**Processing of Polymers and Polymer Composites**

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**Lecture – 01**
**Introduction to Course**

I welcome all of you to this course on processing of polymers and polymer composites. Let us first try to understand the need of this course; that is polymers and polymer composites. Usually in most of the undergraduate courses, we study the metals, mostly the process is that are taught to the students, or the under graduate students, deal with metals. So, if you remember you may have studied casting.

So, casting is a process which is used for molding of a metal. You may have studied machining; the machining is used for removing the material from a metal. So, whenever even you see a numerical problem, always you will see the mild steel work piece was machined using a single point cutting tool with this angles. So, the discussion is mostly limited to the metals.

But there exist 20 of non metals in this universe, and we have to see that how these non metals can be converted into engineering products and one good example are the plastics. So, plastics is the general name. We can, scientific name can be a polymer in which there is a long chain of monomers, which polymerized to make a polymer, and is the polymer in engineering terms, we call it as a plastic, and we have seen, we can see different types of plastics all around us.

For example this pointer that I am going to use in this presentation or during this lecture, you will see, is a made up of plastic. It is not a metallic product, it is a plastic product. The camera, that is recording me or the recording this discussion is also, the cabinet is made up of a plastic material. The glass that is used to capture, is also a non metallic material, which is not a metal

So, we see around us. So, many non metals, and we are as engineers, sometime are unaware of the processing techniques that are used for processing of non metals. So, our course has been designed in such a way that we are able to fully understand at least one class of non metals, those are the polymers. And finally, these polymers are not only used

in a polymer form, only, they are sometimes reinforced with the fibers in order to improve their properties.

So, we are not only going to study polymers, we are also going to study polymer composites. So, in nutshell, to summarize I can share this with you, that in most of the under graduate courses. We do not have polymers and polymer composites or plastics as a course or as a subject matter. So, it is always advantageous to have additional information in the form of this course, which can be helpful to you in your job profile or the company that you join.

So, this is going to be a top up course, which is away from your normal curriculum, and will be helpful to you, for understanding the basic nuances or the basic we can say fundamentals of polymers, as well as the polymer composites. Now let me just introduce the title of the course to you, because the title of the course as you can see, is processing of polymers and polymer composites.

Now, the first word is, processing polymers also have got different dimensions. Now a chemist can see a polymer with a different perceptive or from a different point of view. For example, a person who is studying chemistry, and he is studying a polymer, he would be more interested in trying to understand what is a monomer, how it will polymerized, what are the conditions which will favor its polymerization.

What can be the catalyst that can be added to this polymer in order to improve the specific properties of the resultant polymer, or the developing polymer. How the chains will entangled with each other, whether they will form a 3 dimensional network of chains, or it will be a linear chain, or there will be a brass chain structure for a polymer. So, a chemist or we can say a chemical engineer, or a chemistry professional will look at polymers from one particular dimension

As an engineer, I know that this is a polymer, I have to convert this polymer into a particular product. For example, this pointer or slide changer, this is a product. As an engineer, I may not be too much interested into going into the chains, and the molecular level of the polymer, but I may be interested to see that if our raw material is available to me, which is a non metal, and specifically a polymer, how I can convert it into this particular product.

So, there I have different varied dimensions or different dimensions to the polymers. So, as an chemist or a chemical engineer or a chemistry professional, a different dimension as an engineer, as a mechanical engineer a completely different perceptive. So, our target would be, to understand very basics of both these dimensions. So, we will try to understand the basics of the polymer, may be 2 or 3 sessions on that, and finally, we will see that once we understand the basic chemistry of a polymer, how that chemistry is relevant to the processing of the polymer into its desired form, but major focus would be on the engineering dimension of the polymers; that is how to convert a raw material in to a tangible product, which is the polymer product, or we can say which is the plastic product. We will see number of processes which are used for processing of plastics.

So, first thing would be processing. So, our target will be, to understand the various processes that are used for processing of polymers, but I may share with you that we will not directly jump to the processing of polymers. We will first try to understand what is a polymer, what are the different types of monomers, and how this monomers polymerized in to a polymer, what are the different classifications of the polymer, what are the different types of chain structures found in the polymer.

