Science and Technology of Polymers
Prof. Basudam Adhikari
Department of Materials Science Centre
Indian Institute of Technology, Kharagpur

Lecture - 18
Polymer Products

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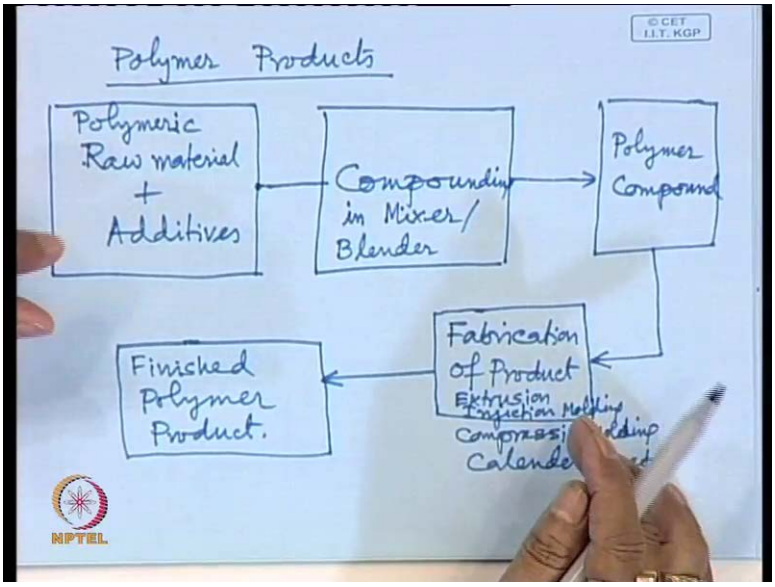

So, good morning. Today, we are going to discuss about the plastic a polymer products. As I mentioned earlier that none of the products are made of polymer contain only pure polymer, it contains various functional ingredients incorporated within the polymer. So, it is mixer or blend of a polymer and additives. So, after getting the origin polymer as raw material for any polymer product, you have to go through some processing steps with machineries, and you have to select a suitable polymer, you have to select various ingredients and then you have to make a compound after compound is made. Then you have to give a proper safe to the product.

So, if we start with say raw materials polymer, raw materials plus additives; whether you write polymeric material plus additives, then go through compounding in mixer or blender. After that we get a compound, polymer compound where it is soft flexible or viscosity will be less file hot actually. Then this polymer compound is a mixer of origin polymer, pure polymer and various functional ingredients or additives. Then it is it has to process by fabrication, machineries, fabrication of products. Now, this actually may be

say extrusion, injection molding, compression molding, calendaring, etcetera. There are various techniques which we will discuss later in detail. So, we get a finished polymer product.

So, basically a polymer product is an impure system. You can say if pure polymer with functional additives, functional additives I mean these additives have certain roles during this compounding, during this fabrication steps as well as after the product is obtained in a finished form. Then during service, the additives have several roles to play. So, all those additives or ingredients or incorporated in the polymer and then finally, we use the finished product.

Now, before going to produce this final or finished product through this discussing, this fabrication of these products, you have to first see what are the functional additives used in polymer to make hot products. Any product we decide to manufacture, you have to go for a selection, proper selection of polymer, proper selection of ingredients, proper selection of machineries, proper selection of process technologies, and then only, we can get a suitable product which will be useful. So, for any useful product, we should go for selection of polymers, selection of ingredients, selection of process, steps selection of fabrication, machineries and process parameters. That means we have to know the technology will develop the technology, product technology in that before developing that product technology.

