Processing of Polymers and Polymer Composites

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Lecture - 02
Engineering Materials and Processing Techniques

Welcome friends to the second session in week one of our course on Processing of Polymers and Polymer Based Composites. If you remember in our session 1 we have discuss the fundamental aspects of polymers and why polymer and polymer based composites are important. We have tried to understand that in UG most of the courses taught or the most of the manufacturing courses taught deal with metals only and polymers and polymer composites are not a part of the UG curriculum in most of the universities.

Therefore, we have planned this course in order to acquaint the learners with the fundamental aspects of polymers and polymer based composites. Although there are number of nonmetals available such as glasses, ceramics and there are host of other non metals for which the processing has to be understood by engineers and scientists, but plastics being one of the most commonly used commodity material. One of the most commonly used engineering material it was decided that we should offer some information some fundamental information to our undergraduate students related to the processing aspects of polymers and polymer composites. I do agree that the fundamentals of polymers are taught in many universities and colleges, in the course on material science.

But the detailed account that how this information of size can be converted into engineering and how the products can be made it is not covered in the curriculum. Therefore, we have tried to develop this course. Now we will try to understand today the two important aspects what is the title of our course the title of our course is processing of polymers and polymer composites. So, we have two materials here may be the basic material is same, the basic material is polymer when it is reinforced with some additives or with some we can say fibers or with some particles, we call it as a polymer composite.

So, we have a polymer and a polymer composite which can we can say the material first part of our title is processing. So, we have two things a material and a technique or a

process and a material. So, we have to see that what are the other type of processes that are there which are used for processing of different types of materials. Also we do need to understand that this is not the only engineering material that is used in the word there are other categories of families or other families of engineering materials that are used. Now for any particular product how to select a process; process will come later sorry I should say how to select a material.

If you have a design in mind you have to select the material for that how to select the material, what parameters come to your mind when you have to select the material. Similarly you have decided that this product will be made by suppose a plastic how to select a process that which process is suitable for converting this plastic into its desired form or into the form of whatever design the designer has meet.

So, basically there are two things are material and a process. So, we will see that; what are the various engineering materials? We will also try to understand; what are the various engineering processes and try to map these two things together. So, for any these days suppose I want to go and by this jacket what will be my target single word that will come to my mind is the quality. There the quality of the product should be good suppose I am why buying a laptop I will say the quality of laptop should be excellent.

Now how quality is related to our topic our topic is processing of polymers and polymer composites. So, quality is not only related to this topic, but quality is a general perception quality is a general thing, which is related to every material which is related to every process.

So, let us see the first slide for today.

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Customers required quality and product quality depends on. Starting from the fundamental thing that we should know that why the imp materials are important why the processes are important this triangle will give you the answer to that. The product quality is dependent upon the materials, the product quality is also dependent upon the processing technology, it is also dependent upon the design. So, right now our focus is on materials one family one class, one classification of materials and the processing technology related to those materials.

So, our focus is on these two we can say major areas that dictate the product quality. So, from the product quality point of view our focus is that we should choose the appropriate material, we should choose the appropriate process combined the two things together and then make a product which is having good quality. So, materials and processing technology is very very important to be competitive in the market. Now why there is a need for these materials or why do we need to develop new and a new materials maybe somebody may be wondering, that from the historical point of view when the metals were already known to us what was the need of developing this nonmetals because plastics polymers v c most of them are synthetically processed.

So, what was the need when we have so many materials all around us, in the universe already existing what is the need of new materials. Now let us try to understand the need

of materials or the need of material development. Now we see there are two terms product design and the requirements in use.

