Manufacturing of Composites
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Lecture – 26
Manufacturing Processes: Selection and Considerations

Lecture number 26. So, we have studied different different manufacturing processes, but now you have to come to a level and understanding that which process to choose for making which product. So, the product has its own shape, size and strength. So, in this chapter we will predominantly focus on how to choose a process and what are all the considerations you should see for choosing a process.

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So, the content is manufacturing process selection will be done, process selection criteria will be thought of, and then we will we will discuss product fabrication techniques, then mold and tool making and finally, methods of making tools.

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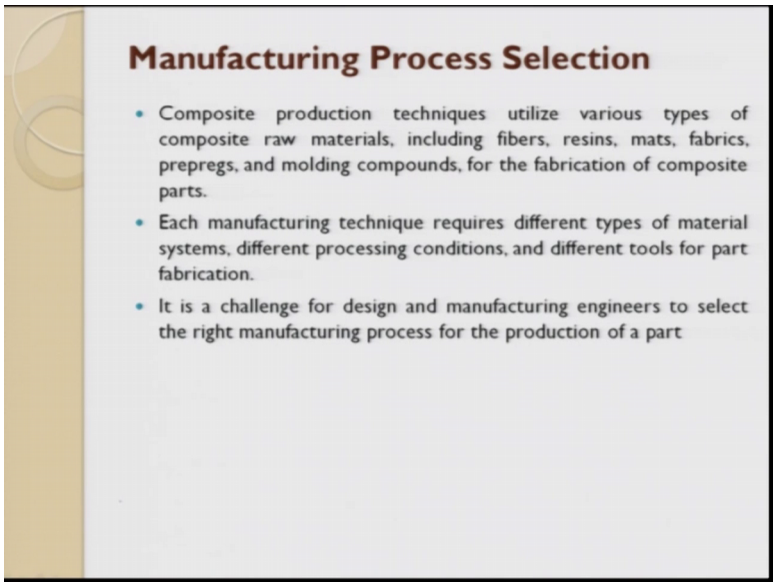

So, manufacturing process selection; the composite production technique utilizes various types of composite raw materials which include fibre, resin, mat, fabric, prepreg and the molding compound for fabricating a composite. Each manufacturing technique requires different types of material systems and different processing conditions, different tools for producing a part. It is a challenge for design and manufacturing engineer to select the right manufacturing process for the production of a part.

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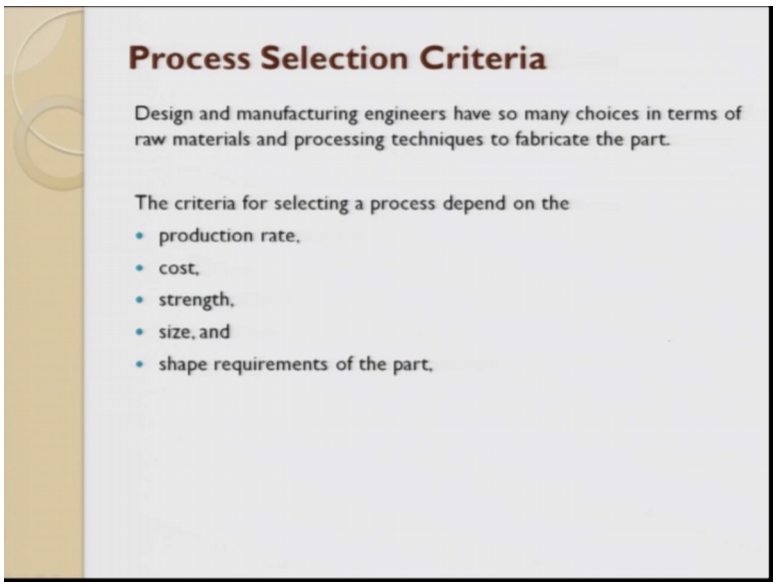

So, the process selection criteria generally followed is what is the production rate, what is the cost, what is the strength, what is the size and what is a shape. So, these are the important selection criteria which are used to choose a process. Production rate is important because here we talk about number of parts to be produced.

