Manufacturing of turbines (gas, steam, hydro and wind)

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Lecture 28

Welcome to this course on manufacturing of turbines. So, in this lesson 28 of the course, we will see more details about the materials which are used in making the wind turbines. So, the outline of this lesson will be as follows, where first we will see the more detailed properties about the matrices. So, we will see the crystallinity in polymers, their resistance to solvent and water, permeability, resistance to gas, fire, electrical properties, toughness, wet out etc. Additionally, we will see the different materials which are added in the matrices which include additives, fillers, pigments, viscosity control agents, surface agents, anti-foaming agents. So, we start with discussion on crystallinity in polymers.

So, as we know the polymers are amorphous materials. So, regions of close packing sometimes also occur in the polymers. They are also known as the crystalline region which are held together using secondary bonds. Presence of these regions in the polymers, it generally increases the melting point.

So, thermoplastics are known to have crystalline regions and cross links in the thermosets they often interfere with this periodic packing of atoms. Molecular motion is often found to be missing in the crystalline region. So, for those regions the glass transition temperature is not noted. Sometimes, the presence of aromatic content that is the closed ring benzene structure, it is known to increase the melting point for most of the polymers. So, we can see on the right hand side the in general arrangement of polymers is known to have amorphous where we have this random entanglement of the long polymer chains.

And in the semi-crystalline polymer, there may be localized regions of regular atomic arrangement. So, because of this localized presence of the crystalline regions, the melting point, etc., mechanical properties of the matrix may increase. So, next we look at how the polymers, they behave towards the presence of solvents and water. The resistance depends on the chemical nature of the matrix and solvent.

Sometimes, the polymers may be resistant, but at times they may not be resistant to presence of certain solvents which may be organic solvents or inorganic solvents or water. More the nature of polymer it resembles with the environmental effect, more is the effect of the environment. So, if chemical structure of the polymer is similar to what is the chemical structure of the solvent or maybe there is some similarity between both of them, so their interaction increases because of which there may be the dissolution of such polymers in such solvents. In this aspect the chemical polarity is very important. So, water as we know is a polar molecule.

So, certain other molecules of polymers for example, epoxy may also be polar. So, in this regard in polarity presence of polarity may enhance the chemical activity. So, other aspect is raising the temperature because, as we increase the temperature, so generally the moisture or other solvents may also increase their activity because of which the polymer may swell and it will allow the solvent molecules to penetrate and thereby increasing the reaction. So, water is a strong polar molecule which makes unsaturated polyesters susceptible to moisture or water attack. Thermoplastic polymers, they are often resilient to solvent attacks due to their tightly packed atoms which have several intermolecular interactions.

Next is the discussion on the fire resistance of the polymers. Aliphatic polymers, which are the polymers which have absence of the closed ring structure. So, aliphatic polymers they often are known to burn fast compared to aromatic polymers. So, here aromatic polymers they have the presence of closed ring structure. Whereas, the aliphatic polymers, they have the open structure, they do not have the closed-link structure.

Because, the closed-link structure is known to provide stability at enhanced temperature, so absence of the structure leads to faster burning of aliphatic polymers. Char formation in aromatic polymers, it resists further burning. So, common method to enhance the fire resistance of such polymers is to mix compounds having presence of halogen atoms. Halogen atoms include fluorine, chlorine, bromine or iodine. Halogens, they often create dense gas environment that smothers the flame thereby preventing the supply of oxygen.

Halogens, can also be added by adding certain inorganic filler such as magnesium chloride or calcium bromide. Other than this, sometimes non halogenated fillers can also be added. This includes alumina, hydrated alumina such as fire retardants. So, in the summary we can say that by addition of these fire retardants, we can enhance the fire resistance of such polymers. Next, are the electrical properties of polymers.

As we know most of the polymers because of their covalent bonds they have no free electrons, all the electrons are shared in the covalent bond. Therefore, most of the polymers they are having non-conductive properties and have very high electrical resistance. So, alumina can increase the arcing resistance in line with the flame retardant properties, and to enhance the electrical properties of such polymers, sometimes some metallic powders may be added as fillers so that they can create an electrically conductive path in the polymer. And this electrically conducting reinforcement may further enhance the electrical properties by improving the electrical conductivity. This may be very vital for certain applications of polymers.

Example, the polymers used on airplane skins to protect it against lightning strikes. So, here on the right hand side we can see how by adding carbon nanotubes in the polymer matrix we can make it conductive because carbon nanotubes are also a type of filler known to have higher electrical conductivity. Next is the property of toughness. So, property of toughness is defined as the ability to absorb energy and is crucial for composite structures, particularly in resisting impacts with fall or strikes. So, toughness of the composite is influenced by combination of properties between the matrix and the reinforcement.