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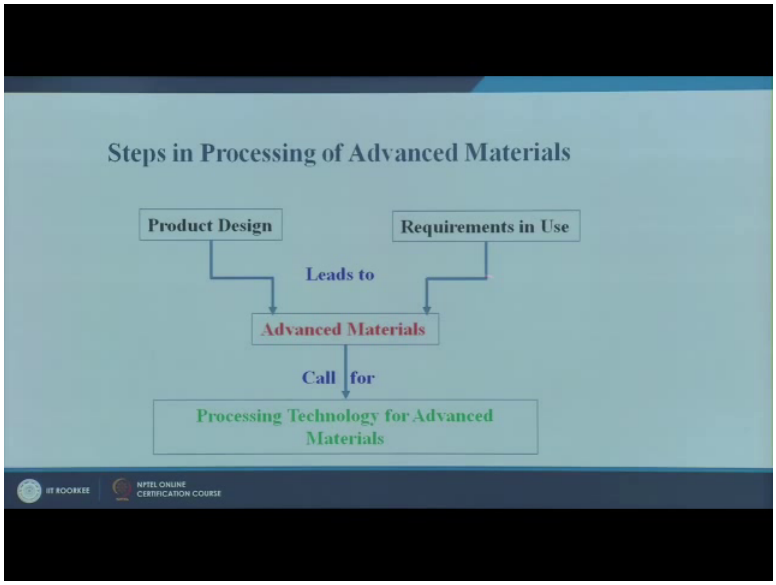

Sometimes we see the designer will design a particular product, it has to be made by a particular material. Now it is important to give that particular shape to that material and it is not possible maybe to give a particular shape to that specific material is not possible, and then what the designer we will do the designer we will have to think of a alternative material. And therefore, more the choice with the designer more will be his flexibility and more will be the more better or excellent will be the design that he will make out.

Therefore, sometimes the product design will lead to the development of new materials because the existing materials are not able to satisfy the requirements of the designer, therefore, he will have to develop invent or find out a new material for his design. Many a times the requirements in use for example, there is a material which has to be used for underwater applications it cannot be a metallic, because their chances of corrosion. Now, the designer or the maintenance professional or the engineer has to find out that what should be the material that has to be used for underwater applications. Now this is the in service requirement the product is underwater, and it has to remain their throughout its service life. So, the specific in service requirement we will force the designers or force the engineers to come up with new materials that is kind of a advanced material.

So, the product design and the in service requirements lead to the development of new materials and once you have developed these new materials for example, polymers when they may have been developed may be so many years back so many decades back, then once you have a polymer, it is now the duty of the engineers or it is the responsibility of the engineers to convert that material into a tangible product. How to convert that material into a tangible product, you can say that is a innovation or a creativity on part of an engineer. Finally, once you develop a new material, you have to find out or it will call for the processing technology for that material.

Similarly, when the polymers were invented may be the next stage was to find out or develop the techniques that can convert these polymers into the engineering products. So, that is the fundamental aspect of coming up with new and new materials, every day you will see there is a new material that is being developed for some certain or some specific application areas, and once these materials are developed next stage is the development of technology, the development of techniques, for processing that material in a cost effective and high quality manner. Because there may be 5 techniques that can be used for processing that material into a tangible product, but you will choose the technique or the technique which will be cost effective as well as will produce the high quality output.

So, there can be so many techniques, there can be so many materials. So, the life of engineer is very very challenging that which material should be chosen for which particular product, and how that material will be processed, which process has to be chosen for that material in order to converted into a product. So, we will try to understand we may not be able to address everything in detail, but we will be able to at least highlight that what are the various engineering materials; what are the various manufacturing processes, and how they club with each other which process is suitable for which particular material, that we will try to understand. Now how once you know that there is a requirement for coming up with the new material. Usually we see we make some internal changes in the material.

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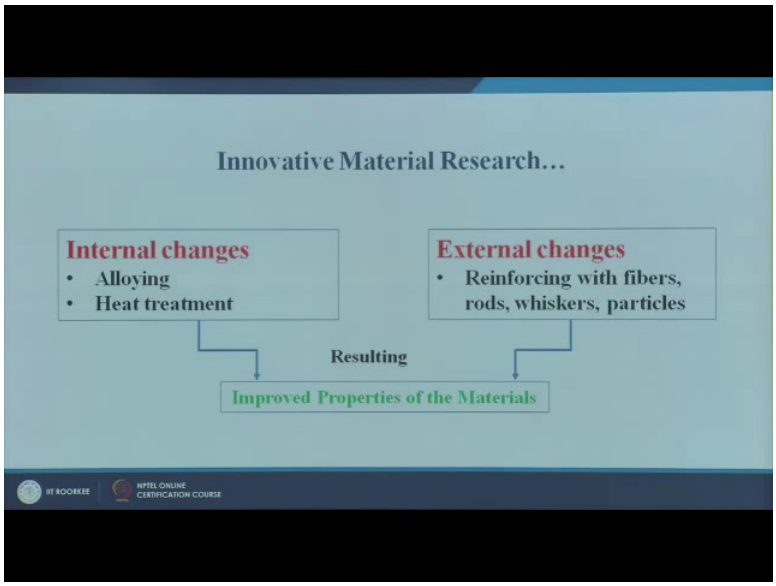