For example if the number of parts to be produced if you invest on a injection molding process. So, there the production rate should be enormously high such that the investment for die fabrication can be taken out. So, production rate plays a very important role and then the economics. So, what is the amount what is the price which people will be ready or a customer will be ready to offered for this part. So, this is the costing then comes the strength, predominantly composite are used for structural applications.

So, the strength is an important criteria for example, should we need a homogeneous strength property, should we need isotropic or anisotropic property you need I do you need quasi isotropic. So, that all depends on the strength and finally, the size and shape place a very very important role, the shape can be complex or simple size talks about the dimensions production rates speed.

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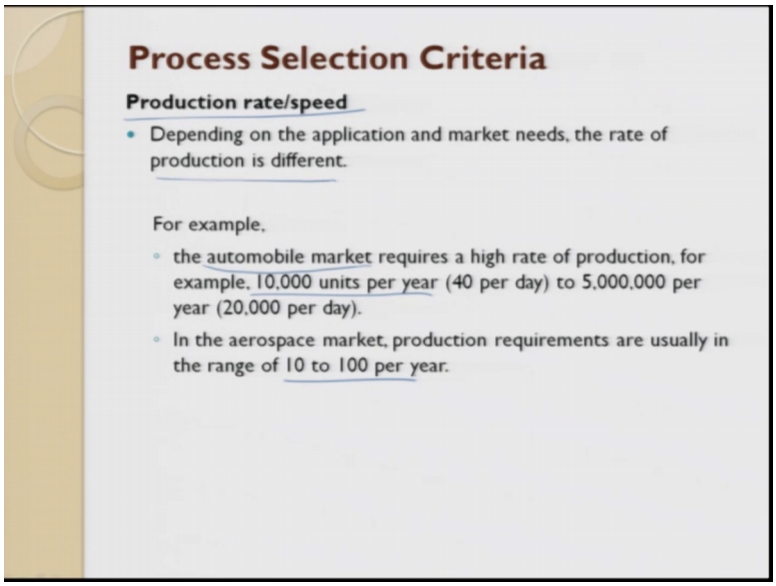

Depending on the application and market needs the rate of production is completely different. Generally the automobile market requires a high production of equal to 10000

units per year. In an aerospace market the highest production or the very high production demand will be 10 to 100 per year.

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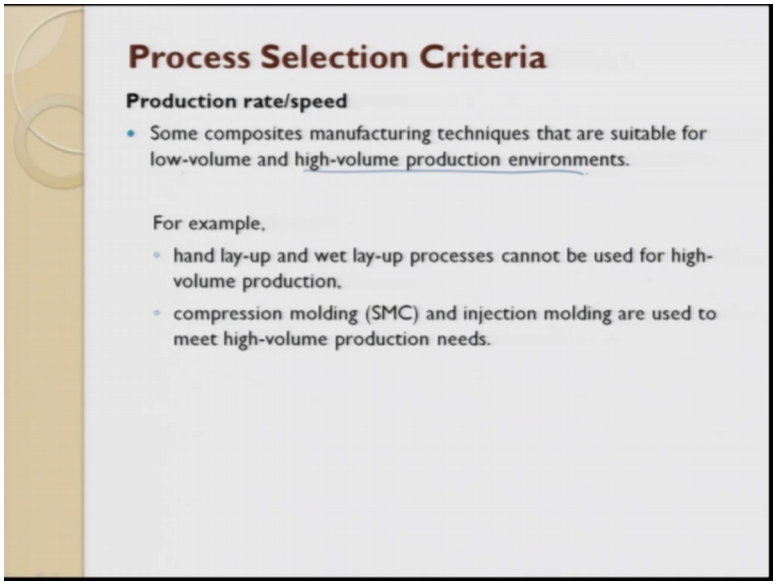

Some of the composite manufacturing techniques that are suitable for low volume and high volume production environment are for example, for low volume we will look for hand layup process, wet layup process, which cannot be thought of a high. High volume production in high volume production we always look for compression molding and injection molding where in which it tries to scatter to the high volume production requirements.