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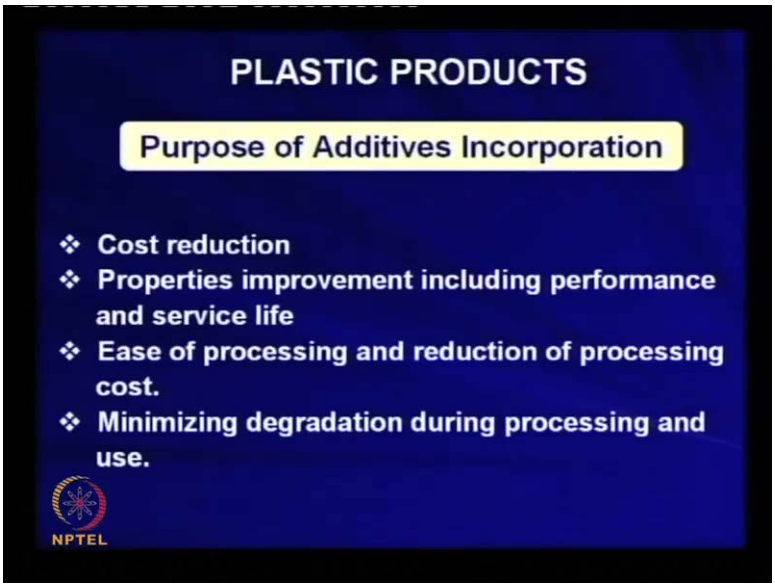

So, we must keep, we must consider the few parameters like say cost of the product. Cost of the product should be competitive in the market, otherwise you can manufacture product. If it does not sale in the market, then you cannot make any profit. That product will not see the market. It will not increase the consumers. So, cost should be competitive in the market, cost should be as low as possible, so that the manufacturer can have some profit as well as the consumers can get the product at the lowest price. So, you have to keep in mind the cost reduction parameter, then you have to develop a product which must provide adequate properties, otherwise it will not suit our purpose.

So, properties improvement including performance and service life, it should be durable, it should be good looking, it should be strong enough, it should not degrade, etcetera. Then during manufacture of the product, the product should be processed through easy and simple steps. You involve in using simple machineries, involve in mile conditions, otherwise that will add to the product cost and then minimizing degradation during processing and use. Now, these words minimizing degradation means this polymers actually passes through some machineries at elevated temperature because you know a origin polymer, a pure polymer, its melting point are all suppose if it is around 130 degree or 140 degree in the processing, temperature would be at least 170 or 180 degrees celsius temperature.

Polymers are made of carbon, hydrogen, nitrogen, oxygen. That means, these bonds are there, covalent bonds are there and these bonds are not stable to oxidative degradation. That means, when these polymers subjected to such processing at elevated temperature, so what happens at the elevated temperature is it will be exposed to atmospheric condition. Ambient condition means it a year which contains oxygen. So, there will be thermo oxidative degradation, thermo degradation due to heat treatment and at that elevated temperature, it will be exposed to oxygen of air. So, oxidative degradation will also occur. So, we can say thermo oxidative degradation both thermal degradation as well as oxidative degradation. So, you have to keep in mind that there should be minimum degradation during the fabrication of the product.

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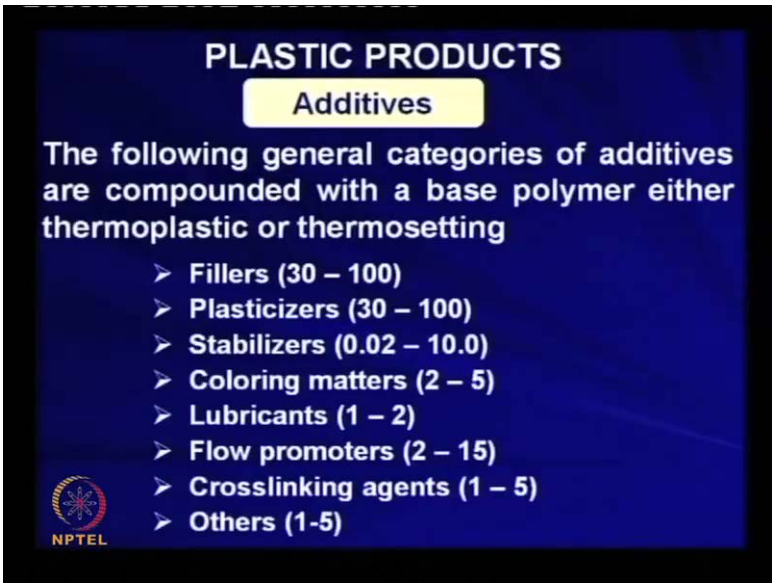

Now, what are those additives? Now, today let us concentrate on the plastic products. Now, products would be of plastic nature, plastic products, fiber products, rubber products, surface coatings. So, products may be of different types and in each case, the ingredients used for making those products are different. In case of plastics, additives would be of one type. In case of rubbers, additives would be of again different type. For fiber, additives would be of different.