For example for metals, we may have we may develop alloys of that metal, we can do heat treatment to force some micro structural changes in the metals, in order to give them the specific properties because we have to come up with the new material, which is going to satisfy our specific requirement or we can do some external changes we can add some fibers rods whiskers or particles into matrix or into the base material and try to change the properties of that material.

So, we can do internal changes, we can do external changes and the resultant material will have the improved properties. So, this slide has specifically been included in our discussion because we are going to talk about the polymer based composites also, and the title of our course is the processing of polymers, which are we can say at base materials and polymer composites. So, polymer composites we will fall in this external changes category where the basic polymer or plastic will be reinforced with fillers or particle, in order to improve the properties of the basic polymer or the polymer matrix. So, that we will try to see there and this slide highlights the title of our course that is polymers and polymer composites, because we need to change the polymers into polymer composites in order to improve their properties.

Now, this slide very busy slide on your screen you can see this is the types of engineering materials; this slide can be contested also. Some of the students may say know there are number of materials which have not been included in this list, but as far

as I am concerned I feel that this summarizes maybe mostly materials which have we see all around us know, but there can be no list it is a very exhaustive we can see area of engineering materials where or I should not say engineering materials to so many different I was types of materials exist in this universe, which is very difficult to put them on one slide, but if we say engineering materials engineering products that we see around us, we will see that this list can suffice, this list is sufficient to may be classify the materials that we use in engineering.

So, let us see maybe if you are doing this course and you see this list in in our we this lecture 2 in week 1, but one exercise I can give you even you are sitting in your room or classroom or bedroom wherever you are undergoing this discussion or wherever you are listening to this discussion, you can just look around you and try to list take a pen and a paper and try to list at least 5 to 7 to 10 materials and then try to fix or club those materials or map those materials or put those materials in this list.

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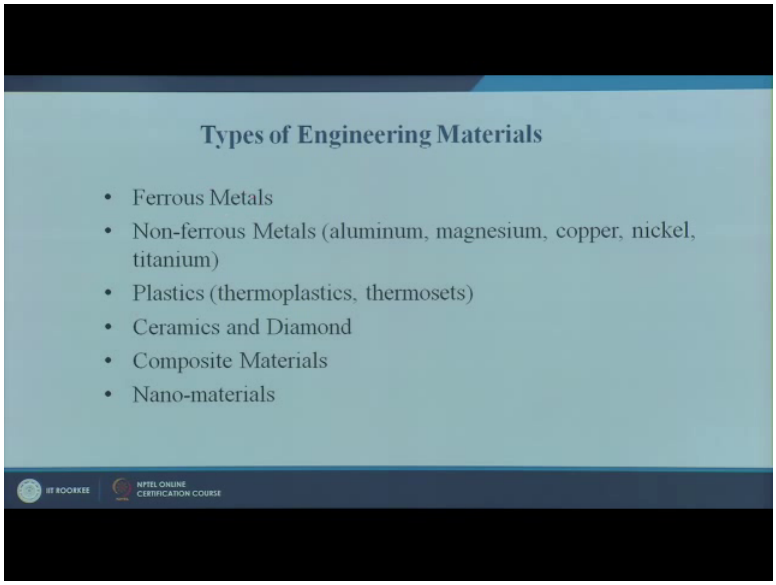

So, you will see that most of the materials you will see maybe they may be ferrous metals, they may be non ferrous metals like aluminum magnesium, they can be plastics that is our course polymers and polymer composites, they can be ceramics or diamond composite materials, they can be nanomaterials nano of course, maybe we may not be able to see with naked eye but some applications of nanomaterials can be there.