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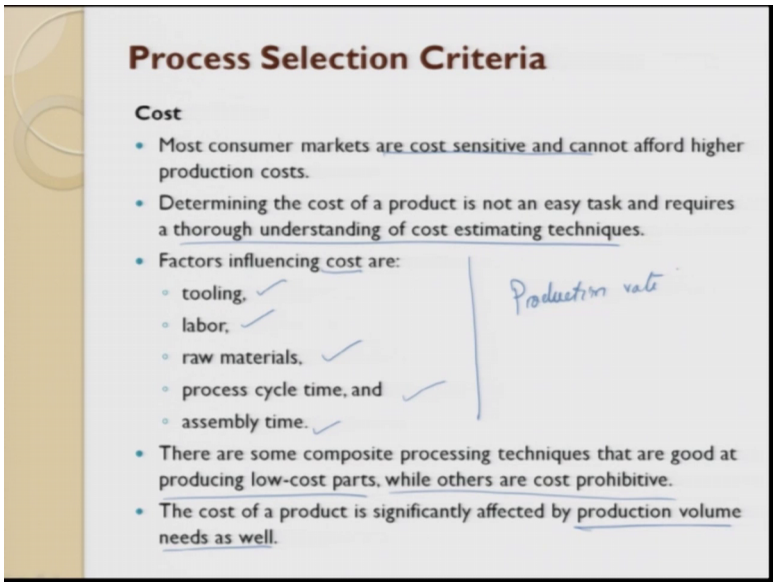

Costing; most of the customer market are cost sensitive and are cost driven. So, the affordability for the product place a very important role. Determining the cost of a product is not an easy task, it requires a very thorough understanding of the complete process product design and then you come out with a technique. The factors influencing the cost are tooling, labor, raw materials, processing cycle and assembly time. So, all these things put together decides the cost, there are some composite processing technique that are good at low volume production while when while the others are cost prohibited. The cost of a product is significantly affected by the production volume needs as well. So, depending upon the production rate, the cost can be reduced down when you divide by number of pieces. So, this is costing is a very important parameter and deciding a costing is a big challenge. So, this goes on various factors which we have discussed.

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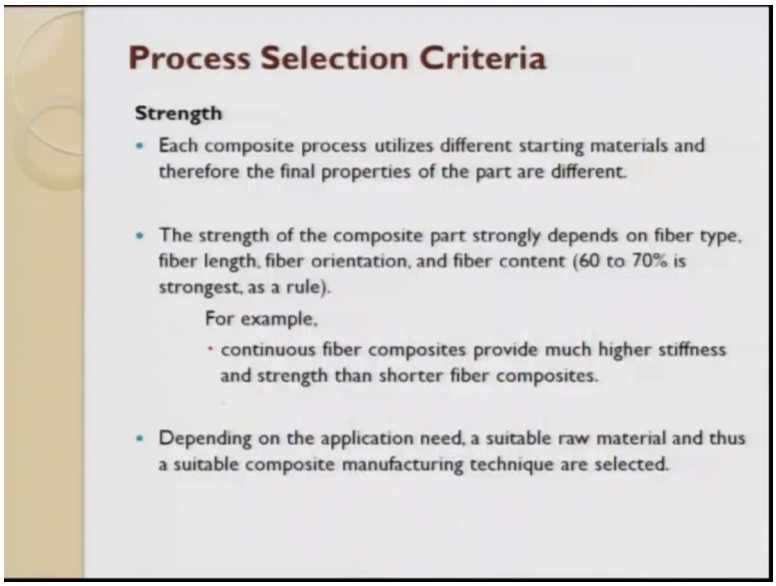

So, the strength so each composite process utilizes, different starting material and therefore, the final properties of the parts are different. The strength of the composite part strongly depends on the fibre type, fibre length, fibre orientation and the fibre content. So, four things are very important fibre type it can be glass fibre, it can be carbon fibre, it can be Kevlar fibre, length fibre orientation 0 45, 90, 0 40, 0 90 all those things then fibre content. So, this depends upon the volume fraction hand layup we say typically 30 40 percent and when you go for automatic process where in which it is machine laid, you can think of going up to 60 to 70 percent.