Their numbers, their quantities, all those will vary as well as in surface coating, that is also a polymer product, there also the number and the quantities of the ingredients used for making those products also vary. So, it is not identical to or same for each category of products. So, for plastic products, but there are certain general aspects, general things which must be used in any of these products. So, you will get some idea if you just go through the additives or ingredients used for making a plastic product. First, for now making a plastic product, the main ingredient is the polymer.

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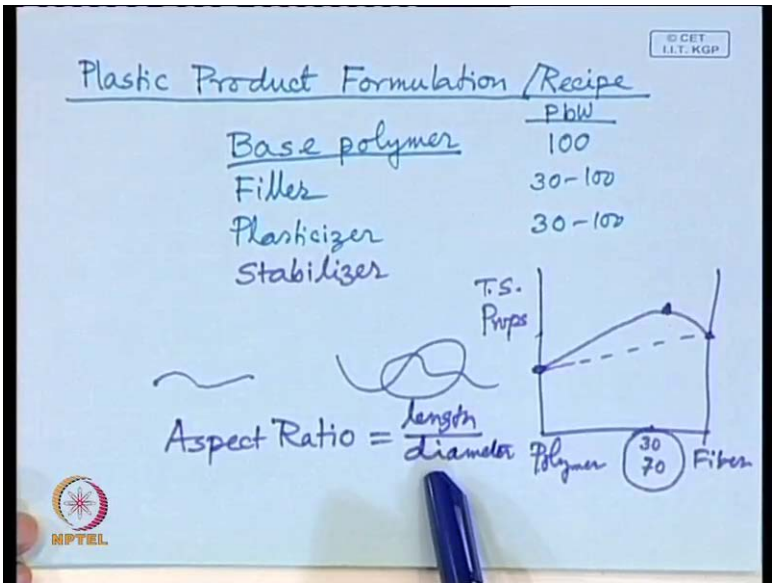

Base polymer. So, we are going to make a product formulation, say plastic product formulation. First, we have to make a formulation, a recipe. That means, what would be the ingredients in what amounts before making any product. You first go for a selection of these ingredients and that amounts, the first comes the base polymer for that particular plastic products. You know that may be polyethylene, that may be polypropylene, that may be polyvinyl chloride, that may be polyacrylonitrile, that may be polystyrene, that may be acrylonitrile butadiene styrene, that may be phenol and formaldehyde polymer and that may be polycarbonate.

So, first of all, you select a base polymer. That means, you should be guided by the final product. You require what is the one you want to make a pen. You want to make a (( )), you want to make a chair, you want to make a pipe, you want to make a cont, your over head container or you want to make a electrical switch, electrical socket switch board or coating of conducting wears, insulation of conducting wears, etcetera or tier. Whatever product you make, first of all you have to go for selection of a polymer depending on the final product you are going to make.

So, if you consider this base polymer, say as I told polyethylene polypropylene polyvinyl chloride etcetera, so you take parts by weight or (( )) are in case of rubber product. We write parts per 100 parts of rubber p age are we write, we say that is the convention pages are here. We can write p b w parts by weight. So, if you take the base polymer 100

parts, then correspondingly what will be the amounts of the ingredients taken? So, this is the base polymer, this is the main face polymer page, main polymer page 100 part. That means, you may take 100 gram, you may take 100 kg, you may take 100 ton like that in one batch of product formulation. We start with on the basis of 100 kg or 100 ton of polymer. This is better to write as 100 k kilogram and then corresponding to that base polymer, what is the amount of filler that you again depend on the type of products we are going to make.

Here, in this screen, you see there is a range of amount shown 30 to 100. You will less, say for overhead tank made of high density polyethylene. What is the amount of filler taken? Neither 30 nor 50 nor 100 kg per 100 kg of polymer. It is much less than that because you have to see what is accommodative capacity of the polymer. You understand before that let me tell you one thing. What is the necessity of using those ingredients? You are not asking me this viscose rayon is any necessity? You can take simply SDP. We can take any other polymer and we can make a product. Yes we can make a product.

