Processing of non metals

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Module - 4
Plastics: Properties and Processing
Lecture - 2
Processing of Plastics

A warm welcome to all of you in this lecture number two of module four in our course Processing of Non-Metals. In module number four, our focus is on processing of plastics. As we can recall in our lecture number one in module four we have seen that what are thermosets and thermoplastics. Basically, we have try understand that what are the characteristics or important properties of thermosets and important properties of thermoplastics.

And we are try to understand or go into the revision mode of what do we know about the plastics. If you remember we have seen that plastics are the materials which can be easily molded or shaped plastics derived their name from a Greek word. So, basically, we have try to go into the history or into the brief overview of the plastics in our lecture number one. And then we have seen that what are thermosets, and what are thermoplastics. We have seen that what are the structure and different types structures that are present in the plastics, we have seen a classification diagram in which we have seen that there are linear structure it can be a bragged structure, it can be cross linked structure, it can be a network struture different types of structure we have seen.

Then we have seen that what are the application areas, because once we talk of processing, so processing means converting raw material into the final product. When we are converting the raw material into a particular product or tangible product, it has to have some application for which whole conversion process or the whole processing is being done. So, it has to have the objective that why raw material is being converted into the final product. And if you remember that there are large variety and there is huge applications spectrums of thermosets as well as thermoplastics. We have also seen that what are the various types of thermosets, what are the types of thermoplastics, and how they are differentiated. If you remember, we have seen thermosets cures irreversible and thermoplastics cure reversibly. And how the curing takes place that also we have

discussed in our lecture number one. And finally, we did the lecture number one with the slide in which in different monomer units for different types of polymers were showed. So, these types of polymers, we would be using as raw material for converting them into the final product.

So, today primarily would be on understanding that what are the various mechanical properties of the polymers and what are the important factors that govern the processing of the plastics, because first we understand that how the plastics are processed. Later on our next module, we would be focusing on the polymer matrix composites in which again polymers would be processed and fibers would be or the reinforcement would be added into the polymers or the plastics to make a different class of engineering material. So, this particular discussion that we are having today is not only relevant for this particular module, this relevant for the module two follow also. So, this is really important we should try to understand that what are the properties of the polymers and why we are incorporating this polymers with additional phase and what advantages we can derive if we incorporate additional phase into these polymers, but before combining them with any other material first we should be able to understand that what are the properties of the polymer itself or what are the mechanical properties of polymer itself and how the polymers would be heat.

Then in today's lecture our focus would be also on one of the most simplest process of making the plastic product that is called casting. Casting is a very common word which is used for process or manufacturing of production of metals in which we use the casting process to get the desired products. But in plastics also we can get the desired shape of the product using the plastic as the raw material, so we would seeing the simple diagram of the casting process specifically in context of the processing of plastics. So, let us starts our lecture with this introduction and a brief review of what we have discussed in lecture number one.

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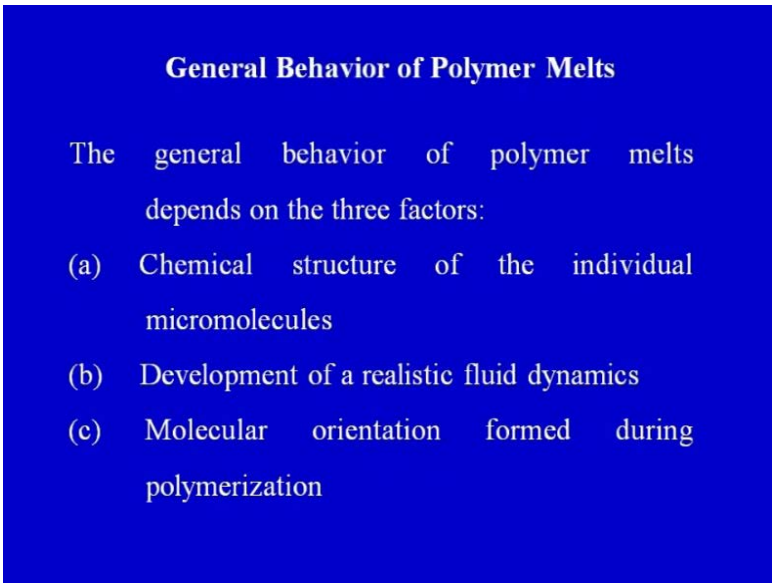

So, first of all, let us see the general behavior of polymer melts. Now we see we know that there are different type of polymers thermosets and thermo plastics, and they have to be converted into the desired shapes and sizes according to the requirement. Now when the polymer will melt, how the polymer melt will behave and what factors the polymer melts depends. On your screen, you can see, the general behavior of polymer melts depends on the three factors. Now this particular factors need be considered when we are talking or when we planned to discussed any of the process techniques for plastics. One important point is the chemical structure of the individual micromolecules. So, in the previous lecture, we have seen different types of structure are there, so that is one important that was important point to emphasize that why our topic is processing, but why we are talking about the structure. Why, because the structure would dictate the processing because depending upon the type of the structure, the particular process or processing techniques would be applicable to a specific set of polymer family.

So, important point, first important point to note is the chemical structure of the individual micro molecules then that would vary for different type of polymer. Second point to note here is the development of a realistic fluid dynamic. So, basically we have to see that how that melt will flow and what would be the viscosity and for how long the material would remain and what are the how much time the solidification process would start, how the flow the solidification, the cooling, all these points have to be taken into account when we are talking about the polymer melt. So, the second point is the

development of a realistic fluid dynamics that how the fluid would behave when it is flowing in the mold cavity or it is flowing in the process. And different process would required different fluidity and different viscosity and this fluid dynamics should be understood properly when we are going to talk about different process which are used for processing of plastics.

The last point on your screen is the molecular orientation formed during polymerization that is also very very important, because this would dictate the final properties of the product or the plastics which has been found by any of the processes. So basically when we are talking about the processing, we have to first understand the basic behavior of the polymer that what is the structure, what is the molecular orientation and what how the polymer would flow under different conditions of different temperature and pressures. Some times is some of the processing techniques, we will see that the polymer will flow at a elevated temperature and as well as at a applied pressure. So, when is the pressure is also acting, the temperature is also high how the polymer melt would behave. So, all these things need to be understood.