Maybe 1 or 2 sessions we will have on polymers, and then we will focus our attention towards the various engineering processes, that are used for processing of polymers. So, first part; processing of polymers. I think I have tried to make it very clear. Now the next part is the polymer composites, which are the latest engineering materials, which are being used for developing different types of products all around the world.

We are seen the applications of polymer composites, starting from the aerospace industry to the automotive industry, to the sports industry, to the bio medical industry, to the house hold industry. So, the polymer composites are finding the wide dimension of applications. We will see in the course of our discussion that what are the specific products, that are made using polymer composites. So, that would also be our topic of discussion.

Now, if they are finding. So, much of applications all around us, it is our duty to understand that how these polymer composites are processed, or how these polymer composites are fabricated. So, our title would be processing of polymers first; that is our plastics, and then composites, based on these polymer polymers that we have already

studied. So, we will see the processes that are used for polymers, and then we will see the processes that are used for polymer based composite materials

So, the course will give you overall, you can say understanding about the plastics, plastic based composites, as well as the techniques that are used for processing of these types of composite materials. And at the end of the day, once you have done this course or you have understood the basic fundamentals of this course, it is expected that you can see a product, and you should be able to tell that this product must be made of this product or this process.

For example, if I give you a water bottle or a mineral water bottle you must be able to tell that, this mineral water might have been made by this process, which is used for processing of plastics. If I show you another plastic product, may be a mouse or a computer mouse, you must be able to tell that, this product may have been made by this particular process. If I give you a tooth brush handle, which is a plastic material or made out of a plastic material, you should be able to tell that this handle of the tooth brush must have been made by this particular material

So, the target not the material only, must be able to tell the process that has been used to make that handle. So, the target of the course is to acquaint you with the basic fundamentals of the polymers, and majorly to understand what are the various types of processes that are used for processing of polymers as well as processing of polymer matrix composites. So, the course has been divided into 20 hours. This 20 hours has been divided further into different weeks. So, we will see that the course will be completed in 8 weeks of two and half hour duration each.

So, every week there will be 5 sessions of half an hour each. So, that is the overall, we can say division of these 20 hours, in which this course will be delivered. So, today our focus would be, to just have a outline understanding of the various topics that we are going to cover in this course, because once you know that what are the various topics that are going to be discussed. Under this course, you will be able to orient your thinking in that direction.

Get yourself prepared for a next lecture, and you can even think of correlating the various topics among themselves, when you go through the various sessions which will be, we can say available to you once the course is completed. Now let us see the course

details, I think the summary is very clear. I will again like to come back to the summary once again towards the end of the chapter.

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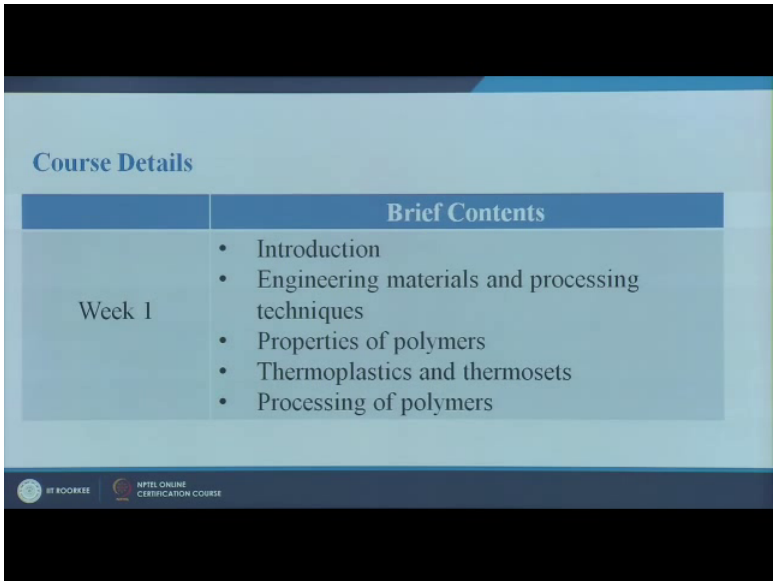


Now, let us quickly go through the contents that we are going to cover in this course. Now course details in week 1, you can see for every week, there will be 5 bullet is here . 5 bullets means 5 sessions half an hour each. So, first is introduction. So, we will have again an introduction about the polymers, and then what are the different types of polymers we will see. We will try to understand the application areas of the polymers. We will try to see that how these materials compare to the other conventional metallic materials or other conventional engineering materials.