In order to get a broad spectrum of properties, we incorporate ingredients. There is a need in incorporate ingredients in order to develop wide range of properties. If you make a container or a pipe only from an origin or pure polymer, you can make a product, you will get a product. It will be said that your purpose to some extent, not to the whole extent, fullest extent. Say, if you take high density polymer, say it is almost color less. In thick, it looks transient in thick seat. In thin film, it is almost not highly transparent, but it is transparent, colorless. So, you can get a plastic, a SDP pipe or SDP container, overhead tank, but the life of that tank will be limited period. The mechanical properties, say load bearing properties or the dimensional stability of that SDP tank of pipe will be low. Its durability will be less. It will be less stable if it is exposed to outdoor condition, even light sun light. So, it will degrade.

So, the life of the product will be less. The mechanical stability, mechanical properties, dimensional stability will be low again, not only that the aesthetic appeal, good look. That means, if it is not colored, customer will not take it. If it does not look nice, very nice, glossy, customer will not buy. So, it should be colorful, it should be stable, it should be durable, it should be strong, it should be dimensional stable. Some person can

stand on the tank and it should not collapse. So, that means, it should be stiff and strong when it is full with water. It should not collapse.

So, in order to develop all those properties, not only that if you take a pipe, in case of pipe, what happens underground is if pipes collapse, it may be deformed. So, in order to develop all sorts of properties, we need to incorporate such ingredients. So, fillers, it has certain purpose to use in plastic products fillers. What is filler? It means, it fills simple meaning is filling effect. Say if you take 100 kg polymer and if you add 20 kg filler, so total product mass will be 120 kg, and the cost of filler if it is 5 rupees a kilogram and the cost of polymer, if it is 80 rupees a kilogram, so you are getting 120 kg that filled plastic at low cost, but if you want to make a product out of pure polymer, so 120 kg polymer will be costing more. So, here lies the necessity of using filler which reduces the cost of the product.

Then, another question automatically comes. So, in order to reduce the cost, we are incorporating filler. What about the performance of the product? Properties of the product will it be reduced or we will it be increased or what? No. There are deferent kinds of fillers. One category of fillers that improves the properties. Another type of fillers that cannot increase the strength other properties, but it only reduces the cost because of the low cost of the filler. That means, other kind of filler can reinforce the properties. Another kind of filler remains simply inert; remain present as inert material in the base polymer only to increase the volume of the product there by reducing the cost. So, this is the situation.

So, here is the purpose of using filler. Then decide or charge what kind of filler you should go for selection, what amount of filler you should use. So, we have to come to a compromise with cost and performance. Although, this is true for all other ingredients where this is a major criteria for fillers because amounts of fillers are much higher than other ingredients. Next come plasticizers. You see again where is the range is 30 to 100. That means, if you take 100 kg polymer, you can use 100 kg plasticizer, you can use 100 kg filler. Also, 50, 50, 50, 50. Then you have to compromise the performance. What is the function of plasticizers?

Plasticizer means, it is coming from plasticity. Plastic properties from plastic flow. It is a flow characteristic. It is related to flow characteristics flowing of a fluid. You know these

polymers in the origin form, in the raw form, there having high viscosity at a mean temperature. At elevated temperature, viscosity is low, but when these products are made through compounding processing fabrication, all these things, it needs to be heated in order to make it soft, so that it can flow. So, it can fill the mold by flowing say if you take solid polymer.

So, suppose this is raw polymeric thing, this one raw polymeric thing, if you want to make a sit from it, you can you make it simply because it is hard. You can make a sit from it, provided you heat it. On heating, it would be softened. Then you apply some compressive load on it. So, it will be compressed to within sit. So, this polymer will fill the mold by flowing through an application of heat and pressure. You understand? Now, that application of heat and pressure that involves inverse consumption that will add to the cost of these product. So, leading product and fabrication, if you have to arrange the high temperature arrangement, both these high temperature arrangement and high pressure arrangement incur huge cost that will increase the cost of the product. So, it is better if the flexibility, if the characteristics, if the processing can be carried out at lower temperature and low pressure. That means that mild condition. Do you understand?