But as our focus is on the processing of the non-metal, we will not go into detail of these aspects, but yes these aspects are important when we have to do research in the area of developing some of the new process for some of the advanced polymers. So, we need to understand all these points, but our focus primarily would be to understand what are the process which are already developed, what are the process details, what are the important points to be taken care of when we are processing any plastics or a polymer with that particular process. What are the application areas of that process, what are the advantages and limitations of that particular process, but certainly when we are talking about any process we should have all these things in our mind that we should understand the chemical structure of the polymer. We should understand the flow behavior of the polymer; we should understand the molecular orientation of the polymer after it has been formed in to the desired product. So, these are important points we should be keeping in our mind when we are discussing the processing of plastics.

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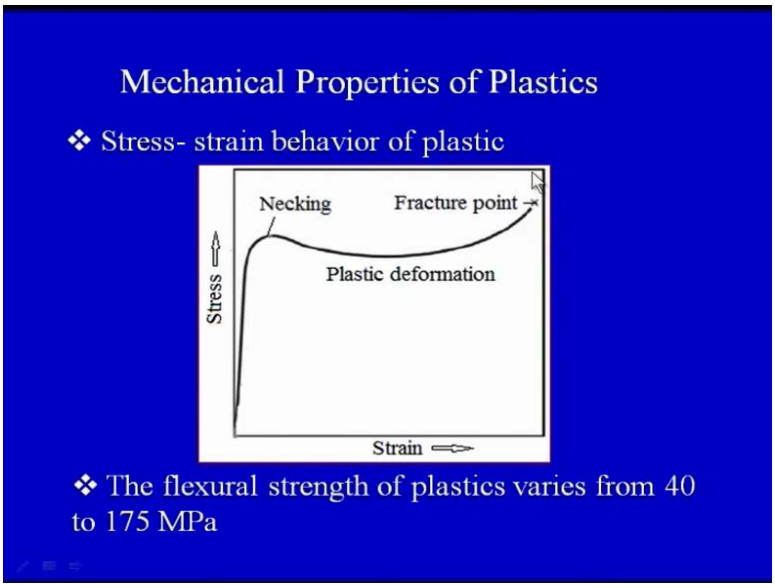

Now, another important aspect are the mechanical properties of plastics. So on your screen, you can see the stress strain behavior of the plastics. So we can see on x axis we have strain, and y axis we have stress. So when load is applied, we can see the necking takes place, then the plastic deformation takes place, and finally the fracture takes place. Now this is specific to one particular type of plastic as you can see if you remember in lecture number one, we have seen the properties of the thermoplastics and thermosets. Now the question can be ask that this particular stress strain behavior is for a thermoplastics or for thermoset. So, if you remember thermosets have a brittle failure. So, therefore, this particular stress strain behavior would be exhibited by the thermoplastics because they have the necking and the plastic deformation taking place when they are loaded under different conditions.

So, this particular stress strain behavior is representative of thermoplastic material in which when we apply the load at the failure point first the necking will takes place, the plastic deformation will takes place, there would be it would take lot of strain, there would be change in length as compared to the original length. And the finally the fracture would take place, but in case of the other materials that is other category of plastics which are called thermosets which have a brittle failure and they are loaded they may not undergo necking and plastic deformation and a sudden brittle failure or fracture of the component made up of thermoset may take place.

So, these are important things the stress strain behavior of thermosets and thermoplastics should be known to us when we are going to talk about the processing aspects of plastics. Why, because in certain aspects, we may be getting a final product which is going undergo certain types of loads, so if it is a thermoset and load is acting during the processing stage only, after it has been formed into a solid product there are the chances that brittle failure may takes place. Whereas in case of thermoplastics even if it has formed a sum amount of load is acting, the failure of chances of catastrophic or brittle failure or less as compared to the thermosets.

So, these are things which need to be understood when we are talking about the processing aspects of plastics. So, one important point is note over here that the thermoplastics will behave differently as the compared to the thermosets when they are loaded under tensile loading as is quite evident from this graph which there on the screen that is stress strain diagram. Secondly, the flexural strength of plastic varies from 40 to 175. This is just a representative data, it may be vary, because so many different types of polymers are been developed these stages, but the flexural strength may vary from 40 to 175 mega pascal.

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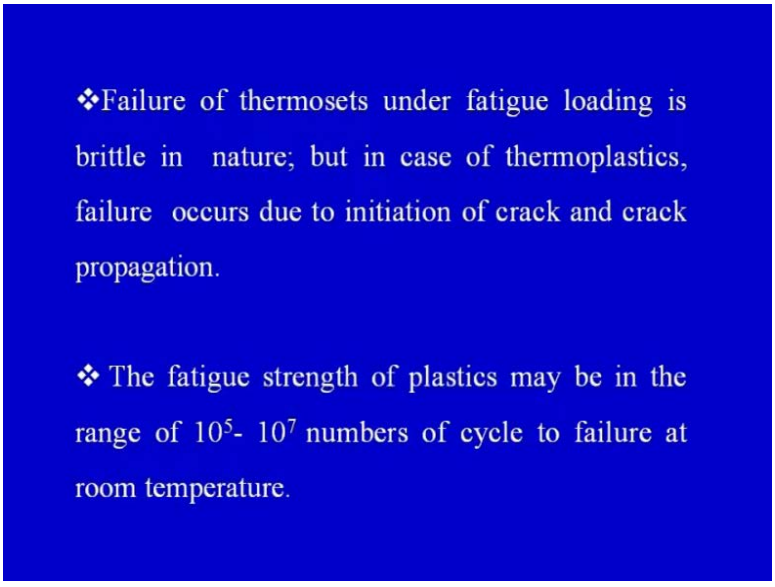

Now, coming on to the failure, so failure of thermosets under fatigue loading. Now the polymers that we are processing can be subjected to the different types of loading. So we can have tensile loading, there can be compressive loading or it can be a cyclic loading,

it can be a flexural loading, so the type plastics that we are processing may be subjected to the different types of loading environment. So, under different loading environments, the different types of polymers would behave differently. So, this is one particular case in which the failure of thermosets under fatigue loading is being discussed.

