Introduction to Composites
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Lecture – 15
Properties of Thermoset and Thermoplastic Materials

Hello, welcome to introduction to composites today is the third day of the ongoing week and in the last 2 days we have been discussing how polymer matrix materials are susceptible to change in the temperature and in that context we have explained the behavior of these types of materials as temperature increases and what we have seen is that three important things. So, we will write down.

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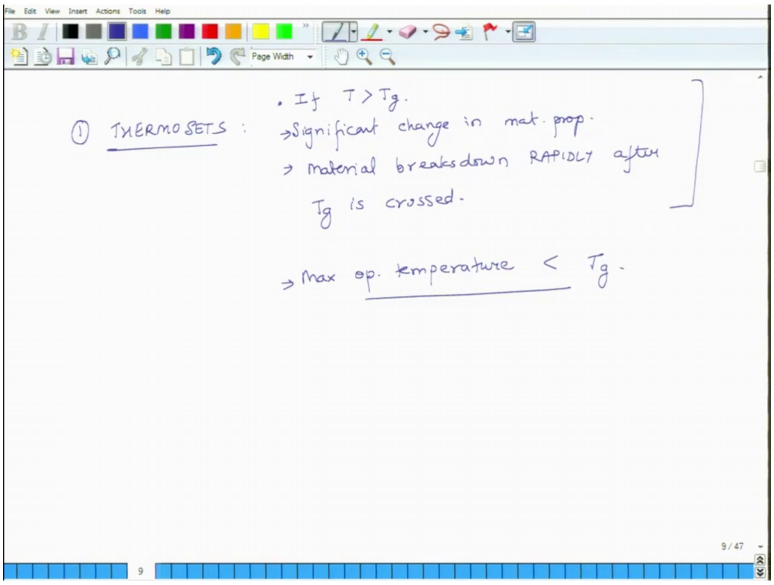

So, first for thermosets; for thermosets not much changes before the glass transition temperature right so, but after the glass transition temperature significant change in material property and that includes density. So, if T is more than Tg, then significant change in material property and material breaks down rapidly after Tg is crossed after Tg is closed what this means is that the operating temperature range of thermosets should never exceed the glass transition temperature of the material

So, the maximum operating temperature should always be less than Tg for thermoset materials this is a direct consequence of our discussion which we had yesterday. So, this is for thermosets. So, if we want to use thermosets we have to know the glass transition temperature and we have to be sure that will remain below it if we exceeded, then the whole structure may get destroyed very rapidly. So, we have to be 100 percent certain that we do not exceed the glass transition temperature second we are talking about amorphous thermoplastics ok.

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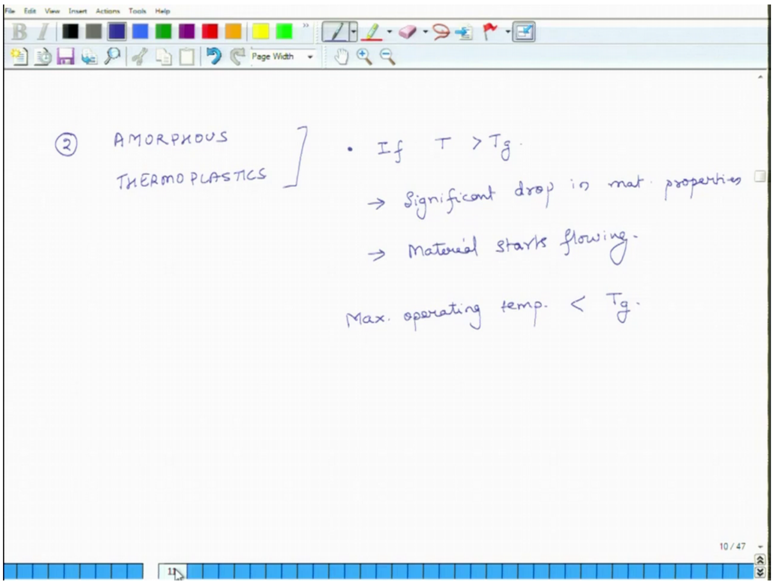

So, in case of amorphous thermoplastics, if T is more than T g; if T is more than T g, what do we see significant drop in material properties, if you see on the log scale e goes down it may go down by as high as a factor of one thousand and then once glass temperature has exceeded because all the connections between the polymer chains interconnect between polymer chains is broken. So, these chains start flowing with respect to each other. So, metal the material starts flowing.