Now, in order to do that you cannot do it if the melting point is high, say 130 degree. You have been heating it up to 130 degree beyond it even for getting proper flow characteristics. If its melting temperature, softening temperature is 100-130 degree, we have to beyond 150, otherwise you cannot make a seat or film other product, but you can reduce the temperature provided use ingredients like plasticizer. Then you can reduce the softening temperature, continuous the softening temperature and you can increase the flow characteristic. That means the rheological characteristic of this polymer will be improved by using plasticizer. Let me give you an example. PVC polyvinyl chloride is a top and hardening polymer, rigid PVC. You have seen rigid PVC products, say medicine strips or PVC doors. You have seen rigid PVC is a dimensional stable also. PVC doors, PVC articles.

Now, if you add some plasticizer to this rigid PVC, it will become flexible which is known as artificial leather. Artificial leather like rexine table top, table cover, rexine film, plastic film, PVC set or curtain or upholstery covers, these are nothing, but plasticized PVC. So, when they are around 30 to 35-37 percent of plasticizers is blended with this PVC. Then only, we can get this flexible PVC film or set. Do you understand

how it is been done because these plasticizers are low molecular weight organic ester compounds that is miscible with this polymer. That means it behaves like a solvent. This plasticizer behaves like a solvent in the polymer matrix and you get a soft flexible polymer. So, here is a role of plasticizers. Not only that it reduce the flow temperature, it increases the flow characteristics at lower temperature

Then comes the stabilizer. Stabilizer meaning is very simple. Stabilizer, it stabilizes the product. That means it prevents degradation from various degrading agencies. What are those degrading agencies? Air is one degrading agency which contains oxygen, ozone, sunlight. We use there some radiation high energy radii. Other high energy radiation gamma, rays gamma radiation, x-ray, x radiation, these are also harmful because these are high energy that degrades the polymer, that breaks the chemical bond and simply high temperature also thermal, even if the atmosphere is inert that is the oxygen or inert gas is there, but even high temperature can break the bond. That means it is the energy.

So, source of energy stimulants, may be stimuli may be different, but that can degrade the polymer product. If you just keep one of your garment expose to sunlight for a prolonged period, you will find its color will go. It will be toned, it will break, it will cut, it will be bit torn. So, tear properties, strength properties, all these properties will be decreased that is due to degradation of the polymer which this product is made. Even curtain that is a polymer, if you keep it expose to sunlight and air and humid condition that will be degraded. So, that is degradation due to several influences of several degrading agency. Again microbial degradation is another source. Microbe scan attack, microbe scan seat on it can colonize on it, can grow on it and microbes will eat the polymer. So, in order to prepare from those degradation, stabilizers are used. Stabilizers are of different kind of I will discuss in detail.

Then, coloring matters in order to give good looks to the polymer product. Here you see nice looking, again this is a nice looking colors are developed in these products. So, these are coloring matters and these coloring matters may be organic or anything. Again, lubricants, now you see these pens are made through injection molding process. You know what injection is. You will know hypodermic syringe pens nibble is same in one sort 5 ml, 2 ml, 0.5 ml of liquid is injected within the muscle. So, injection molding functions by the same principle, but in one sort of movement of the plunger from one side to the other side. Other side it is if it is connected to several molds. So, several items

can be formed in one sort, say may be 50-60 if that mold in one sort. That means, you will think of the productivity.

So, he use numbers of pens or items are made by this injection molding process continuously through automatic process. So, after injecting the molten polymer into the mold, there is a cycle of heating and cooling mold is to be cold because the molten polymer should be hardened by cooling. After it is cold, then mold should be opened and then product should be injected out and all these steps are fully automatic. Today, machine technologies are available, machines are available.

Now, for injection of the product from the mold, again there is certain problem because it mistake to the metal surface. This polymer, molten polymer can remain stick to the mold surface. So, it should not remain sticking to the mold surface. It should be injected for that some mold, lubricant should be used. Not only that during making the plastic or polymer compound during fabrication, all those things or passing through machineries, it should not stick to the machine surface.

So, that needs some lubricants. So, lubricants are such there those lubricants will come very thin. Film of the lubricant will defuse or use out or exude to the interface between the polymer and the mold surface and that will help to injecting out to the mold. Flow promoters in order to control the flow characteristics, so that the surface finish is very good. So, some flow promoters are used and then final product may remain in thermo plastic stage or in thermo set stage. If it is produced in thermo set condition as thermo set type of product, then you have to use some cross linking agent. Then there various miscellaneous ingredients of like, say anti-static agents, flame retardant agents, fire retardant agents. So, ingredients are used.