So, when the thermosets will be subjected to fatigue loading that is cyclic loading, the failure of thermosets under fatigue loading is brittle in nature which I have already told that if we load them in tensile loading environment also there also we will see that brittle failure of the specimen of thermosets would take place. Similarly, in case of fatigue loading also, failure of thermosets under fatigue loading is brittle in nature, but in case of thermoplastics, because the two materials are different that we understood in our lecture number one also; incase of thermoplastics, failure occurs due to initiation of crack and crack propagation. So, under fatigue loading, when the cyclic load is acting on the thermoplastic there may be chances of formation of occurring crack and under repeated cyclic loading. This crack may propagate forming a bigger crack leading to a catastrophic failure of thermoplastics, but it would not be a sudden failure or a brittle failure as incase of thermoset.

So, we have seen that if we are loading a polymer under tensile loading how the stress strain behavior would becoming, under fatigue loading thermosets will have a brittle failure whereas thermoplastics would certainly fail by taking sometime to failure. First crack will be appear, the crack will propagate, and finally this crack may merge with some other cracks or catastrophic failure may take place. The fatigue strength of plastics, this is another representative data which may be quite range may be quite wide or sometimes it may be on the lower or higher side also, but this just gives an idea that what are the number of cycles to failure for different types of plastics, so this is the range which is given. So the fatigue strength of plastics may be in the range of 10 to the power 5 to 10 to the power 7 number of cycles to failure at room temperature.

Important point to note is that this particular data is for room temperature and if the fatigue loading is acting on any polymer at an elevated temperature, certainly the number of cycles to failure would change. And if it is being done under cryogenic conditions or at very low temperature again these number of cycles to failure may change, but here our point is to just have an idea that a large number of cycle to failure may be subject may be taken by any plastic before it finally fails. So, again I am reading the second point on the

screen, that the fatigue strength of plastic may be in the range 10 to the power 5 to the 10 to the power of 7 number of cycle may failure at room temperature. And this figure may change depending upon the requirements or the conditions and environment under which the fatigue loading or testing is being done.

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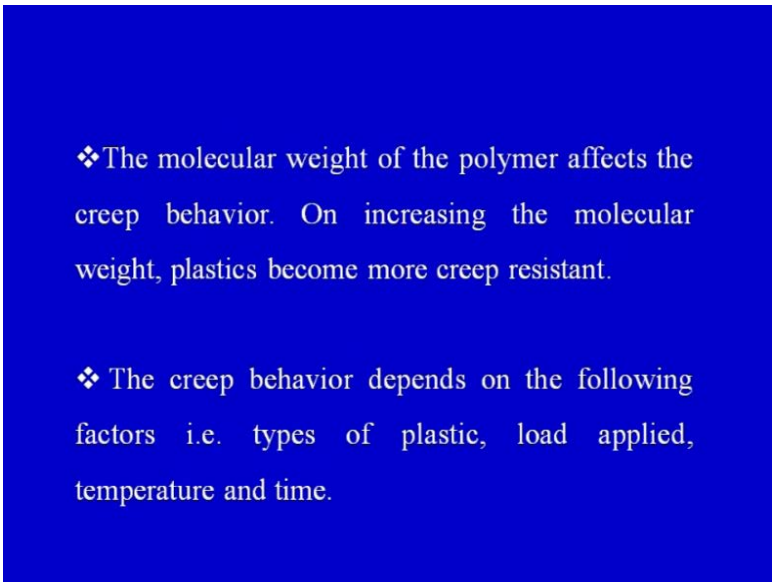

Another important property is the creep property. So, on your screen, you can see the molecular weight of the polymer affects the creep behavior. So, creep basically is a combined type of loading which mechanical as well as the temperature load is being acting on the specimen or on the material of which we are investigating or studying the creep behavior. So, the molecular weight of the polymer affects the creep behavior. Now if you see that show all these things are interrelated, in lecture number one we have seen the structure, different types of structures, and we have seen different types of isomers also. So, at chemical level, there are few differentiation in different types of polymers and then different type of molecular structures are there. The monomers are arranged in different or specific patterns in different types of polymers. So, that arrangement of monomers the cross-linking among monomer chain all these things are affecting the mechanical properties. And the mechanical properties would be subsequently affect the processing also.

So, once the polymer is being made or once the plastics product has been made, many of the properties are we can say all of the properties of the final plastic products would be

depending upon the all these levels of understanding that is the chemical level of understanding, the mechanical properties of the polymer, and the finally, the final properties of the product. So, all these things are interrelated; there is nothing existing in the differentiate. So, again on this particular slide, you can see the molecular weight of the polymer affects the creep behavior. So, that is one important point and the creep behavior depends on the molecular weight in a particular fashion which is there on the screen.

On increasing the molecular weight, the plastics become more creep resistant, so higher molecular weight more creep resistant. So, once we are thinking of a particular product that will be coming under temperature loading also and mechanical loading also we should think of that what type of polymer we should select for this particular application, because it is constantly coming under the creep loading. So, this particular point gives us an idea that increasing the molecular weight, plastics become more creep resistant which means that high molecular weight can be chosen, but there would be certain other conditions which also have to be satisfy it cannot unilateral single direction decision. But there can be many other conditions which would be acting on the this particular selection criteria or this particular selection decision which would be many other criteria would be affecting this decision.

So, basically we will see that what are the various factors which should be taken into account when we are selecting a particular material for a particular product application that would be covered in another lecture. But important point to note in this particular slide is that the molecular weight of the polymer affects its creep behavior and on increasing the molecular weight that material becomes or the plastics becomes creep resistant. So, for creep resistant applications, we should choose polymers which have high molecular weight. So, that is one relating the properties of the polymer with mechanical property and then the mechanical property would finally be related to the application for which the polymer is being used. And the creep behavior depends upon the following factors. Now these are the other factors which have to be taken into account when we are discussing the creep behavior of the polymers. So, what are these factors? These are the types of plastics or the type of polymer that we are using, load applied and temperature and time. So, there are three- four important points which we will dictate the creep behavior of any plastics.