Then we will see the engineering materials and the processing techniques. So, we will try to see that, what are the various types of engineering materials that are used, what are the various types of processing techniques that are used and what are the techniques that have already been developed for processing of plastics. So, this is our lecture 2. This is the introduction section that we are having today. I have already tried to introduce you the topic the concept, and I have tried to emphasize the importance of non metals in our life. So, that is basically the introductory part of the course

Then properties of polymers, we will try to understand the. Next we will try to differentiate between thermoplastics and thermo sets. Most of the time when you ask a simple question from a student, how do you classify plastic, how do you classify a

polymer. Few students are never able to answer, or very rarely they will be able to answer this question. So, we will try to highlight that the polymers can be classified into thermo plastics and thermo sets, and what are the specific characteristics of each one of these we will try to understand that.

Then we will see a introductory course or introductory session on processing of polymers that vis a vis metals, whether the processing of polymers is easy, or processing of polymer is difficult. If the processing of polymers is difficult what are the chances that we will succeed, or what are the things that we should keep in mind, while going for processing of polymers.

If it is easy, then how it is easy as compared to metals. So, all that we will try to understand the basic concepts of the processing of polymers. So, week 1 will be basically a fundamental about the polymers, and the classification of the polymers. Next session, would next week, would be dedicated toward the processing of the polymers. So, I have as I have already introduced, that we are coming down from a broader range to a narrower range.

The broader range are vary 5 to 6 families of engineering materials. From there we are coming down to 1; that is the polymers, and from polymers then we are trying to understand that what are polymers, what are the various types of polymers, what are the properties of polymers, and then we are going to see that how the polymers are processed into engineering products. So, week 1 will be focusing on, this coming from a broader range to a specific range, and within that specific range trying to develop a fundamental information.

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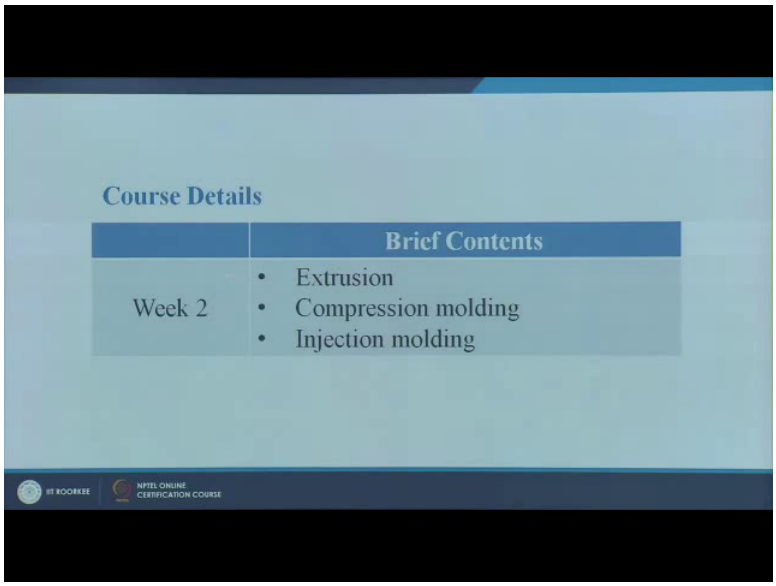


Then week 2 our focus will be, you see 3 bullet us here, but there will be five sessions of half an hour each. So, here we will have discussion on extrusion, compression molding, and injection molding. So, here we will see that in these processes we may have to go for 2 sessions on a single process. For example, compression molding, we may have to go for a half an hour discussion, regarding to the basic concepts of the compression molding, the details of the process, the details of the machine, the various operating parameters.