So, here you see the stabilizer is used ingredients in small quantity. From here, it is small 0.0 to 10 parts. Sometimes one part is sufficient, sometimes two parts is sufficient, sometimes less than one part is sufficient. Lubricants 1 to 2 parts, flow promoters 2 to 15 parts, cross linking agents 1 to 5 parts and other miscellaneous ingredients may be 1 to 5 parts. So, this is known as a formulation, product formulation recipe. So, if you are asked to write a formulation or a recipe, you have to write the name of the best polymer and its amount. Then name of the ingredients which must be used for that particular product along with their quantities in parts. Understand? So, formulation means, I repeat

formulation means the ingredients and their amounts before making the product, say think of a cooking recipe. It has also a recipe. Any menu, some vegetable that is a main item, vegetable or chicken or mutton, then what we add is some masala. Again that masala may be discrete. One or it may be again a mix masala and then spices are your oil, some sugar, some salt. So, these are ingredients.

Now, if you are careful about the quantities, suppose 1 kg mutton you add 1 kg 50 percent salt, would you be able to eat it? No. Likewise, here also if you take 1 kg polymer base polymer and if you add 1 kg cross linking agent, 1 kg coloring agent that product will not be useful. So, if cooking recipe should be eatable, it must be there in proportion optimized recipe. So, here you have to make an optimal formulation, optimized formulation, so that will give you the best performance, that will give you the cheapest cost and that should provide product fabrication in a very simple manner, simple fashion.

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Now, let us look into fillers. Now, fillers are usually solids material and these fillers may be inert fillers or reinforcing fillers. Could you name on reinforcing filler? Carbon black. Yes, carbon black is reinforcing filler for tyre. Silica fillers are also reinforcing filler for rubber. Reinforcing means it must interact with polymer. You think of, you just imagine a polymer network or a thermo plastic (( )) dimensional polymer block and within the polymer block, there are ample free volume available. Within those free volumes, free

spaces if you can incorporate particulate fillers, today nano fillers are there in our class. There is one nano person who is working in nano materials. He likes nano very much, ok. Nano dimension filler, nano dimension material.

When these materials are incorporated in a base polymer, then you get a nano composite. So, composite may be macroscopic, microscopic and nano macroscopic, microscopic and nano, provided we incorporate fillers or reinforcing agents inert fillers or reinforcing fillers within the polymer matrix. Matrix means continuous page. Then you can get some improved mechanical properties or we can get improved properties. Also, other properties improvement also.

Now, let me tell you the meaning of this free volume. I was telling you in case of high density polyethylene, you cannot incorporate the 30-40 parts of filler. It cannot accommodate because this polyethylene's are crystalline in nature. The free space availability of free space in polyethylene is less because the morphology of the polymer is compact polymer chains. This polyethylene chains lie side by side in compact fashion. So, free availability of free space in polyethylene is less whereas, if you take natural rubber, if you look into the configuration of natural rubber molecules and compare with that of polyethylene molecule, we will find in natural rubber molecule that there is this kind of chain folding whereas, in case of polyethylene, the extent of chain folding is quite less.

So, here if you add, say 100 part of filler to 100 part of polymer, you can again incorporate and you will be surprised to know that in some rubber products to 100 part of rubber, more than 1000 parts of fillers are incorporated. Check floor mats, flour rubber mats, these are made by simple incorporation of river bed silt clay, filler clay. There clay is used as filler. So, with 1 kg of polymer, 1 kg of natural rubber, one can incorporate say 129, 100 gram, 21 kg of clay. You understand how much amount of this, sorry 9 to 1 kg of polymer to 1 kg of rubber you can incorporate 1 kg of filler. Otherwise, you can incorporate to 1 kg, you can incorporate 400 gram, you can incorporate 500 gram, you can incorporate 600 gram, like that now that is accommodated in natural rubber for that large number of filler is not accommodated in case such rigid polymer. So, you have to see why the polymer is rigid or flexible.

