have tried to explain with the help of an example.

Now let us see what is given in the slide, so the mechanical properties describe the behaviour of materials in terms of deformation and resistance to deformation under specific mechanical loading, so when the materials is subjected to different type of mechanical loads, how it is going to behave that is going to define the mechanical behaviour of materials. These properties are significant as they describe the load bearing capacity of the product.

So we need to understand that these properties are important because they define the load bearing capacity of a product. So let us take a example of this dias, this is the wooden dias and there is a console panel here, this has a dead weight, so this dias has to have the mechanical property to take the load of this dias, sometimes I may be standing like this so I am also putting some weight on the dias.

So this dias must have the mechanical property to take that type of load that is being exerted on it plus a factor of safety I may not be the most heaviest person who is applying the load here, there may be other people who may exert more load and this console may be changed by another display which maybe heavier than this. So we have to see that this product must have the load bearing capacity for which it has been designed.

And if suppose we keep a material which is having much more loading or much more weight so this may also fail under that type of load. So we have to see the load bearing capacity of the material before proposing its use or specific applications.

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Now these are the various mechanical properties, there can be other properties also, some of these properties we can see here this is strength, hardness, toughness, stiffness, elasticity, plasticity, ductility, brittle behaviour, malleability. So we have different types of mechanical properties which define the mechanical behaviour of an engineering material. So we cannot go into the detail of each one of these.

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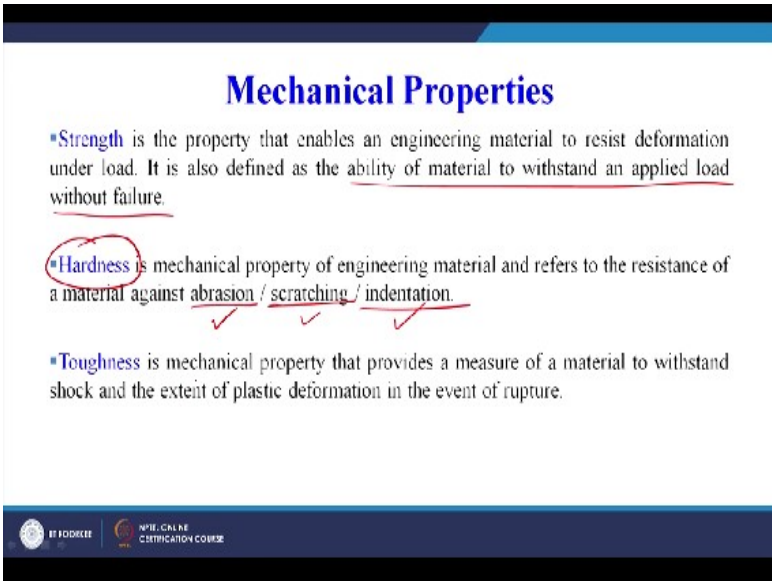

So let us quickly see the 3 important definition, strength is the property that enables an engineering material to resist deformation under load, it is also defined as the ability of the material to withstand an applied load without failure. Hardness is the mechanical property of engineering material and refers to the resistance of a material against abrasion, scratching and indentation. So hardness is related to resistance to abrasion, scratching and indentation.

Strength is related to ability of a material to withstand and applied load without failure. Toughness is a mechanical property that provides a measure of a material to withstand shock. So toughness is related to shock, absorption, or withstanding the shock and extent of plastic deformation in the event of rupture. So how much plastic deformation can take place before the final failure.

So we are just giving you a hint about these 3 properties, but the list is very very exhaustive a material may be defined or characterized for its mechanical behaviour using large number of mechanical properties. Now the finally we can go for fourth category of properties which are the thermal properties.