And then we may have to further go for the application areas of compression molding, that where compression molding can be used. What are the limitations of compression molding, what are the advantages of compression molding. So, compression molding may involve may be 2 half an hour sessions, then injection molding may also involve 2 sessions of half an hour each. So, we will see that these 3 processes are covered in week 2, in which we will have 5 sessions of half an hour each.

All these processes we will discuss initially in context of polymers. All these processes can also be used for polymer composites. So, we will again come back to these processes when we will start our discussion on polymer composites, but there we will see that how the processes changes, when you try to incorporate the reinforcement in the polymer, or when you try to reinforce the polymer or a plastic with reinforce the metrics with the

reinforcement; that is reinforcement will mostly be in terms of fibers. So, week 2, all these processes again I am emphasizing, dedicated to plastics or polymers.

Then week 3 again, we will discuss some other processes; like resin transfer molding, rotational molding, blow molding. So, we will see 6 different processes for processing of polymers into engineering or tangible products.

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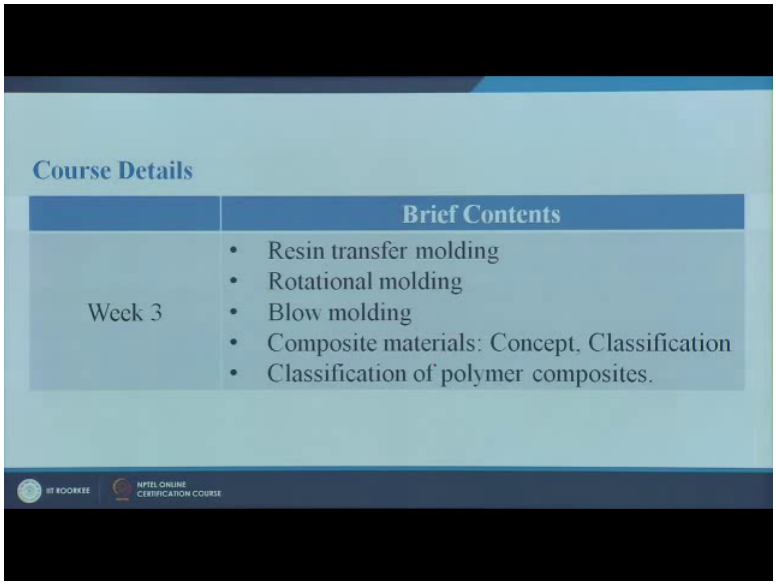


So, these six processes are. Let me once again go through the processes, we will see extrusion, we will see compression molding, we will see injection molding, we will see resin transfer molding, we will see rotational molding, we will see blow molding.

Now, whenever we will go through these processes for polymers, our focus would be to see that what can be the input materials that can be used by these processes, what are the process details, how our rotational molding machine will look like. What are the operating parameters that we have to control, whether it is temperature, or it is pressure, or it is combination of both, or it is the holding time. So, we will see what are the parameters that have to be controlled. Finally, we will see what type of specific products can be made using these processes.

So, our focus would for each process, we will try to understand the raw material, the final product, the process itself, the mechanism, the operating parameters, the advantages, the limitations. So, each process would be an individual process that we will

discuss, and then we will try to compare the different processes that which process can be used for which particular type of application. So, that would also be a comparable analysis or a comparative analysis, among the various processes.

So, once our discussion related to the processing of polymers or plastics is over, then we will shift our attention to the composite materials. And in composite materials also there are 3 broad classifications of the composite materials. It can be a metal matrix composite, it can be a ceramic matrix composite, it can be a polymer matrix composite. So, our focus area would be the polymer matrix composite. We will not discuss anything about metal matrix composite, as well as about ceramic matrix composite. So, our focus is on polymers and polymer based composites.

So, in composite materials we will see, that how we can classify them, what is the concept of a composite material, and finally, we will focus our attention on the polymer based composites, that how the polymers can be reinforced with the fibers to make a composite material. Then we will see the classification of polymer composites, that once from the metal ceramic and polymer, we are come to polymer based composites, within polymer based composites how the further classification can be done, based upon the type of reinforcement, the shape of reinforcement, the type of matrix, all that we will see and then try to understand that .