So, the continuous fibre composite provides much higher stiffness and string than a short fibre composite. So, you can take a unidirectional. So, this continuous fibre is nothing, but a unidirectional that this is a chopped strand mat. Depending on the application needs a suitable raw material and thus a suitable composite manufacturing techniques are chosen.

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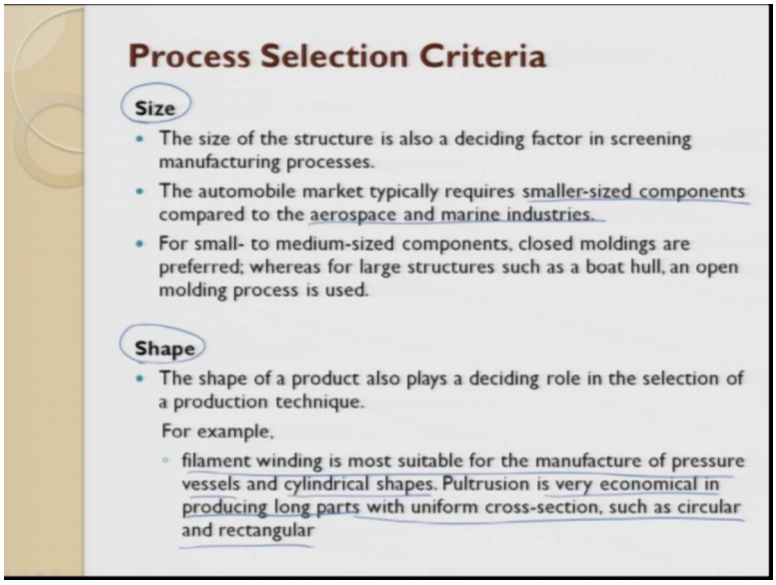

The size of the structure is also a deciding factor in screening the manufacturing process, in automobile market typically requires a small sized components compared to aerospace and marine application, the small and medium sized components closed molding are preferred for small and medium sized, whereas for a large size it will always be a single side die or it will be a open mould process. So, this also plays a very very important role size with respect to close or open mold process. Shape, shape what we talk about is the complexity of the shape, the shape of the product also plays a deciding role selected the production technique. So, filament winding is more suitable for manufacturing of a pressure vessel and cylindrical shape. A pultrusion is very economical for a long part with uniform cross section of cylindrical and rectangular. So, a shape plays a very important role size plays a very important role.

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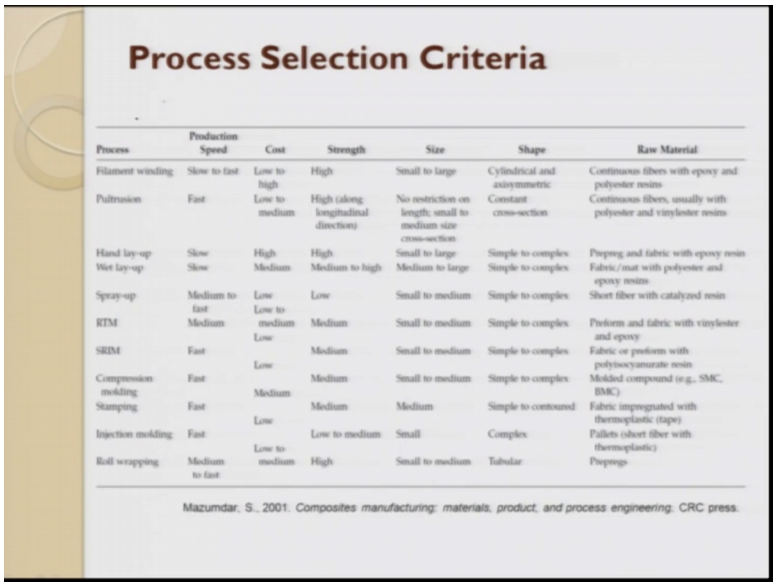