So, on your screen, you can see the nature and type of the polymer that is one load applied that temperature and the time for which temperature and load the acting on the polymer will dictate the creep behavior of the polymer. So, we can see the different mechanicals properties are there, we have seen the stress strain behavior of a thermoplastics, we have seen how the brittle failure of thermosets would take place. We have seen the fatigue strength is depended upon the properties of the polymer, and we have seen under fatigue loading how thermoplastics would fail, how thermosets would fail. And in this particular slide, we are trying to understand the creep behavior that the creep behavior is dependent upon the molecular weight of the polymer.

So, the mechanical properties can be correlated with the basic characteristics or basic physical and chemical properties of the polymers. So, basic physical and chemical properties of the polymer dictate the mechanical property or they have a influence on the mechanical properties of the polymers. And finally, these mechanical properties are the polymers are important to us when we are going to make the product out of these polymers and these products will be used for different application which we have seen in the last class. We have seen two slides in which we have seen what are the important applications of thermosets and what are the applications of thermoplastics. So, till now we have tried to understand the basics of the polymers and we have tried to understand how the properties are affected by the chemical and physical properties or how the mechanical properties are affected by the physical and the chemical properties.

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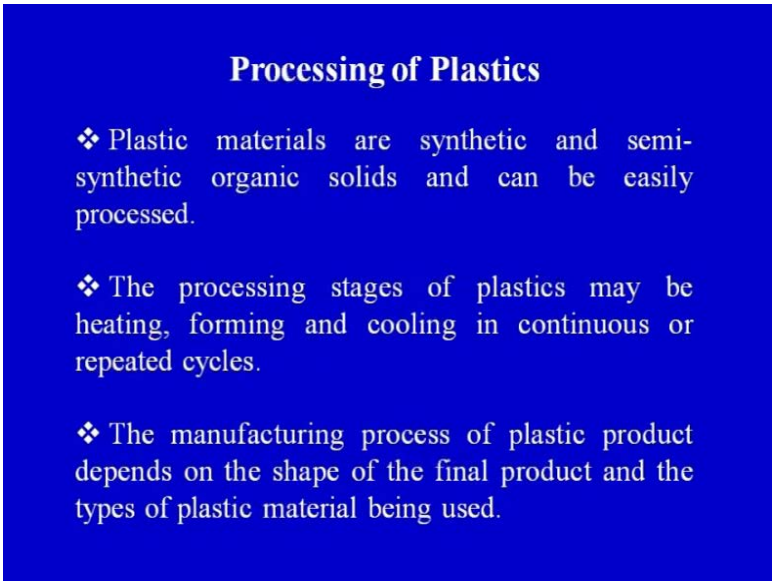

With this we come to the end of the basic discussion about the plastics. We have seen again and again, I am revising the same thing that what out focus, our focus was primarily to understand that are revise what are thermosets and what are thermoplastics. Because we are not gone into that much details about the basic nature of thermosets and thermoplastics, we are not understood too much depth that how the thermosets and thermoplastics are formed or may be the basic chemical nature of thermosets and thermoplastics. But we have tried to understand them from the application point of view that how they behave, what are the various properties or what are the various mechanical properties of the thermosets and thermoplastics. We have tried to seen the that difference between that what are the various types of structure like the linear structure, brag structure, a cross linked structure, network structure. We have try to see what are isomers, different type of isomers all things we have try to just revise in lecture number one.

And today we have seen that how the physical and chemical properties or the basic properties of the polymers affect the mechanical properties. And we have just taken the revision of few properties only, there can be a mechanical properties also like hardness which we have not discussed. We have just seen a typical stress strain behavior for a thermoplastics, we have seen under fatigue loading, how the polymer or plastics would fail. We have try to understand the creep behavior because that is one of the important point regarding the use of plastics in the high temperature application and when the temperature and load both are the acting on the polymer then the creep type of loading is there. And under creep loading how the material behaves or what factors should be taken into the account in order to have the good response of the plastics under different types of conditions that we have tried to understand. So, that was all that we have to revise before going taking up lunch into the processing of plastics because now we are going to discuss the various processing techniques for these plastics which we are going to cover in our subsequent lecture.

So, processing of plastics now we are going to start, the basic introduction about the plastics now over. So, processing of plastics, on your screen, if you remember in lecture number one the very first slide we have seen that plastics derived their name from the word plastico, which means that it is easy to mold and shape. So, processing of plastics is not too we can say difficult or complicated process, but yes it is easier set then done

there are so many control variables that have to be taken into account. And if you remember the very first slide today, we have to taken in to the account chemical nature and the flow behavior of polymers when we are talking of the processing of plastics.

So, basically although from the word from which the plastic has been derive in means easy to mold and shape, but still we need to understand that what are the complicacy, what are the problem areas, what are the issues, what are the challenge in the various processing techniques related to the processing of plastics. So now onward, our discussion would be focusing on primarily on the processing of plastic. So, whatever terms would be used related to the basic raw material or the structure, we have already covered in lecture number one and in the beginning of today's lecture.

Now our focus would be primarily would be on processing of plastics. So, plastic materials are synthetic and semi-synthetic organic solids, and can be easily processed. Again and again the word easily is coming, but when we will see that details of the various process which are used for processing of plastics we would see that there are many control variables which have to be optimize in order to make a good quality product out of plastic. So, the processing stage of plastics may be, now this is just giving an over view or the outline that what are the various stages and these stages would be different in different process and we would be seeing the different types of process is in our series of lectures on processing of plastics. So, what are the various broad steps or broad category of steps that would be followed in converting any raw material which is the plastic material into a final product.

So, the various stages would be heating, we would be heating the that is any polymer or any plastics. It would be forming, forming means we would be converting it into the desired shape, now suppose we want to make up and so polymer would be melted and would be made in a pen or formed in the form of a pen. Now suppose I want to make a plastic bucket, the raw material would be in the form of a plastic, it would be heated and it would be deformed into the shape of bucket. Suppose, I want to make a mug, the mug would be formed given the shape of mug via heating the raw material that is the plastic and converting it or forming it into the desired shape.