So, if we do this exercise you take a pen and a paper, and you write down maybe around ten materials that you see around you, all engineering materials must fall in any of these categories. Now coming on to our specific or special focus our special focus here is this number 3 that is plastics and the composite materials. So, our focus is bullet number 3 and bullet number 5 that is plastics and composite materials. As I have already highlighted lot of discussions lot of books are available on ferrous metals, nonferrous metals the processing or the processing techniques or manufacturing techniques or fabricating techniques for these materials, ferrous metals and non ferrous metals.

But for nonmetal such as plastics and ceramics not much discussion is there are available for the undergraduate student. Therefore, this course has been designed. So, our focus would be on bullet number 3 and bullet number 5, now these are the this is the list or these are the materials which are used for making engineering products. Now what can be the processes that are used for converting these raw materials or these materials into engineering products, let us see we will go to the discussion first let us see that when you have a wide variety of engineering materials you can see.

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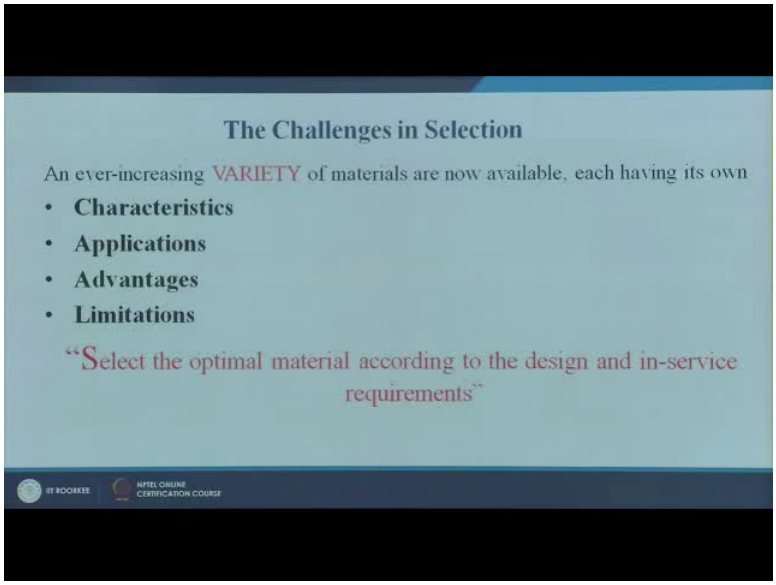

We a ferrous nonferrous plastics ceramics composites and nanomaterials when we have plenty of options available with us how to select a particular material for a particular application. It is a challenging thing same product can be made by a metal same product

can be made by a plastic if I ask you give me an example product that is made both it can be made by a plastic also it can be made by a metal also.

Just think over it I think some of you may have got the answer to that question if you see the chairs you can have the plastic chairs also you can have the metallic chairs also and on top of that you can have a wooden chair also. So, you see that there is a list of engineering materials, there is a there is a single product and 3 types of these materials can be used for satisfying the same need that is making a chair. So, there is always a challenge of selection, that how to select a appropriate material for a appropriate application. So, you have a list of materials. So, what will help you with the following things we will help you and ever increasing variety of materials are now available, the variety I have already listed in the previous slide metals, nonmetals, polymer ceramics diamond, nanomaterials, composite materials, that is the variety.

But each material will have its characteristics, it will have its application areas it will have its own advantages, limitations now we have to see that for our specific requirement need which material can satisfy that so that we will select. So, we will select the optimal material according to the design and in service requirements. Now as per the design of the product we will choose that which material we will satisfy our requirement and second thing also the in service used means that when the product will be used, what type of conditions it will have to sustain or what type of environment it has to sustain or what type of loads that are going to act on that particular product. So, the in service requirement and the design both will dictate the selection of the material for that particular product.