So, there is no; it is not that we have way wait for a melting temperature for the material to start flowing and as a consequence of that we can say that the maximum operating temperature of. So, these of these material the maximum operating temperature should never exceed T g we do not have to worry about the melting point in this case also because the thing starts melting just above glass transition temperature because all the interconnects are broken.

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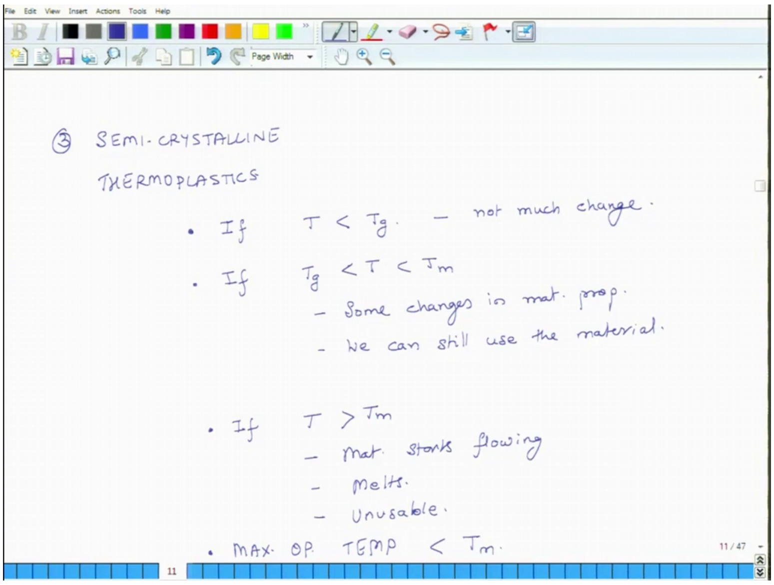

So, this is for amorphous plastics and the third thing is semicrystalline thermoplastics; semicrystalline thermoplastics. So, what happens in this case if T is less than T g; not much change; the material expands a little bit it becomes soft a little bit, but not a whole lot of changes are happening in the system the second case is if the temperature is more than the glass transition temperature, but it is less than the melting point what happens some changes in material properties.

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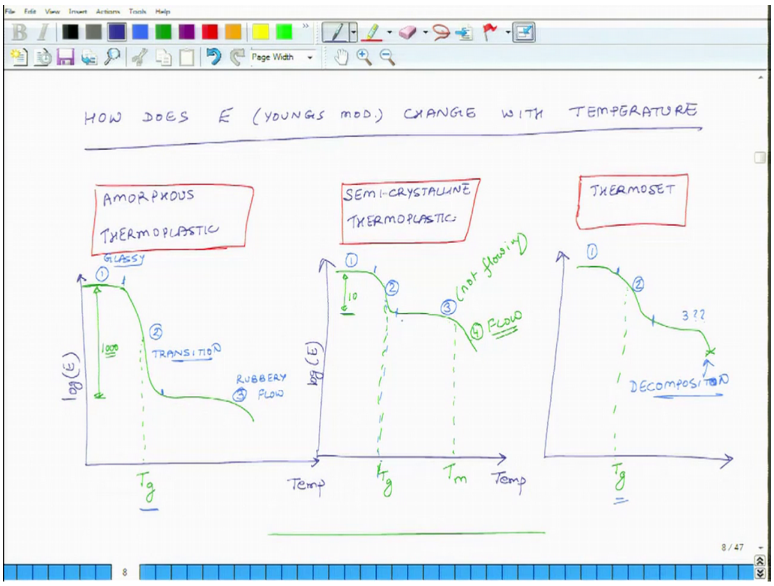

So, we saw it some changes in material properties, but still the overall modulus is somewhat maintained it goes down appreciably, but does not go down by a factor of thousand and the material still retains its solidity.

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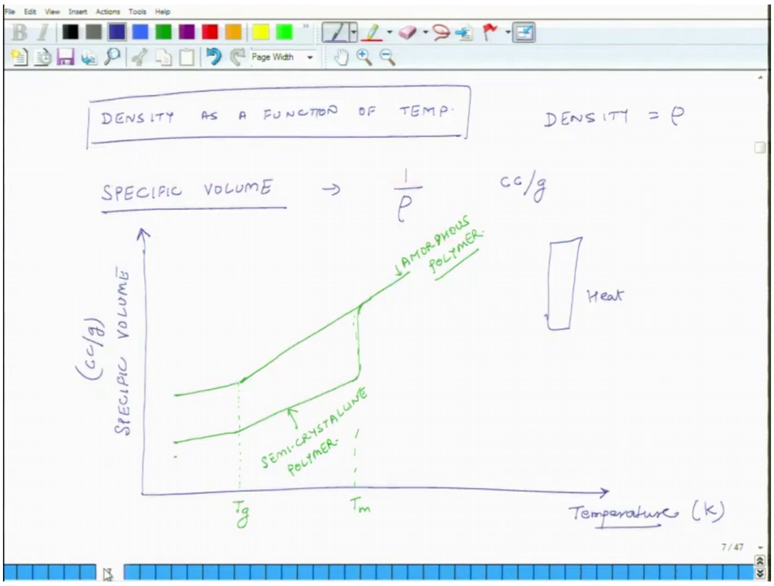