So, different examples can be given for processing of plastics, but primary stages are heating of the raw material. Forming means giving the desired shape to the raw material

and finally, allowing it to cool to that particular desired shape. And that shape can be given by a mold. Now what is molt that we would be seeing in the subsequent lecture, basically, the process is the fairly simple. Heating the raw material, second stage is giving the raw material a particular shape, and final stage is allowing the raw materials to cool inside the molt cavity or the mold or the die, so that we get the desired shape or desired product out of a raw material which in this particular module is a plastic material. So, this particular thing can be done on a continuous scale or in repeated cycle.

So, this means the product can be coming out continuously or it can be coming out in a cyclic fashion may be 60 part per minute or it can be hundreds parts per hour or it can be 200 parts per day, so depending upon the production rate we can get discrete number of products also or these can be continuous products also. But, technical definition of the processing of general terms in terms of processing would be heating of the raw material giving it a desired shape which can be called as forming, and finally cooling to the desired shape, that is the shape of final product. So, in most of process is that we would be covering in processing of plastics. The basic stage is would be same that is heating, second stage is forming, and the third stage is cooling.

So, we can say heating h, second is forming f, and cooling c, and h, f and c; heating, forming, and cooling. So, we should keep these three words in mind that is h, f, and c; first the raw material would be heated, then it will be form and finally it would be cooling to desired shape. And if you remember in our series of lectures in another module in which we have seen the forming of glass, there also the steps over quite similar, but there were a few additional steps involved also. So, we will not going details of glass forming and this particular lecture, but we just trying to draw and analyzing between the forming of glasses and the forming of the plastics again the stages are nearly same, that is h f and c heating forming and finally cooling.

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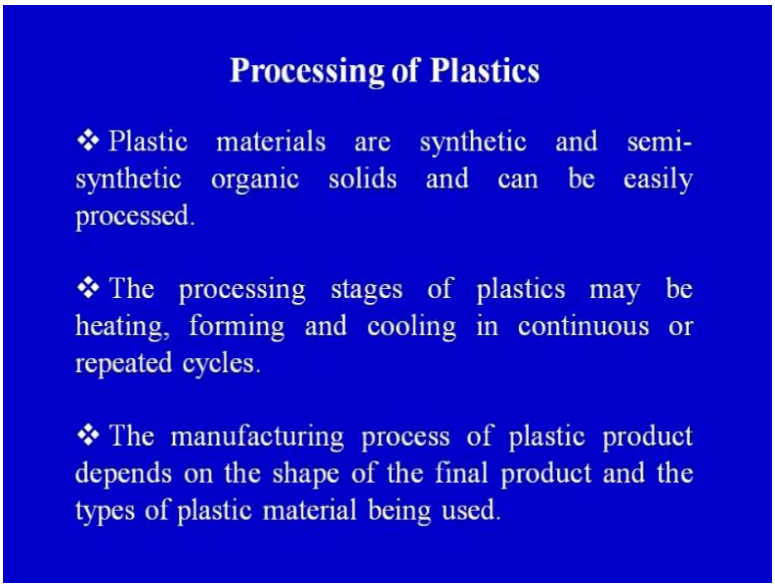

The manufacture process of or manufacturing process of plastics products depends up on the shape of final products, and types of the plastic material is being used. So, the processing techniques broadly can be classified on the basis of two important criteria; the other two important criteria are there on your slide. Now, what are these two criteria, let us take one criteria at a time, criteria number one the shape of the final product. Now, we can have very huge product, we can have a very discrete and a small product, it can be a very complicated product, it can be a simple product. So, we can depending upon the shape and the size of product different process is can be there for processing of plastic. Second criteria is the type plastic material is being used, that is plastic material may be a thermoset or it may be thermoplastic.

Now, for a thermoset, because of the basic differences thermoset and thermoplastic, the processing techniques may also vary. So, that is why we have taken lecture number one thermoset and thermoplastics why because we needed we need to understand that what are the basic differences between the two, so the two criteria that are very, very important in order differentiate between the processing of plastics is that the shape and size of the product is one criteria on the basics of which the process is will be differentiated classified, and the type of the raw material that we are using is another criteria in the basis of in which the process is would be classified.

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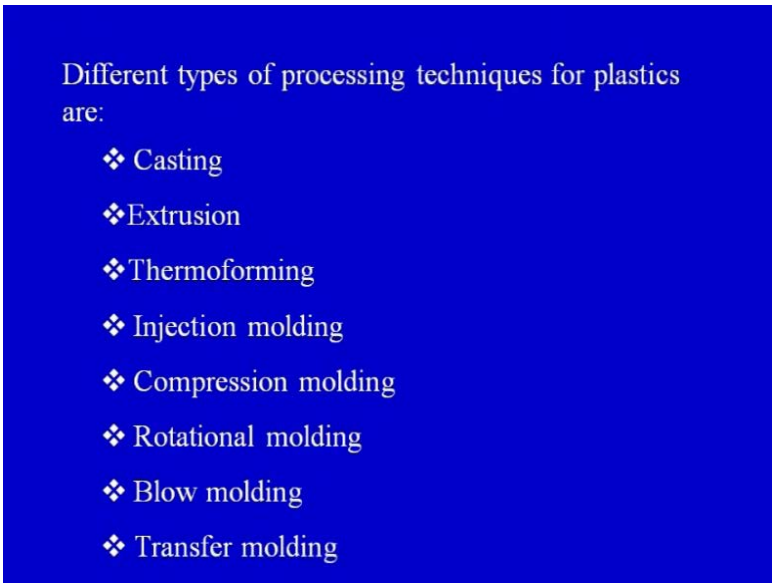

Now, without going into the details of the classification process, we have just listed down all the process is which can be used for processing of plastics. There can be other process also, so the list is not complete. There can be other process which can be used, but certainly these are some of important process is which can be used for processing of plastics on your screen, we can just read different s of process which are used. Different types of processing techniques for plastics are casting, extrusion, thermo forming, injection molding, compression molding, rotational molding, blow molding, transfer molding, and there can be other process is also used.