So, depending upon all these things, I have listed down various processes and I have listed down their criterias. So, the processes are filament winding process, pultrusion process, hand layup, wet layup then spray up RTM resin transfer molding then SRIM compression moulding, stamping, injection molding and roll wrapping. So, if you see that for example, we will take hand layup is very slow, the cost is high, the strength is high, the size is always small to large it can go, shape can move from simple to complex and raw material can be prepreg and a fabric with epoxy resin. So, we will take the RTM process, RTM process the production speed is medium, the cost is medium, the strength is medium it can move from small to medium simple to complex preform and fabric with vinyl ester and epoxy can be used as a raw material. Then let us take another process for discussion compression molding is very fast, it is used for medium cost is medium strength is medium, it can move from small to medium simple to complex and here what we use is mold component is SMC or BMC.

So, filament winding process is a slow to fast passes and costing is low to high, the strength is extremely high the size can move from small to large, the shape is always cylindrical or an axis symmetry part, the continuous fibre with epoxy and polyester resin can be thought of. So, this matrix is used to decide which process to choose for which shape and what will be the raw material. This is a consolidated process selection criteria several softwares have been developed and several expert systems have been developed

the product fabrication needs generally are to make a part there are four major items which are required, one is raw materials the other one is tool, then heat and pressure.

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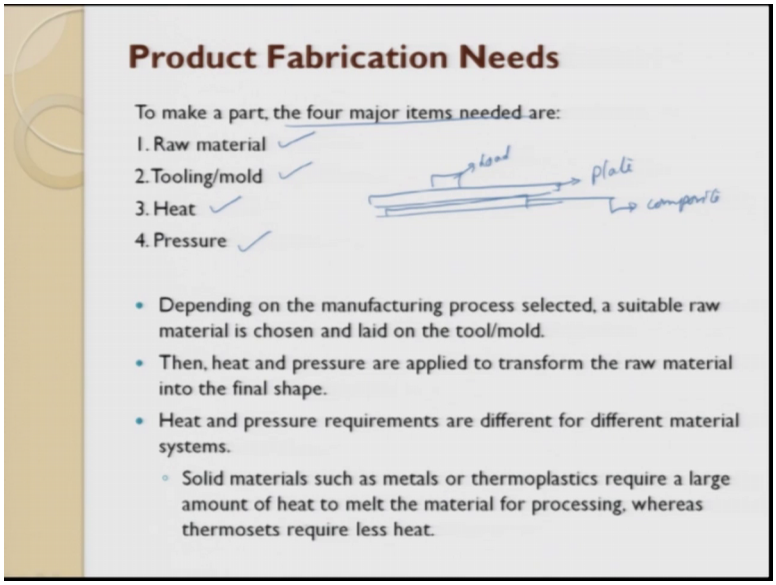

Depending upon the manufacturing process selection suitable raw material is chosen and laid in a tool. Then heat and pressure depending upon the requirement heat may or may not be applied or a combination of these two can be applied. For example, when we do a hand layup process and when the volume fraction is expected to be more than 40 or 50 then what we do if we try to place the composite and the several layers, and then what we do is we try to place a sheet on top and then put a stone there. This is a load and this load is distributed over a plate and this plate it gets distributed to a composite. So, here it is only the pressure there no heat is applied. So, the heat and pressure requirement are different for different processes, solid material such as metal or a thermoplastic requires a large amount of heat to melt the material for processing whereas the thermoset they need a very less heat for processing.