So, once we venture into the broad area or into the ocean of composites, we will further take our discussion towards the issues and challenges and primary processing of polymer composites. now there is a new terms which has been introduced here; that is primary processing. So, in primary processing our focus would be, to give the shape to the polymer composite; that is for example, this particular product, it has been given as specific shape. If you can see it has got a specific shape. Now primary processing means how to give the shape to the product.

So, we will see different processes that are used for giving these shapes. So, we will see hand layup technique, spray layup technique. Again you can see the name compression molding, which we have seen in processing of polymers also. So, again we will see how compression molding process changes, when you are going to process the polymer composites. And we will see another process which is specific to polymer composites; that is pultrusion.

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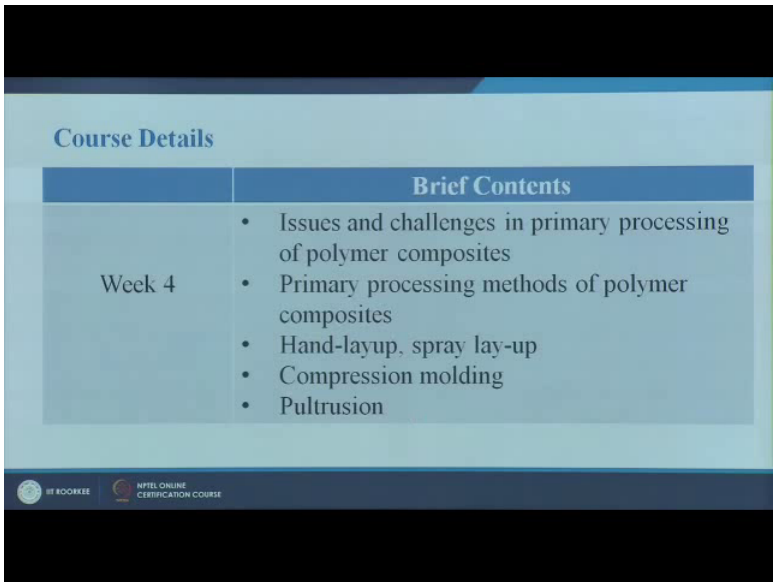


Again we will see injection molding, autoclaving technique, pre pegging, sheet molding.

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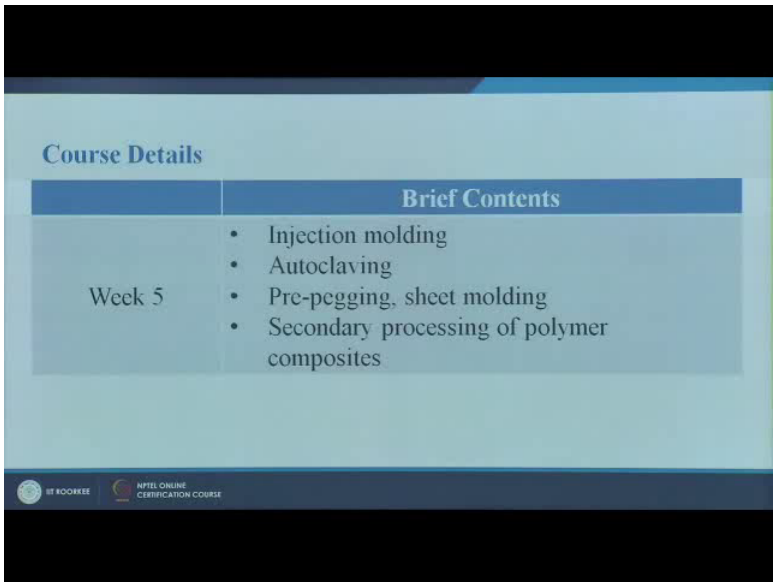


So, we will see at least there can be a addition if the time permits, we may also go for a different process that is resin transfer molding, specifically in context of the polymer composites. We may even go for filament winding, which I think is not mentioned in this list. So, we will try to, may be incorporate whatever information possible in the course.