So, in our series of lecture that we have already told that this particular lecture is delivered under the course processing of non metals, and in processing of non metals this particular module is focusing on producing of the plastics. And in this particular module we have to engage seven different lectures, and this is the lecture number two. Now in this subsequent five lectures our focus would primarily on understanding the basic theory about these process. So, we will try to understand them with the help of the diagrams, and we will try to see the different animations that how the process actually works, and how the raw material is converted into the final product. Our focus would be on what type of materials or type of plastics or which type of plastics can be processed by these process individually. How the process actually (( )) are take place, what are the important control variables, and what are important decisions that have to be taken for a particular process, what are the important precautions, what are the advantages of particular

process, what are the disadvantages of particular process or the limitations of particular process. And finally, what are the types products that can be made by that process, and finally we will see what are the various application areas for products made by the different process. So, different types of processing techniques for plastic are shown on your screen, so we can see that their list is quite long and we have covered most of these processes is in out subsequent lectures.

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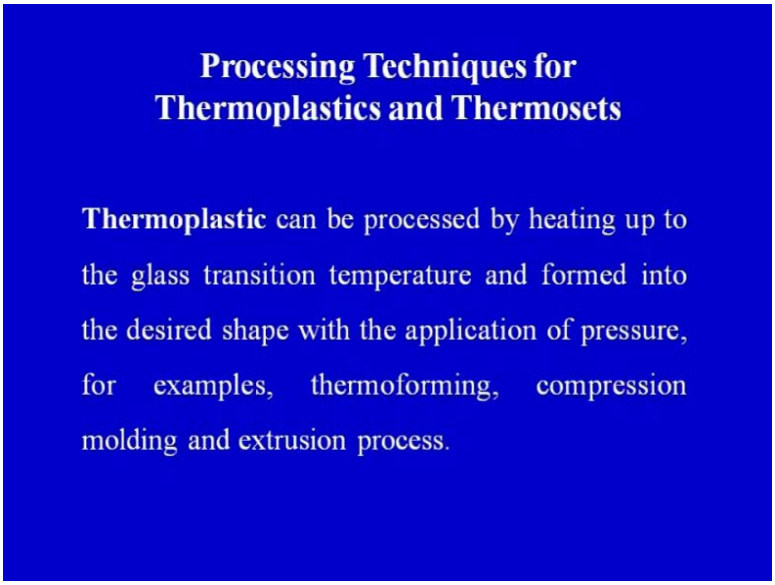

Now, processing techniques for thermoplastics and thermosets we have already seen that the two categories plastics are there and the process is or the processing requirements for the both have certain specific, we can say needs or certain specific requirements. So we have to see that which particular plastics can be use for which particular material. So, thermoplastics can be processed by heating up to the glass transition temperature and formed into the desired shape with the application of pressure. So, we can see in these three lines two important variables that are coming into picture variable number one is the heat that is heating has to be done. Variable number two is the pressure; now the raw material has to be heated to a particular temperature, and then at that particular temperature some times the pressure may be required to be applied in order to give a shape to the final product.

So, thermoplastics can be processed by heating up to a glass transition temperature and formed into the desired shape. Now h - heating that is already there; forming - f formed

into the desired shape with application of pressure, examples are thermoforming, compression molding extrusion process. So two or three examples of the process is are also given, but again from this particular slide our on going discussion is further getting substantiated that the process involved two or three common steps that are heating the raw material and deforming or forming into the desired shape under that application of pressure.

Again we will see thermosets thermosets can be processed onto two steps first is it can be melted and then poured into the mold make a desired shape for example, casting transfer molding and injection molding. So, in case of thermosets we can see we can melt them and we can bring them into the liquid state and the and this liquid can flow into the mold now depending upon the shape of molt we would be able to generate the final shape of product and final shape of product would be shape of the molt that we would be try to under stand the one of the process that we are going cover today in today's lecture that is casting that we have already seen molt and we have raw material and raw material is melted and it is poured into the molt and heat the final product is according shape of the molt or the raw material take the shape of molt.

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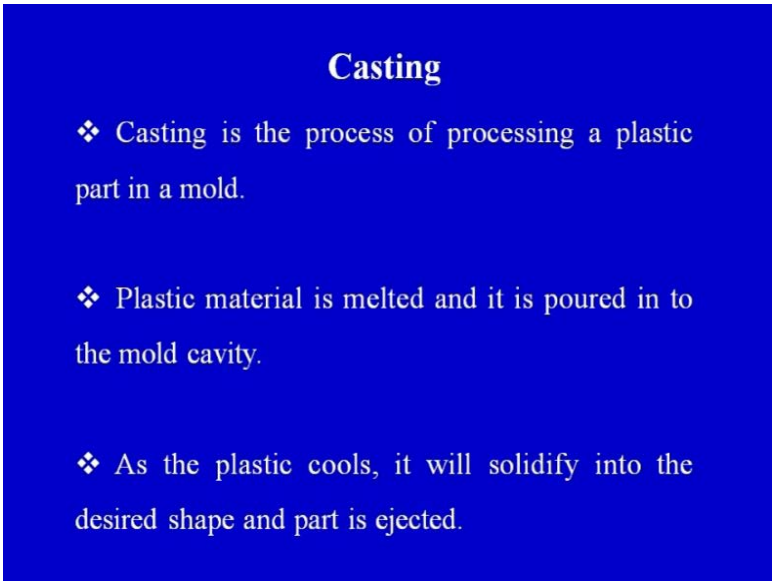

Now, this is one of the simplest process which is used for processing of plastics. Now casting is the process of processing plastic part into a in a mold. So, basically it is a process in which a plastic part is made in a mold. Now we have to first what are the

requirements, the requirements are we should have a furnace or we should have a equipment in which we can melt the plastic that is first requirements. And second requirements is that we should have a mold; the mold should be of the shape of the final products. So, we will see with the help of diagram that how a typical mold can look like, but here we have to melt the plastic and we have to poured that molten plastics into the mold. The plastic material is melted and it is poured into the mold cavity that is point number two on your screen. So point number one casting is the process of processing the plastic part in a molt, so final processing would be done in the molt that is one of the prerequisite, mold is the prerequisite for the casting process.