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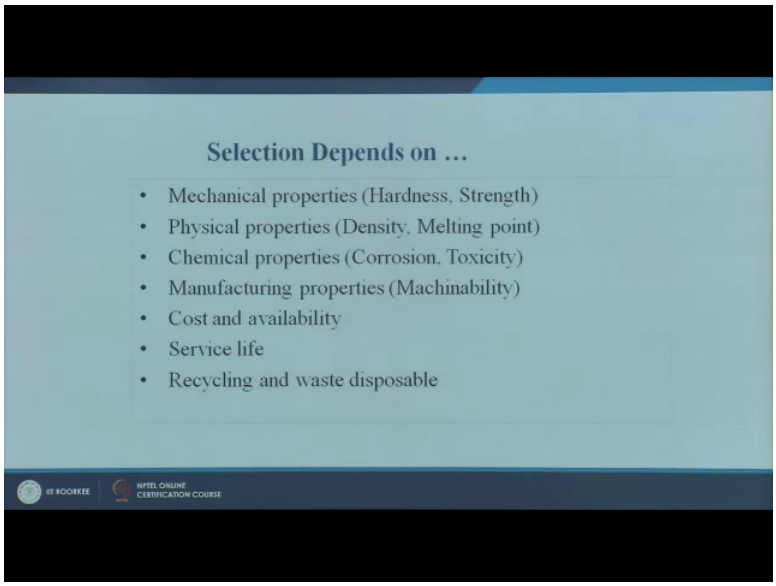

Now, this selection we will depend upon, it was very easy to say in the previous slide select the optimal material, but how to select we will select that based on the mechanical properties we will see that what are the mechanical properties, that the product their sorry not the product that the material possesses for example, metal we will see what is the hardness, what is the strength. For plastic also we will see what is the hardness what is the strength then the physical properties such as density melting point suppose we have application where the light weight is the prime design criteria, the product has to be light in weight whatsoever may come and go.

Now, for lightweight product what is the physical we can say property that we would like to and sure we would like to see the density of the material that we are choosing for that particular product. So, your physical properties are equally important. So, we will see the mechanical properties physical properties, similarly the chemical properties such as corrosion and toxicity. Now for example, we want to select a material for food packaging requirement. So, if the food has to be packaged in that particular material, it has to be non toxic. So, that is a specific requirement for this application. So, our selection of material for a particular product we will depend upon the mechanical properties, physical properties, chemical properties, manufacturing properties, cost of the material, availability of the material, service life of the material, recycling and waste disposal characteristics of the material.

Now, each one of these points can be explained in a very very exhaustive manner for example, the last point recycling and waste disposal there is lot of focus these days on selection of materials, which are non-biodegradable which are biodegradable sorry which are recyclable. So, most of the products that are made by non biodegradable materials usually have very poor and of life characteristics. To these days the trend is to word selection of biodegradable materials. Now selection of material is equally important now what I expect from all of you is that we you can try to understand that where the plastics fit in in all these requirements because once use make a product using a polymer you have to justify the cost, you have to justify the manufacturing properties, you have to justify the mechanical and the physical properties.

Now, our target is to study about the polymers and the polymer based composites. So, once you propose you postulate you say that for this particular application a polymer based product should be used or to simplify that a plastic products should be used. Now once you say that you have to justify the use of plastic based on all these characteristics and you have to compare based on all these characteristics comparison with the other materials, which can be used for making that particular product. So, once you think of polymer you have to think of polymer in all these context. So, that you are able to develop a product with that polymer because whatever we study, we study it for business we study it for maybe application and application will only come once you are able to displace some application with a new material.

For example a product is being made from a metal, now you say that the same characteristics same things same in service requirements can be met if you replace this metallic product by this plastic product or a polymer product what is the advantage maybe density is less so the weight will reduce. So, that justification comparison is only possible if you have this list in your mind that where which material can be applicable. So, your selection of polymer as a engineering material, we will depend upon these characteristics or this justification that you need to develop for proposing the use of polymers. Now ones that is done we need to understand the types of manufacturing processes. Now once we have decided that as particular product is going to be changed it is currently being made by wood. So, wood is an important material it requires cutting of trees.

So, we are going to replace that by a plastic material. So, we make a justification based on the points which were highlighted in the previous slide, now we have to understand that what are the various type of manufacturing processes that are used for processing the engineering materials.