It still has its stiffness its density is still not that high I mean that low it still retains its density to a certain extent.

So, all the some changes are material properties and we can still use the material we can still use the material, but if temperature exceeds tm then what happens material starts flowing it melts and because of this it becomes unusable. So, if we have to use the semicrystalline thermoplastic we have to make sure that maximum operating temperature of the material should be less than the melting point should be less than the melting point.

So, this is an important thing to understand thermosets. We should never exceed the glass transition temperature amorphous thermoplastics, we should never exceed the glass transition temperature semicrystalline thermoplastics, if we are smart and if we design a structure correctly we may be able to exceed glass transition temperature, but we should never exceed the melting point.

So, the next thing I would like to do is we should get some appreciation of what are the values of these glass transition temperatures and melting points for different materials.

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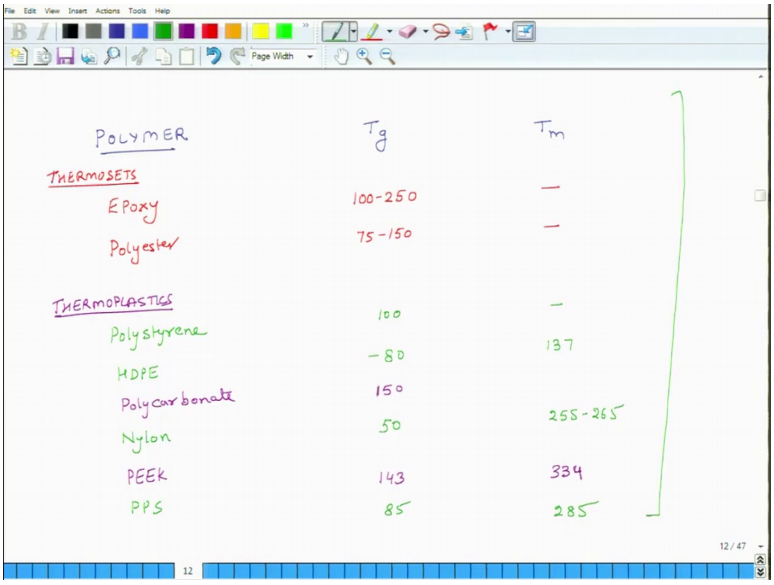

So, we will just write down a table. So, we have polymers different types of polymers they are Tg in degree centigrade and their melting point. So, first we will write it for thermosets. So, thermoset materials; so, we have epoxy. So, what is the glass transition temperature depends what type of epoxy we are working with it can vary between hundred and 2 hundred fifty degrees centigrade and melting point for a thermoset doesnt have a melting point it just breaks down after glass transition.

So, its element and with the very popular thermoset so, these are the 2 most popular thermosets polyester and epoxy polyester is much cheaper than epoxy, but its material property; particular strength are inferior to that of epoxy. So, polyester glass transition can be anywhere between 75 and 150 degrees centigrade. So, that is why if you want to use these materials at even some higher tell temperatures people go for epoxies because they can take a lot of temperature they can go up to 250 degrees and once again its melting point does not exist. So, the next guy is thermo plastics and we will give you some examples. So, the first one is polystyrene. So, this is 100 degree centigrade and we are talking about the amorphous version of it and then this is important as HDPE high density polyethylene.

And if you use a semicrystalline version of it high density polyethylene its glass transition is actually pretty low minus 80 degrees, but if you are using it semicrystalline version then we can we do not have to worry too much about the glass transition what we should be really worried about is its melting point. So, that melts at one thirty seven degree centigrade.

Let us look at some other interesting numbers polycarbonate. So, this is an amorphous guy and it has a glass transition at 150 degrees nylon. This is very interesting again nylon glass transition is pretty low 50 degree centigrade. So, even we are you know during summers you can get close to 50 degree centigrade, but its melting point is 255 to 265 degrees pretty high.