Second is the plastic material is melted and it is poured into the mold cavity that is second important point. Third is the as the plastic cools it will solidify into the desired shape, and the part is ejected. Again the h, f, c is coming into the picture that is the heating, plastic material is melted, it means heated and it is poured into the mold cavity and the plastic will take the shape of the molt cavity that is it is getting form the word f the alphabet f forming according into the shape of the mold. And finally, cooling into the desired shape. As plastic cools, it will solidify the desired shape. So, heating, forming that is giving a shape, and finally cooling into the desired shape. So, this is the again the basic processing steps involved in processing of plastics, in casting also the same steps are being followed.

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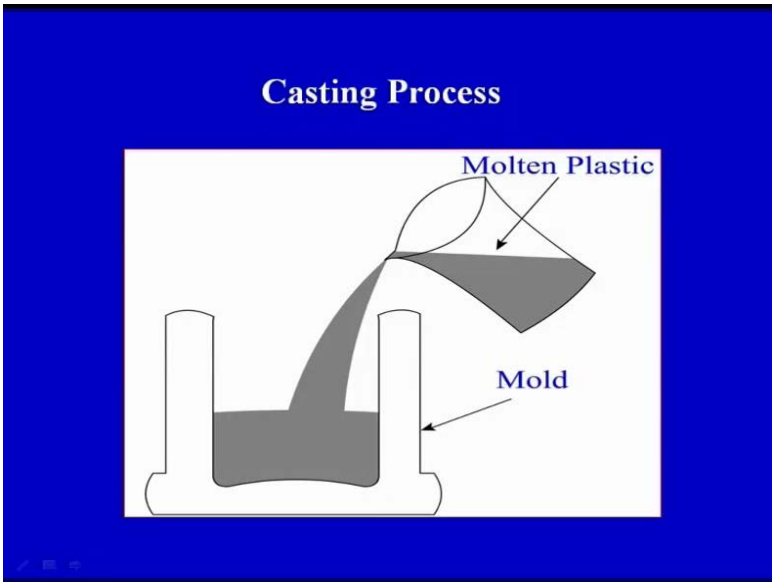

On your screen, you can see a very simple diagram. This is a molten plastic - grey color and it is poured into the mold - this is the mold. The molten plastic is been poured into the mold. The final product that will come out will be according to shape of this mold. So, most simple process, we have a plastic, we are melting it, a molten plastic is being poured into the mold, the final shape of the product would depend upon the shape of the mold.

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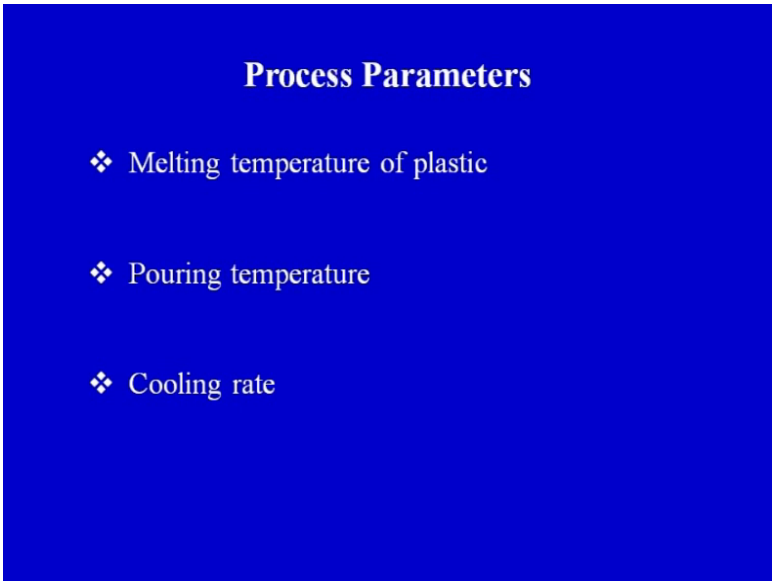

Now, what are the important process parameters that have to be taken into account that is the melting temperature of the plastic that has to be taken into account, when we are selecting a particular plastic for a particular application we should take into account that what temperature this particular plastic is going to melt that is one important point to be take care of. Second important point to be take care of is the pouring temperature that at what temperature we are going to pour the material, and finally how it will be allowed to be cooled that it would be allowed to cool at room temperature or at slightly elevated temperature or at a lower temperature. So, that is these are the three important points that have to be taken into account that is at what temperature the plastic will melt or what is the melting temperature of the plastic, the pouring temperature and the cooling rate. At the rate at which the cooling will takes place.

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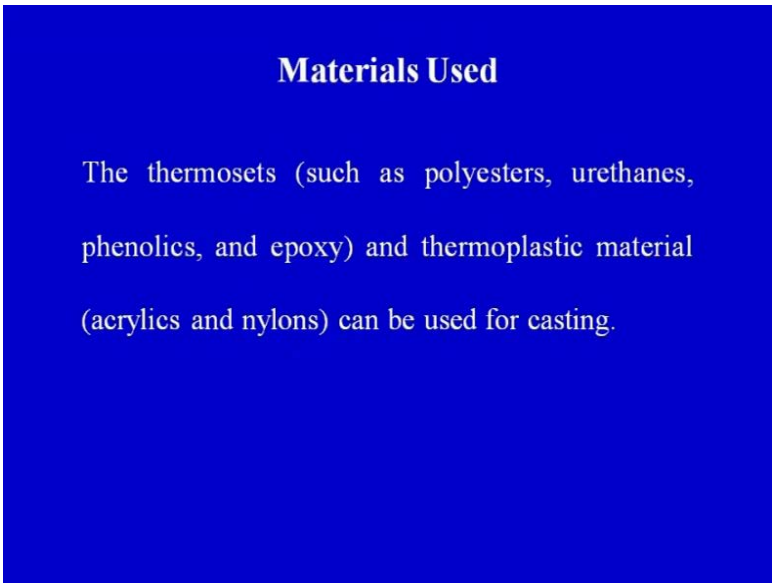

Now, what are the materials used in the casting process. The thermosets such as polyesters, urethanes, phenolics and epoxy, and certain thermoplastics materials like acrylics and nylons can be used for casting process. This particular process can be used to cast a wide variety of plastics into that desired shape. A large type of plastics can be converted into the final shape of the mold using the casting process.