If the polymer is flexible, yes you can incorporate higher quantity of filler. There you understand. So, this accommodative capacity of the polymer has to be looked into, has to be kept on the consideration if it can accommodate. Yes, you can use more amount figure and the product will be stiff, product will be stiffer. You understood? So, inert fillers which do not interact with the polymer chain, simply it remains pleasant within the polymer matrix and it reduces the cost by increasing the volume. It is known as inert filler. It will decrease the mechanical properties, it will decrease the tensile strength, it will decrease the modulus, increase the modulus of course, because its modulus is a lower extension properties. It will increase the modulus, but it will decrease the tensile strength, decrease the elongational break, decrease the dynamic property, it will increase the hardness. This is the effect of filler. You can just correlate.

If you take an inert filler incorporated, inert filler in a polymer, what happens is it will increase the stiffness means modulus, it increases the modulus because this modulus is a low extension property. That means, low elongation property modulus whereas, tensile strength, it is breaking properties. You are pulling tensile, applying a tensile strength and then it may break somewhere if the strength of this product goes beyond the load applied and then compressive strength again load under compression.

There also deformation occurs. So, the compressive strength will be high because the stiffness is high. If you use inert polymer, inert filler, so that will increase the stiffness and modulus, but that will decrease the tensile strength that will decrease the elongation and break. Now clear, but reinforcing filler on the contrary, what happens is it interacts with the polymer. That means, it may either form a physical or chemical bond with the polymer, say you think of carbon black as filler in natural rubber. What happens there by virtue of this structure and morphology of carbon black is these rubber molecules.

The segment of folded segments of rubber molecules and the end of the rubber molecule chains penetrates go inside that carbon black particular because it is floppy pours particular it goes inside. So, there it anchors by through physical anchoring or it can chemically interact also. There are certain functional groups available and those functional groups interact with the polymer chain, rubber chain and it becomes permanent. So, there is permanent or physical, but tangent anchorage with the filler. So, that increases the strained properties of filet polymer.

In case of rubber tier 45 parts of carbon black is used, that 45 parts of carbon black increase the tensile strength of a origin rubber from say 16 megapascal to 24 megapascal. You understand how much increase is there? Say if the tensile strength of gum rubber compound is 16 megapascal, the tensile strength of the same rubber compound will increase if you can incorporate 45 parts of carbon black in that rubber. So, there is improvements in tensile strength along with its hardness also increases as well as tensile strength, sorry is a elongation or break also decrease by incorporation of this filler.

This kind of filler in rubber is known as reinforcing filler. So, if there is some reinforcement of these strength properties of the base polymer, then we can call it reinforcement. Think of a composite. Now, in composite what we do is we take some fibers or particles. You take the fibers, say it may be long fiber or soft fiber or it may be particle in nature. You can make a product and then these fibers will have some interface between the polymers with the polymer. So, there will be some interaction between the polymer and the fiber surface at the interface and that enhance is the properties. So, it reinforces. That means fiber reinforces the matrix.

So, this strength properties of the composite will be higher than those of the polymer as well as that of fiber. So, if you look in this show, suppose this is the polymer axis. This is the fiber axis and these are the properties. Suppose, this is the polymer property lies over here and fiber properties lies over here little higher than that of a polymer tensile strength. Now, by incorporating, say 30 percent of fiber, you can get an improvement of properties like this. So, suppose this is the product, say here fiber is 30 and polymer is 70, so in 30 parts filled or reinforced fiber, reinforced composite, you will have properties of enhancement like this. So, this is your properties means tensile strength of the pure polymer. If this is the tensile strength of the pure fiber, then the strength of the composite will be more than the individual strength of polymer as well as fiber.

So, here is the advantage of using these fillers or reinforcements. You understand? It is called the reinforcement because there is some interaction between the filler and the polymer. If some interaction or anchor between the filler and the polymer, then only we can say some reinforcement is there and entire composite technology, composite product are based on this principle. High performance composite, low profile composites, all these are based on these principles. Fillers may be a particulate rubbery resinous or fibrous in nature. Then we will say it is a portal fill composite, it is a filler reinforced

rubber, it is a polymer reinforced composite resinous fiber, a filler or fiber reinforce composite.