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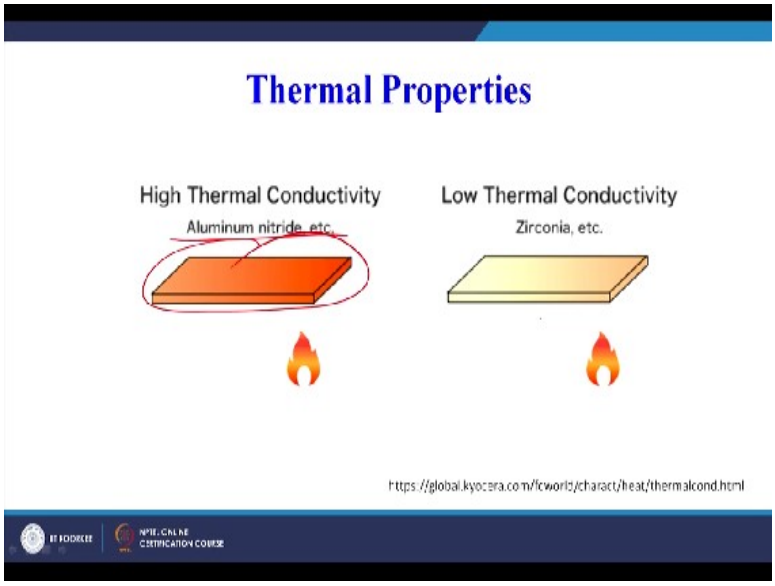

So heat high thermal conductivity example is given so it has high thermal conductivity thermal conductive, low thermal conductivity a example is given here, so we can see from the picture also when it is getting heated how to heat is getting conducted in the material, here less conduction because of the low thermal conductivity.

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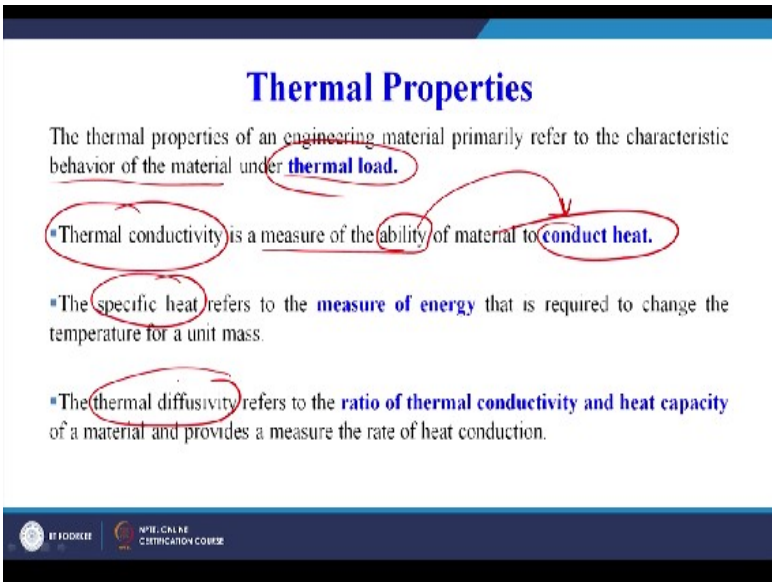

So what are the thermal properties let us see thermal properties of an engineering material primarily refer to the characteristic behaviour of the material, behaviour of the material under thermal load. So when thermally you are applying, you are giving heat to the material how it is going to behave that is known as the thermal characteristics or behaviour of the material. So thermal conductivity is a measure of ability of material to conduct heat.

So measure of the ability, now what is the ability of a material to conduct heat that is going to define the thermal conductivity. The specific heat refers to the measure of energy that is required to change the temperature for a unit mass. So we can have different parameter, so when you are going to design a particular product and then you have to understand that how it will behave when subjected to heat.

You need to understand few parameters, you need to understand important parameter that is thermal conductivity, you need to understand what is the specific heat of the material and these quantities for the material will be available in the tabular form. So we need not worry that how we will get to know that what is a specific heat of the material, how we will get an idea that what is the connectivity of the material.