So, it is the matrix which would effectively diffuse the energy from the impacts. Because, it is the matrix of the composite which is covering it from the outer surface and it is first coming in contact with impact of any type. So, matrix which is capable to elongate or stretch when force is applied can contribute to greater toughness. Aliphatic polymers, with minimal secondary bonds and aromatic with pendant configurations are much suitable to provide matrix toughness. In addition to this, toughening agents or reducing crosslinks within the matrix may further increase the toughness as by reducing for example the crosslinks, we give the ability to the atoms to move slightly about their mean position under the influence of impact load, thereby improving the property of toughness.

However, if extensive crosslinks are present, so in the situation of impact, the cracking may be directly observed instead of energy being dissipated in some other form in the polymer matrix. Next, is the ability to wet out the fiber. So, this is a very important property of the matrix which influences the manufacturability of the respective polymer matrix composite. Because a good wet out of the fiber by the matrix will enhance the interfacial bonding between the matrix and the fiber. So, in this regard, it is the viscosity of the matrix which strongly decides the wet out ability and in this regard, higher is the viscosity, poor is the wet out.

So, therefore, it is said that viscosity of the resin or matrix is strongly dependent on the wet out and both are inversely correlated. So, this means if we increase the viscosity, so the atoms of the respective matrix will not have enough flowability so that they can effectively wet out the fibers. So, it is also known that with increase in molecular weight that is number of monomers in the polymeric chain, the increased molecular weight also impedes the motion of the molecules thereby increasing the viscosity of the polymer. So, in general thermoplastics as they do not undergo any type of crosslinks. So, they do not change their molecular weight.

Therefore, fiber wet out is very difficult. So, thermoplastics are very difficult to process with their composites. So, we will find that in several high strength or high loading structural applications, the composites which are used, they often utilize epoxy or some other type of thermoset as the matrix. Because of lower room temperature viscosity, which enables a better wet out of the fiber, thereby enhancing the interfacial bonding between the fiber and the matrix. So, thermosets which often have low molecular weight at room temperature that is before the development of crosslinks are much ideal to be used in such composites such as wind turbine blades and this fact has led to overwhelming use of thermosets especially with continuous and long fibre composites.

Next are certain other additives which are added in the matrix to enhance several other properties of the matrix and they overall contribute to enhanced functionality of the polymer composite. So, these include additives, fillers, pigments, viscosity control agents, surface agents and anti foaming agents. So, we will see in detail each of this filler and what role does it play in the polymer matrix. So, first is the additives. So, additives are basically the materials which are added in the composite material be it the resin system and reinforcement to improve a specific property.

Most of the additives they may be added only in small concentrations although fillers can sometimes become a major component of the mixture. Here example includes the fire retardant additives which have a specific role to play to enhance the fire retardancy of the polymer composite. Other than this, we can also add additives which can enhance electrical properties or enhance ultraviolet light inhibitors or can act as tougheners. Second type of additives in the matrix include fillers. So, fillers are basically solid materials which are ground to fine powders and they are added to resin matrix to reduce the overall cost and occasionally they may also impart some other beneficial property.

The most common fillers are materials such as limestone, talc which are generally added in purified and grounded form. Fillers in general don't possess any specific length to weight ratio and are classified as particulates or particles rather than fibers. And fillers are also known to have less cost than the resin. So therefore, it is sometimes economical to use combination of resin and filler and where the total weight and volume of the resin can be reduced. Cost reduction is one of the important reason to utilize fillers in composite materials.

But for high strength applications, the use of fillers is seldom. So, here we can see that how by adding fillers the mechanical properties especially by adding fillers in lower concentrations are not disturbed and especially in presence of fiber enforcement although there may be some increased stiffness or reduced strength or elongation may be observed. Fillers can also impart special benefits such as fire retardancy, color or dimensional control. So, here we can see the addition of various type of fillers using the scanning electron image, scanning electron microscope image and we can see how after the tensile test the different fillers are stuck around the fibers. Next additive in the matrix includes pigments and dyes.

So, sometimes the color of the composite material is affected by the way how light or visible light is absorbed or diffracted by the polymer or its constituents which include fibers or additives there. So, these additives which can cause specific light to be absorbed are known as colorants. These colorants can be organically derived based on carbon containing molecules, which in this case they are known as dyes. Alternatively, these materials can be ground into inorganic powders, sometimes known as pigments. Dyes and pigments, they are available in wide range of colors and shades.