Some others peek what is peek polyether ether ketone polyether ether it is a very good material thermoplastic material for aerospace applications why because its melting point or glass transition itself is reasonably 143, but its melting point is pretty high 334 and for this reason it is all so costly. The other one is PPS polyphenylene sulfide. So, this is 85 and this is 285. So, this gives you an idea as to which temperatures are important what type of for what type of material you cannot blindly or without thinking say glass transition temperature is the one we have to worry about for all materials ok.

For instance nylon or high density polyethylene its glass transition as I said minus 80 degree and something like that, but you can safely use it at least till 60, 70, 80 degree centigrade because its melt point is 137 degrees for the same reason this peek, you can use it maybe when up to 200 degree centigrade 200-250 because its melt point is very high 334 c. So, you have to look at the material and first have to figure out whether it is this thermoset or thermoplastic and then if it is a thermoplastic you have to again question and figure out whether it is having an amorphous structure or whiter it has a semicrystalline structure. So, this is important to understand.

The last thing very quickly in a couple of minutes I like to give me some ideas. So, you will wonder I had earlier explained that you can have the same material nylon in amorphous version and semicrystalline version. So, what is done to make semicrystalline version of some of these thermoplastics and there are 2 broadly speaking methods which are used to produce semicrystalline versions of thermoplastics the first one is the method of evaporation.

So, what do they do what they do is they somehow using some organic solvents that dissolve the material in some solution phase and then they boil it these organic solvents boil very easily at very less temperatures. So, some of heat it and remove this material and when the; this solvent and when the molecule these polymer chains somehow align themselves in a semicrystalline fashion and you get a good semicrystalline thermoplastic.

So, that is the method of evaporation. So, evaporation is one method the other one is known as precipitation. So, there are precipitation reactions which you may have learnt about in your chemistry classes when you are getting into engineering or even in high school at high school level.

So, we make these types of we inject crystallinity in polymers using either the method of evaporation or the method of precipitation. So, these are the 2 methods and this concludes our discussion on the overview of polymers. Now what we will start doing is we will start looking at specific polymers we will start looking at specific polymers and we will understand their properties little bit about the chemistry not a whole lot, but little bit. So, that we have some understanding and. So, we will look at thermosets; we will look at thermoplastics we will look at ceramic based materials we will look at metal based matrix materials and that will give us an overview of different types of materials which are used for matrices.

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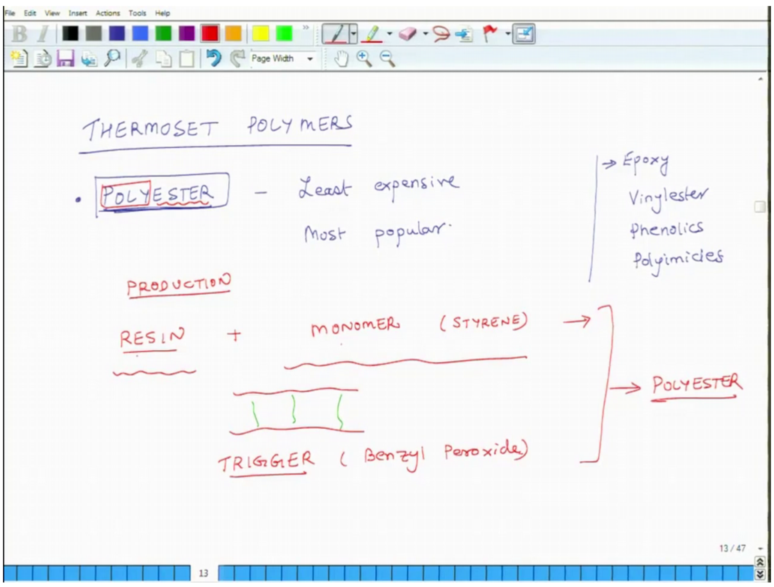

So, we will start our discussion with thermoset materials and thermoset polymers and the first material, we will look at is polyester amongst all the matrix materials which are used to produce composites this is the least expensive, it is the least expensive and perhaps most popular there are other materials also thermoset materials which are used in good amounts vinyl esters polyamides phenolics and epoxies, but polyester is the most popular, but maybe the second number is epoxy that is the second most popular then we have vinyl esters phenolics and polyimides. So, these are the different materials, but this is the most popular one and maybe this is number 2 ok.

How is polyester as a matrix material made; how is it first thing we learn is how is it made. So, it is it has 2 terms there is a poly term and then in there is an ester term. So, the way it is done is that you have a resin. So, this is about production. This is about production. So, what is this resin it has you know unsaturated polyester it has unsaturated polyester.