So this type of data is already available, but as the product designer I must know that this data is available I must look at this data while before suggesting material for a specific product application. So what is specific heat, it refers to the measure of energy that is required to change the temperature of a unit mass. So that therefore for a specific product where we want to change the temperature of a unit mass.

We must know what is the specific heat for a material or of the material. So thermal diffusivity another property thermal property refers the ratio of thermal conductivity and heat capacity of a material and provides a measure of the rate of heat conduction. So you have thermal diffusivity specific heat, thermal conductivity, then there can be other properties which define the thermal behaviour of any engineering materials.

And as a product designer I must look into these characteristics or properties which define the thermal behaviour only in those cases where the product is going to be subjected to heating conditions or may be high heating conditions. Now this is the last slide for today physical and mechanical properties of engineering material.

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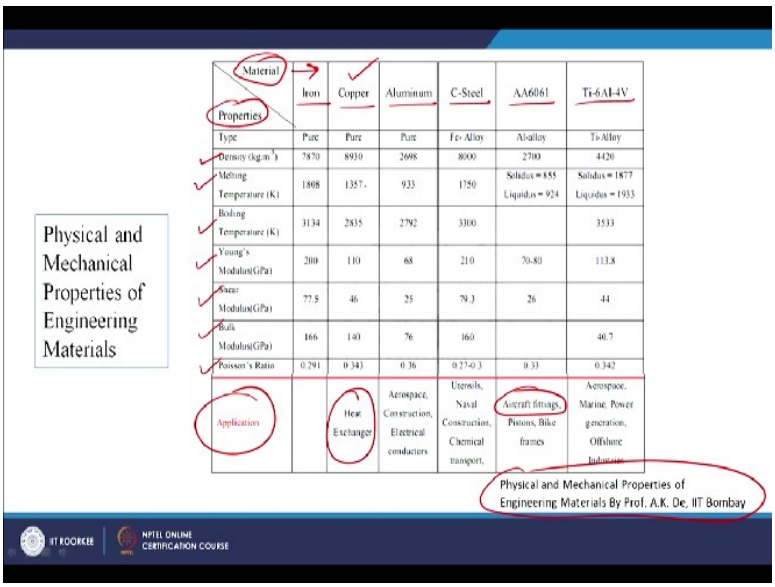

Source is also given physical and physical and mechanical properties of engineering materials by professor A. K. De from IIT, Bombay, this is taken from the source, so we can see what are the different types of material in this direction iron, copper, aluminium, steel, aluminium 6061, titanium 6AL4V, so different types of metals and alloys are there and then the properties are given.

The properties of density if if you remember today only we have taken an example density falls under our physical properties then the melting temperature is given, boiling temperature is given, young's modulus which is the mechanical properties, shear modulus which is the mechanical properties, bulk modulus which is the mechanical properties, poison's ration which is the mechanical property.

So a combination of physical and mechanical properties are given in this table for various engineering materials and finally the applications are given. So you can see that although thermal properties are not mentioned here, but copper is used for making heat exchanger why, why it is used, it is used because of its good thermal properties, what are the thermal properties that we can look for, we can look for thermal conductivity.

We can look for specific heat, we can look for thermal diffusivity, so when we are suggesting an application for heat or for where the temperature is important we must look for the thermal properties of engineering materials. Let us take one more examples may be aircraft fittings, we are taking for this AA6061 material so we can see that the mechanical properties what is the poisons ratio, what is the density and depending upon that we will propose. Now in aircraft what is required.

In Aircraft the lightweight material is required and for lightweight if you remember today we have taken an example of density, so then we can focus on density and see that which material is going to give us less weight and for aircraft fitting we are going to use aluminium AA6061 why because it is giving us less weight as compared to the other engineering materials.

So with this I think we have been able to correlate the properties with their applications and as a product designer we must know that when we are suggesting a particular material for specific applications like heat exchanger or aircraft fittings we must look at the various properties of the various engineering materials and then select our material in the most judicious manner. So with this we conclude the today's session, we will start our discussion in the next session related to the engineering materials, thank you.