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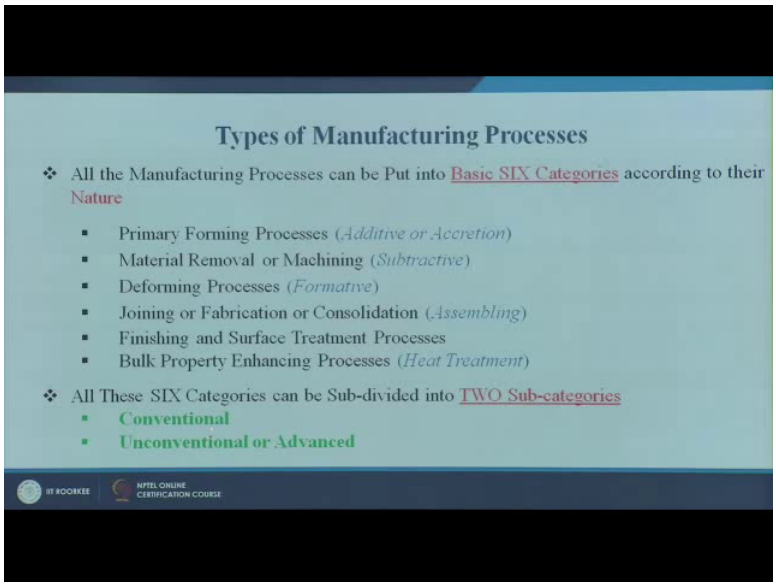

There are broadly six categories, there can be primary forming processes material removal processes, tree forming processes joining or fabrication processes, finishing and surface treatment processes and bulk property and enhancing processes. Now for specifically polymers I must highlight primary forming processes are very very important now primary forming processes are where we give a shape to the product, your compression molding, injection molding, extrusion thermoforming all these processes rotational molding all these processes we will fall under the primary forming processes.

So, next is the material removal or machining processes, sometimes you need to make a hole in a polymer plate or in a plastic plate. Sometime you may be required to cut a screws inside the polymer or maybe threads inside the polymer plate. So, that we will fall under the material removal or machining processes, sometime you may need to be the edge trimming in order to fix the two parts together. So, all that we will fall under the material removal or machining processes first are the primary forming that I have examples I have already given deforming processes not very common in case of plastics,

because you mould the things in the primary forming stage only, you mould you melt the plastic and give it a desired shape that we consider in the primary forming processes.

But yes sometimes we will make long tubes of polymers or plastics that we can say may fall under the deforming. When joining or fabrication it is very difficult to join the polymer parts together, difficult I am saying because if you permanently you have to join you need to do that has you joining which is also a challenging task. So, we will see the joining behavior of the polymers and polymer composites, but the joining can be a adhesive joining, it can be mechanical fastening.

So, those are the processes specifically for polymers and then finishing and surface treatment processing may be finishing and surface treatment in terms of plastics can be some specific coating on the surface that can fall under the surface treatment process. And finally, the bulk property enhancing processes such as heat treatment which is very very uncommon in case of polymers and polymer composites.

So, broadly these 5 processes primary forming, material removal deforming, joining finishing these are the processes which can be done on polymers and polymer composites and if you see all these processes can also be done not only can also be done, but they are usually done for metals also. If you see metals you can see the processes in primary forming example can be casting material removal turning drilling milling all processes we will fall under the material removal deforming it can be a tube drawing it can be wire drawing, it can be extrusion, it can be forging you have processes like deforming. Joining maybe most common welding is one of the most important process for joining.

Finishing grinding is one process which is used for finishing, and bulk property enhancing such as heat treatment there are number of annealing and then there can be hardening or sometime it can be austempering, martempering number of processes which are falling under heat treatment category. So, if you see for metals all these processes are well developed and this classification holds good for metals, but as soon as you go to plastics, you have to think that which process will fall under the primary forming which process will fall under the joining. So, most of the processes are not very well developed for polymers, but are very well developed for metals that we will try to understand with the help of a slide. So, further these processes can be further categorized into two parts

they can be either conventional processes or they can be unconventional or advanced processes.

So, we will see mostly the conventional processes, but towards the end when we go to the material removal of polymers and polymer composites, we will see some advanced and unconventional processes also that are specifically dedicated towards the polymers and the polymer based composites. So, this is a classification of manufacturing processes, I have tried to bring two things into picture one is classification specifically for polymers and the second is classification specifically for metal. So, the similar classification holds good for polymers also and for metals also. Now this is important slide taken from a particular source available in the book also. So, here you can see A means widely used.