Generally, dyes are more subtle in color compared to pigments because pigments provide a more intense or a vibrant color. Pigments are also known to be more stable at high temperature. So, in the nutshell, we can say use of pigments and dyes are basically to impart specific color to the composite or the polymer. Next additive in the polymer matrix is the viscosity control agent. As we have just seen in the wet out capability, viscosity control is one of the important property of the molding of the resin or the thermoplastics.

Because, it is essential that viscosity should be controlled appropriately for proper wet out of the fiber so that the composite whatever is produced has a continuous interface between the matrix and the fiber. If the viscosity of the matrix is too low, so in this case the matrix material may run down from the side of the mold or may also drip off from the fiber. Fillers may certainly added in the matrix to thicken the mixture or increase the viscosity, but sometimes they cannot be used or alternatively the fillers in the material are too thin. So, in this case a thixotrope may be added to significantly increase the viscosity of the mixture only by adding it in small amounts. So, a common type of material added to control the viscosity is fumed silica which can significantly increase the viscosity either by itself or by addition of thixotrope enhancers.

This is accomplished because there is some secondary bonding induced between the polymer chains by adding fumed silica. These secondary bondings may decompose in the presence of heat and therefore they may not be very significant in the final product but during the processing they may add considerable viscosity to the resin thereby controlling its flowability and interaction with the reinforcing fibers. Next are the surface agents. So, surface agents basically they target the surface energy and charge on the surfaces of the matrix or the fiber. So, surface energy and charge is the tendency of some surfaces to not to be wetted by the resin.

So, by presence of some electrostatic charge they may inhibit the wetting of the respective fibers. This problem may often be solved by adding a surfactant to the resin mixture. The surfactant may change the charge or energy of the surface to be coated and facilitates the wetting by the resin. By lowering the surface tension, the surfactant enables the resin to quickly spread on the surface and surfaces that might have this problem may include molds or fibers here.

Next are the antifoaming agents. So, some resins may have tendency to foam that is to develop a foam like structure thus complicating their application especially while spraying. Hence, some additives may be added in such resin to reduce the tendency to develop the foam. These additives usually work by changing the charge or energy on the surface of the resin or the filler particles in the mixture. Silicones are a popular material to be added as anti-foaming agents in this type. So, now we can see the environmental agents which can strongly affect the matrix.

So, environmental agents means the conditions such as heat, solvents, staining agents and gas. So, we will see one by one. Heat in general for thermoplastics they can melt, thermoplastics can be melted as the heat induces the temperature up to the melting point and it is dependent on the polymer's specific nature such as molecular weight and secondary bonding. Thermosets are often softened but not melted. Excessively high temperature in case of thermosets may lead to degradation.

Solvents, so in this regard interaction of the polymer with solvent depends upon chemical reactivity of the polymers and how it is similar to the solvent. So, highly polar molecules react strongly with highly polar solvents. Staining agents, sometimes polar staining agents may have strong interactions with the polar matrix materials leading to a more strongly embedded stains. Sometimes, the gases may lead to oxidation and may lead to degradation of the polymers. Especially, this is more pertinent in high reactivity of the bonds along the backbone.

Increased gas permeation into the polymer enhances this effect particularly when the chemical nature of the gas is similar to the polymer. Permeation also increases with greater distance between the atoms in the polymer. Cross-linking and crystallinity reduce permeation. Fire is another important environmental agent. So, fire retardant properties, they are also dependent on several factors of the polymer.

Often increasing aromatic content or by adding fire retardant fillers such as, halogenated compound are common methods to enhance fire retardancy. Electrical properties, most of the polymers as we know have high electrical resistance and dielectric strength and low conductivity. Changes in polymer type may cause minor changes in these properties but they may significantly differ from the metallic materials. In case of light, it is the ultraviolet light which has significantly degrade the polymers and in this case also the presence of aromatic compounds in the polymer chain may be more sensitive to ultraviolet light compared to the aliphatic compounds.

So, with this we come to the end of this lesson. We will now summarize what all topics are covered. So, in this lesson we have seen in summary the various properties of the matrices. So, in this regard we have seen how the addition of various fillers in the matrix are done to change the various properties of the matrix and in the overall composite. This include fire retardants, viscosity control agents or we can say these agents are also sometimes added to enhance color which include pigment and dye. Then we have also looked how various environmental agents, they affect the various properties of the matrices.

In the next lecture, we will look at the properties of epoxy which is a very popular material to make the wind turbine blades. Thank you.