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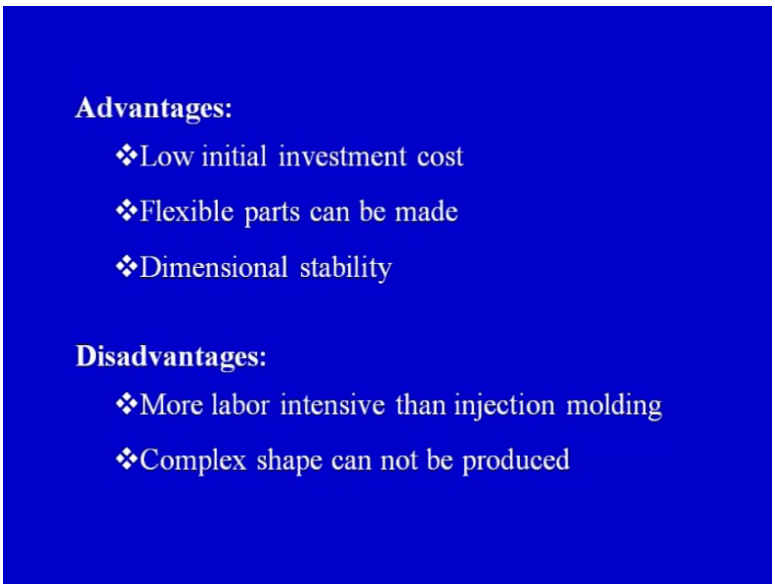

Now, what are the advantages of the casting process? We can say we the only requirement or that we should have a equipment to melt the plastic that is first

requirement. Second requirement is a mold, which will adhere to the shape of the final product. These are two important requirements. So, initially investment cost is low for the casting process. Flexible parts can be made that is another thing because mold can be flexible. Different types of parts can be made, dimensional stability is good because of the final shape would be coming according to shape of the molt.

Now what can be the disadvantages? It is labor intensive because like it has been compared with one of the process, which would be covering in our subsequent lecture that is injection molding. It is more labor intensive. What does that mean? So, labor intensive means, it is manual process; most of the time is melting and pouring can be done has to be done manually. And complex shapes cannot be produce, because the mold also has got its limitation, and if you make a very complex mold that is the molten plastic may not be able to reach each and every corner or cross section of the molt. So, the complexity of the mold is also a limitations in case of the casting process, but certainly the casting process has got its own advantages, and it is very simple process to give shape to the plastics parts.

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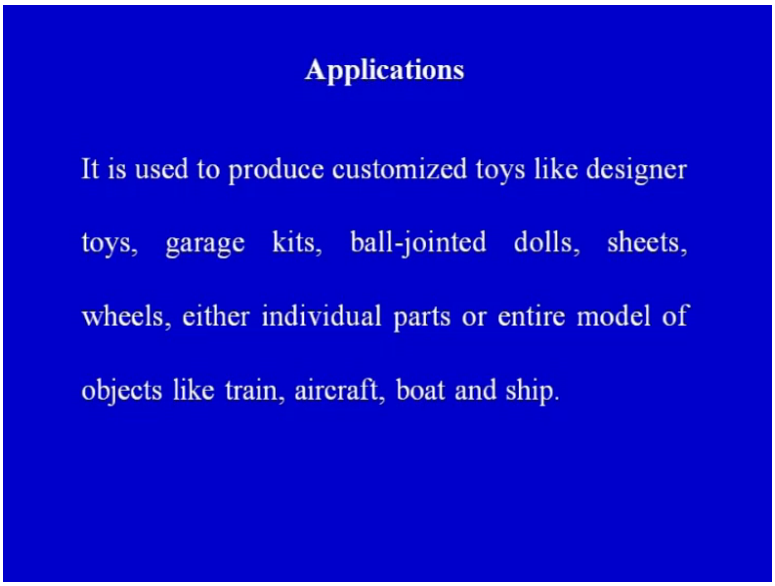

Now, what are the important applications areas of the casting process. On your screen, you can see, it is used to produce customize toys like designer toys, sometime we want to give a very specific shape to a particular toy we can mold of that toys. Melt the plastic and poured into that mold and we would able to get very customize or very good quality

toy. We can make garage kits, ball-jointed dolls can be made, sheets, wheels can be made. Either individual parts or entire model of the objects like it can be used you can see that fairly intricate products can be made that is train, aircraft, boat and ship. Certainly, toy trains or toy ship can be made. So, these individual parts or entire models of these particular important objects are mentioned on the screen can be made. So, we this is the simple process, most simple process of processing plastic parts. Subsequently, we will see what are the important processing techniques for plastics in which we would be covering other techniques such as injection molding and thermo forming.

So, with this we come to the end of today's lecture that is lecture number two in module number four. So, we would just revise what we are covered in today's lecture. If you remember, we have seen that what is the general behavior of the polymer melt and what are the important factors that dictate the behavior of the polymer melt. What are the important points we should taken into the account while we discuss the processing of plastics. We have seen very briefly the mechanical properties, we have seen the stress strain behavior of a thermoplastics, how the final failure would take place. And we have also seen that in case of a thermosets and thermoplastics, how the behavior would be different. We have just overviewed the fatigue behavior of the polymers. We have seen typical ranges of certain values of the mechanical properties related to the polymers.

And finally, we have seen one of the important technique of processing of plastics that is casting which is one of the simple techniques of processing. We have seen that what are the important steps that are there in processing of plastics which we have said it is heating, forming and cooling, and these are the important steps which would be followed in the other processing techniques for plastics also, which we would covering in the sub sequent slides or in the subsequent lecture. We are going to have five more lectures on processing of plastics in which we would be covering certain other techniques such as injection molding, thermo forming and certain important aspects related some others techniques which are used for making of plastics.

Thank you.