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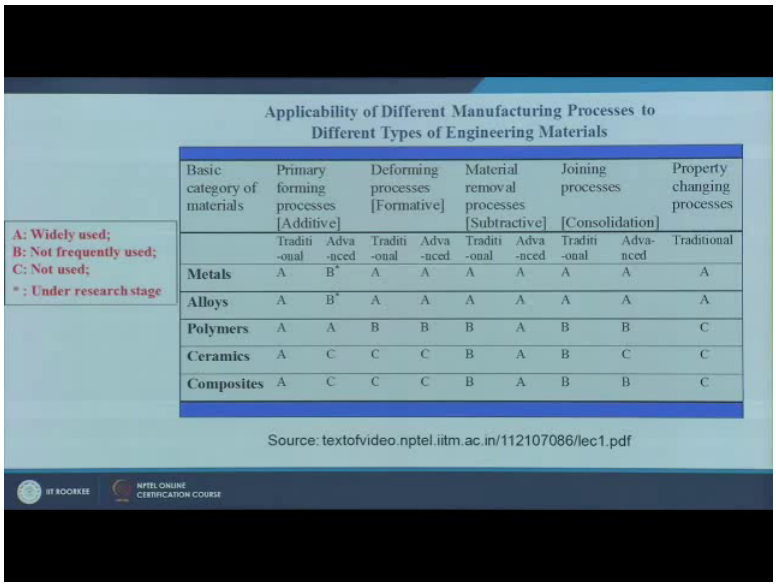

Basic category of materials	Primary forming processes [Additive]		Deforming processes [Formative]		Material removal processes [Subtractive]		Joining processes [Consolidation]		Property changing processes
	Traditional	Advanced	Traditional	Advanced	Traditional	Advanced	Traditional	Advanced	Traditional
Metals	A	B*	A	A	A	A	A	A	A
Alloys	A	B*	A	A	A	A	A	A	A
Polymers	A	A	B	B	B	A	B	B	C
Ceramics	A	C	C	C	B	A	B	C	C
Composites	A	C	C	C	B	A	B	B	C

B means not frequently used and C means not used, I will just ask you regarding polymers you can see A A B B B A B.

So, only property changing processes which I have already told the heat treatment process is not very common for the polymers. See rest all A and B which means widely used processes and not frequently used processes. So, if you see polymers primary forming widely used both in the traditional and the advanced method deformity processes maybe not widely used as I have also given example a deformity processes is not very common material removal processes for polymers here advanced processors are

there which I have also told that for this we will go to the advanced processing of polymers. And then joining processes B and B not widely used, because I have already told there this challenge when you even use the odyssey for joining the two polymer parts together or two plastic parts together.

So, this slide gives you an overview of the processes that are dedicated for processing of polymers. Now one more thing I want all of you to see is the composites because our title is polymer composites also processing of polymer composites. So, you see for composites C C C that is not used c number of Cs are there number of Bs are there. So, A is only 1 and 2. So, only two processes we can say are widely used for processing of polymer composites, rest all processes are either not used or are under the research stage. Therefore, the topic becomes even more important as engineers that we should know that; what are the processes which are widely used for polymers and what are the processes that are being used for polymer based composites?

Now, this is another taken from this source in 1991 this diagram was maybe published.

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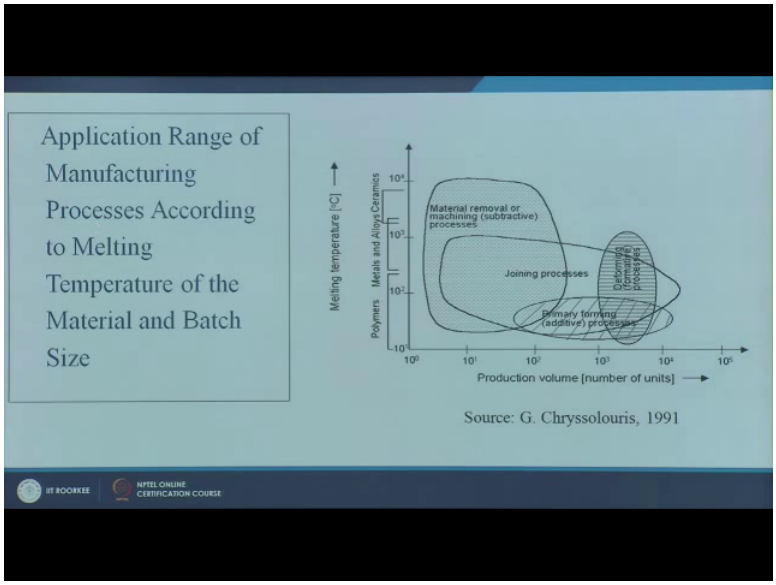