So, this is the resin and this you mix with a curing agent you mix with curing agent. So, resin has what it has long chains of molecules, but all the molecules are not well connected there are a lot of unsaturated bonds and then this curing agent is added and when you add these somehow reaction is created and then you have the cross linking of all the chains. So, curing agent is added. So, that you develop cross linking of the chains.

So, this curing agent is typically the styrene. So, when you add these 2 then you have a chain and in presence of curing agent you would start developing these cross linking. So, the everything becomes solidified. Now if you add these 2 guys just by themselves the reaction will not happen. So, for this there is also something which is known as a trigger or initiation agent. So, it acts like a trigger. So, for an instance, I will give an example you take hydrogen and oxygen you mix them, they will not react, but then we have to trigger it by providing a spark or something similarly the this thing that you add a trigger and this trigger is typically known as examples of it could be benzyl peroxide ok.

So, this is the trigger excuse me. So, maybe this is probably the not correct term I will call this monomer which is the styrene. So, this trigger when you add. So, when you add all these three things up then you get this cross linking in the resin and you get polyester and the thing about is that if you process them in the right proportions you add resin and monomer in the right.

Proportion you do not get any bi-products the whole of this monomer the whole of this monomer it gets absorbed into the resin and you get one final product and then you have the final product and everything is well cross-linked and these cross linked bonds are covalent bonds. So, they are very strong. So, by a regular at small temperatures they do not break easily only once you cross the glass transition temperature these guys break and the whole thing collapses.

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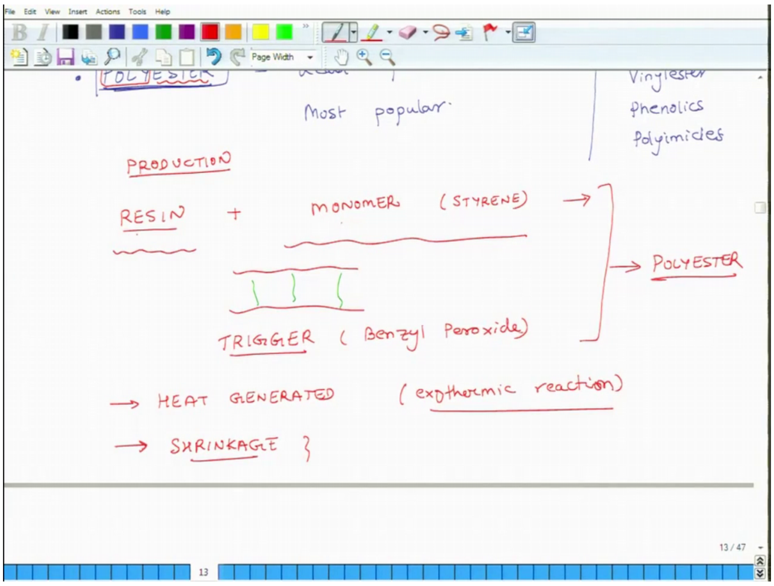

Now, another thing is that in the production process there is a lot of heat generated actually it becomes very hot. So, it is an exothermic reaction. It is an exothermic reaction and. So, what; that means, is that you are mixing these 2 things up and suppose you are also having fibers in process in the composite. So, in when you want to make a real composite what do you; you have put resin and monomer you mix them that is the raw material, but you want to start the reaction.

So, suppose you want to make a composite you take resin plus monomer of styrene mixture of it mix it with fibers or the fabric and the you somehow also add to it trigger and as a consequence of it things start heating up things start getting cured and things start between solid, but this solidification happens at an elevated temperature at an elevated temperature not at room temperature because there is a lot of heat which is generated and so, the solid becomes formed at the higher temperature and then it cools and it comes to room temperature and when it comes to room temperature internal thermal stresses get developed and if your engineering or the design of the composite plate is not correct you may not get a flat or the desired shape, it may be bent or webbed from the shape which you want.

So, this is an important thing to understand the other thing is that in this process you have shrinkage. So, you have let us say 10 litres of the overall material resin plus monomer, but when it becomes solid the overall volume shrinks it shrinks. So, this shrinkage also has to be understood and accounted for while the thing is being used polyester as a resin. So, this is some basic idea about polyester we will continue this discussion tomorrow also and then we will discuss polyesters we will discuss epoxies we will discuss other matrix materials also and that us how we plan to proceed. So, that closes our discussion for today and tomorrow, we will continue our discussion.

Thank you.