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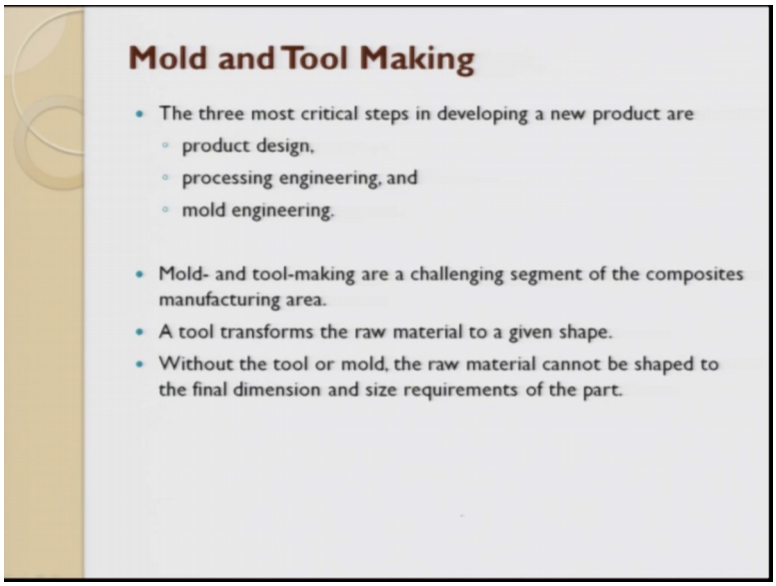

Mold and tool making three most critical steps which are involved in a new product development are product design processing engineering and mold engineering tool and die making or mould and tool making are a big challenge in the area of composite manufacturing. The tool transforms here raw material into a finished shape without a tool or a mold the raw material cannot be shaped to a final shape and the size required for the part.

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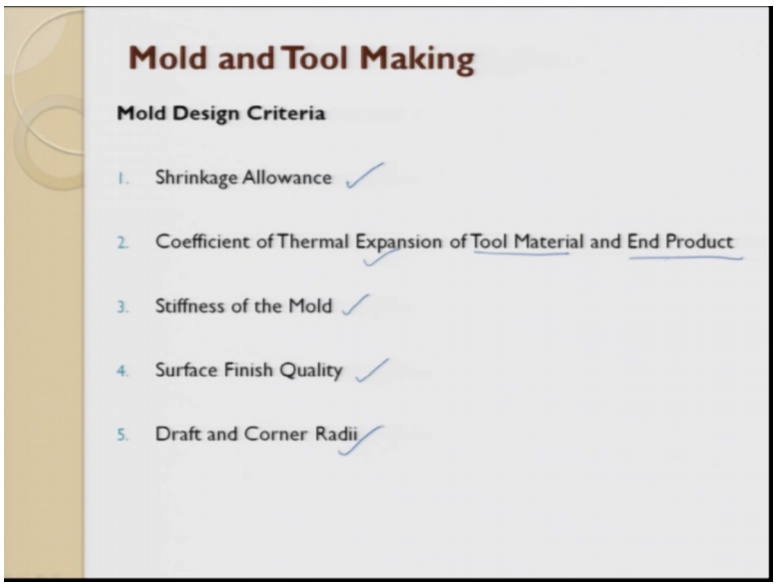

So, what are the criterias for mold design, shrinkage allowance, coefficient of thermal expansion of tool material and the end product stiffness of the mold, surface finish quality, draftt and corner radius are some of the mold design criterias which are to be followed. Shrinkage allowance as far as thermoplastic is concerned shrinkage allowances is given more as compared to thermoset, coefficient of thermal expansion of the tool material and the end product two different end product is what do you want the plastic injection moulding right.

Injection molding means an injected thermo plastic composite tool material can be wood, can be if you talk about injection molding it can be made out of steel right and if you are talking about autoclave where and which you want to make shapes the patterns are made out of wood, a patterns are made out of carbon fibre, the patterns are made of steel, but when we use steel there is a coefficient of thermal expansion because of that there is a deviation in the end product. Stiffness of the mold is very important when you talk about very high pressures used for making them product, surface quality is very important the draft and the corner radius this is for releasing the part from the die. So, these are some of the mold design criterias, which are to be considered while developing a product.