Application range of manufacturing processes according to melting temperature of the material and the batch size. So, when we have to select the material we have to see that how it will be processed and for processing point of view, we have to see that which process would be suitable for making that product. Now when we have to select the manufacturing process we will see such type of information is available. If you see the

production volume is less material removal processes are most commonly used and when the production volume is very large the deformative type of processes are majorly used. So, from production volume point of view, if we have to which means if we have to make smaller number of products go for the machining route.

If you have to make a larger number of products go for the deformation route and from the melting temperature point of view, which is very very very very common in case of polymers and polymer based composites. The volume maybe from industrial engineering point of view important, but from technical engineering point of view, the melting point is very very important. So, you see that when the melting point is less the polymers are falling under this category. Again I would like to highlight because this is an important slide you can see the polymers you can see are falling here. So, the temperature or the melting temperature for polymers is less.

So, you see the primary forming processes are most common for the processing of polymers. So, we can conclude from this particular slide, that the melting temperature for polymers is less and therefore, the primary forming processes are most common for processing of polymers and we will see the different primary forming processes that can be used for processing of polymers. Now the selection of the manufacturing process we will depend upon, as we have seen the selection of engineering material we will depend upon so many parameters like a mechanical properties, physical properties, chemical properties manufacturing properties cost and availability.

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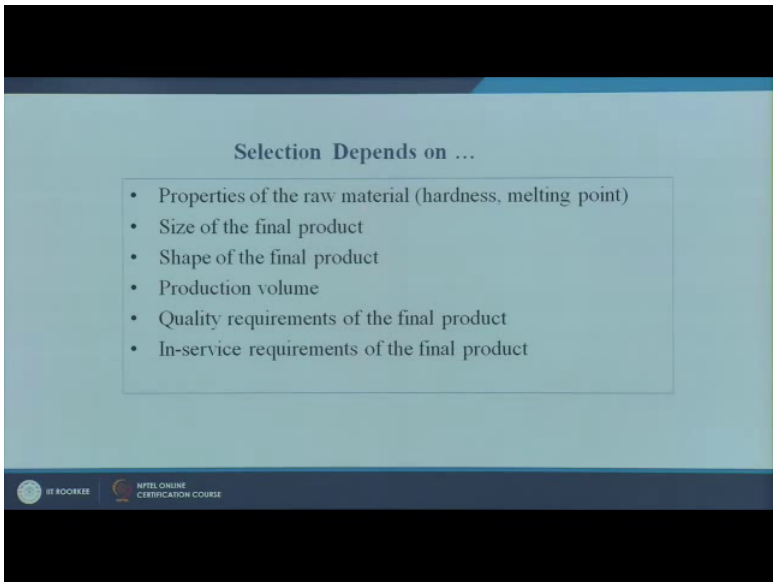

Here we will see that the properties or the selection of a particular we can say process we will depend upon the properties of the raw material, the size of the final product because this is a smaller product, if I have to make a very big product the process has to be different. It will depend upon the shape of the final product is the shape is simple you will select one process is the shape is complicated, you will go for a different process.

So, for a small size different process large size different process, simple shape different process complex shape different process. Then the production volume how many products you want to make you want to make hundred products or you want to make one million products. So, you will select the process accordingly then the quality requirements of the final product what type of surface finish you require, what type of surface characteristics you require that will dictate the selection of the manufacturing process also the in service requirements of the final product, because the processing technique we will also affect the properties of the material. And the properties we will further affect its behavior once the product is put into service.

So, we will try to understand each one of these things that which process is suitable for which particular application and when we will try to understand the various processing techniques for plastics and plastic composites or polymers and polymer composites, we will see that how these parameters or how these characteristics or how these factors. We

will influence our choice of a particular manufacturing process or a for a particular processing route for the processing of polymers or polymer based composites.

So, with this we come to the end of discussion number 2 in week 1 on our course on processing of polymers and polymer composites.

Thank you.