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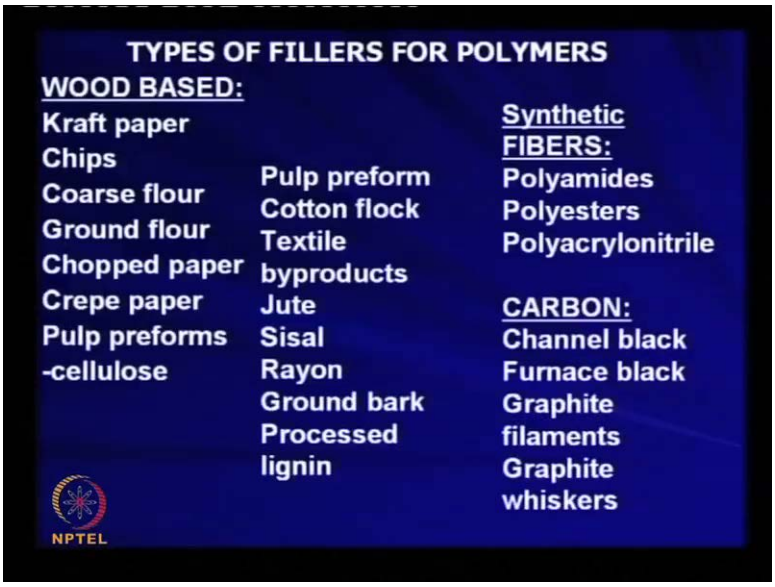

Now, look huge number of examples can be sighted for different types of fillers. For polymers, this is wood based. You see wood based fillers look kraft paper, chips, coarse flour, ground floor, wood flour, chopped paper, crepe paper, pulp performs is alpha cellulose. Actually, alpha cellulose alpha is not there. Alpha cellulose pulp performs. You know paper pulp, wood pulp? How pulping is done?

All you know what pulping is, how pulping is done, how this news prints are made, how the paper is made. You know the process is very simple. You take some wood based material, either bamboo or soft wood that contains cellulose and lignin. There are pulping technologies, say (( )) technology or key pro ammonium technologies. These are available. So, when these chemicals are mixed with this wood, it become soft and viscose and lignin goes out, solvable things goes out and you get a pulp. Then that pulp is further used for making fiber, for making paper seats, for making products say cellophanes. It comes through pulping. They are all wood best materials, wood best products wood cellulose.

So, these textile byproducts, then jute natural fiber, sisal, another natural fiber rayon, it is a semi synthetic fiber discos rayon, ground bark, a trees plant processed lignin. Lignin is the wood waste, paper industries waste that lignin is the store house of chemicals. Those

lignin can be used for making again as you can used as a raw material for polymer product. So, there is huge number of wood based fillers available. Then there are again examples of synthetic fibers, say polyamides nylon fibers, aliphatic polyamides nylon, aerobatic nylon, say Kepler. Then polyester fibers, polyacrylonitrile fibers or many other polymers can be drawn into fibers. Only few are mentioned over here.

Then, carbon based fillers. Carbon you see, carbon black there are available in various grades, say there are three major grades-channel black, furnace black and thermal black. Here only two are mentioned, channel black and furnace black and thermal black is not mentioned here. Channel black is for making printing ink. Channel black's particle size is very low and is less than 10 nanometer particle size channel black carbon black. That means, it is made by a channel process through by combustion of natural gas or petroleum oil. Furnace black is made from again natural gas or petroleum oil by furnace process and thermal process. You see black, you know you have seen lam black. If you shoot formation is there that is shoot is nothing, but unbolt carbon. That is also a carbon black.

Then, graphite. If you heat this black, carbon black in order atmosphere, it will transform into graphite structure, in graphite fiber. These are also available, made. You know carbon fiber if you want, if you are interested, if you come to my room, I will show you how carbon fiber looks. I will show you some polymers samples also. There are different types of polymer samples, different types of fibers including glass fiber, carbon fiber, and aerobic fiber. I have lot of specimens in my room. You come to my room and I will show you graphite fiber, carbon fiber made from polyacrylonitrile precursor I mentioned earlier, ok.

Then, graphite filaments, graphite whiskers. Whiskers is a single crestline material sort of fibers. Whiskers single crestline fibers is having high aspect ratio. You know what aspect ratio is. That means, if the diameter is very low, very less, the length is quite high. That means, this is thin fiber, very thin fiber and its surface series is very high. So, it will be high, reinforced highly. Reinforcing aspect ratio is very high. It will give excellent reinforcement properties.

Thank you.