Then once our primary manufacturing processes are well known, then we will go to the secondary manufacturing. Now primary manufacturing as I have already told, is this

particular giving shape. Now suppose I have to cut a slot inside this, I have to create a slot. So, once I have this shape, for cutting this slot I will have to go for the secondary processing of polymer composites. Also if I want to join the two independently made pieces, assemble these pieces together, I will have to go for the secondary processing of polymer composites.

Now, you have a product, now it has to be assembled to another product, then you will need to go for secondary processing. So, in secondary processing our target would be to understand the machining behavior of the polymer composites, to understand about the joining behavior of the polymer composites. So, our next 3 weeks will focus about the secondary manufacturing techniques.

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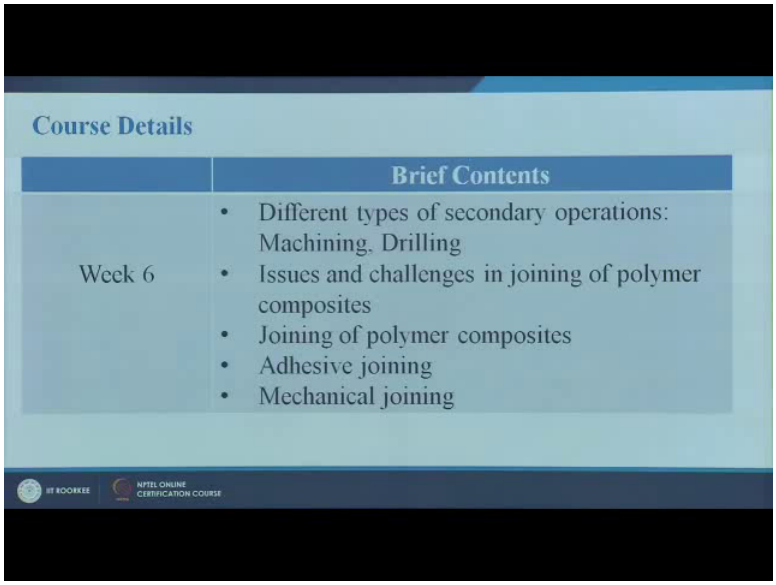


So, we will see the different types of secondary operations; like machining, drilling. Then we will see the issues and challenges in joining of polymer composites. We will discuss the various techniques of joining of polymer composites. We will focus on adhesive joining. We will focus on mechanical fastening or mechanical joining.

In week 7, we will try to understand a very novel method of joining the polymer composites; that is the microwave based joining of polymer composites.

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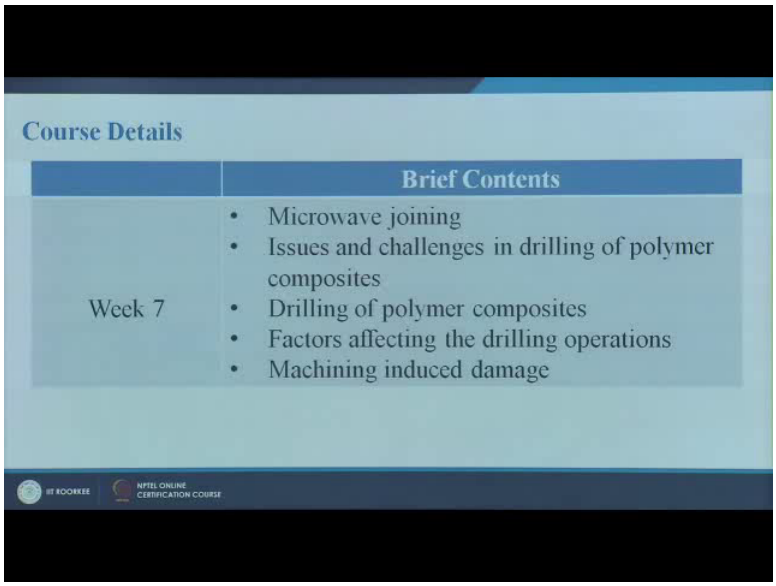


Then we will see the issues and challenges in drilling of polymer composites. So, right now whatever we were discussing, about the joining. Now for after joining may be sometimes we may need to join these 2 parts together, we may require hole also in the polymer composites. So, all these are secondary processes, may be joining, drilling, machining, adhesive joining, all these processes will fall under the secondary manufacturing.

So, we will then go to drilling, why drilling, because why joining we have discussed earlier, because in mechanical joining we will require drilling of holes, because you have to join two parts together using a nut and a bolt fastener like this. So, when this fastener has to go inside the polymer composite, you require a hole. So, the mechanical joining will definitely require, making of holes, fabrication of holes, drilling of holes.

So, then we will try to understand that what are the challenges in making of holes in the composite parts, then we will try to understand that when you make a hole inside a composite part, then you are having this machining induced damage. So, this machining induced damage has to be seen and checked.

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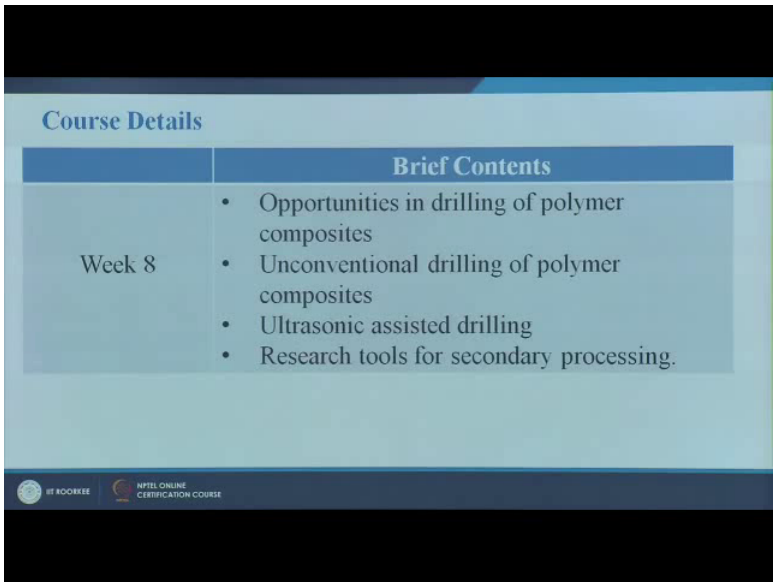


Finally, we will see what are the opportunities, because we are trying to understand the basic, then the we can say processing techniques. Finally, little bit of the research input also, that what are the challenges in making of holes in composite laminates, specifically in polymer composite laminate. Then we will focus our attention on opportunities in drilling of polymer composites, that what are the requirements, why we are not able to make good quality holes in polymer composites, that we will try to understand.

And finally, unconventional drilling, may be when the conventional drill. Conventional drilling means we have a hand held drilling machine, if with standard method we are not able to make a hole, that what are the other methods for making holes in polymer composites, that we will try to understand. We will try to understand a new process ultrasonically assisted drilling; that is used for making holes inside the composite materials. And finally, we will try to understand some research tools, which can be used for solving problems related to polymer composites.

For example the finite element method, which is a standard practice in design. How this tool can be used or how this tool can be helpful in case of polymer based composites that we will try to understand. So, if you have seen the plan for the 8 weeks, it has got a summary or a fundamental about the polymers. It has got the engineering thing where we will see how the polymers can be converted into products, and it has got a element of research, where the people who are in their post graduation or who are doing research,

can try to understand the problems associated with, the application of polymer matrix composites or polymer based composites.

So, we will try to address all categories of ordeals; that is starter's basic polymers basic processes, and slightly may be on the higher sides of learning, we will try to address the research aspects also. So, with this, I come to the end of the introductory part of our course on processing of polymers and polymer composites. In our second session we will see, that how the engineering materials can be classified, and then we will try to understand that what are the various manufacturing processes that can be used for processing of these engineering materials, and how to select a specific process for a specific material that we will try to understand in our lecture number 2, or session number 2 in our week 1 on processing of polymers and polymer composites.

Thank you.