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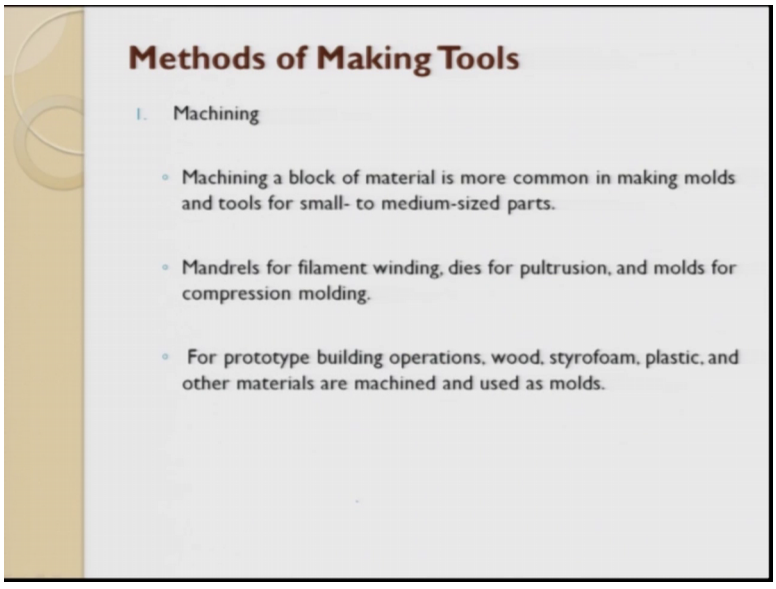

Methods of making tools. So, one is machining, machining is a very important thing though composites are said to be made for near net shape, but finally, we have to do some amount of machining so that we use it for assembly applications. So, machining a

block of material is more common in making a mold and told for a small to medium size parts, mandrel for filament winding, die for pultrusion and mold for compression molding all these places we use machining. For prototype building operations wood Styrofoam plastics and other materials are machined and used as mold. So, machining becomes part of mold making process which is a tool.

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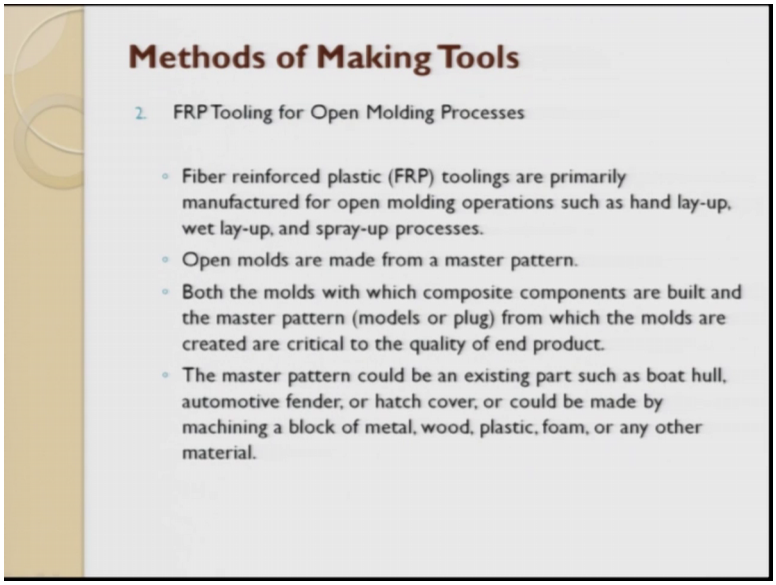

So, that are FRP tools for open molding processes, FRP itself is used as a tool. So, the pattern is made out of FRP, instead of making a wood pattern, instead of making a steel pattern we make a pattern out of composite itself and this is good enough for large area structural application parts, you want to do you can use fibre reinforced plastics as they are die itself.

So, the fibre reinforced plastics FRP tool are primarily manufactured for open molding operation such as hand layup, wet layout and spray up process. What is process you mix the polymer with a chop stand and glass fibre and it is sprayed to the required thickness so that you get the part of it. The open mold are made from a master pattern the open mold. So, both the mold with which composite components are built and the master patterns from which the mold are created are critical for the quality of the end product. So, both the molds with which the composite components are built and the master pattern are very important for the quality of the end products. The master pattern could be an existing part such as a boat hull, automotive fender or hatch cover or could be made by

machining a block of metal wood and plastic foam. So, these are the master pattern which are used for making the mould.

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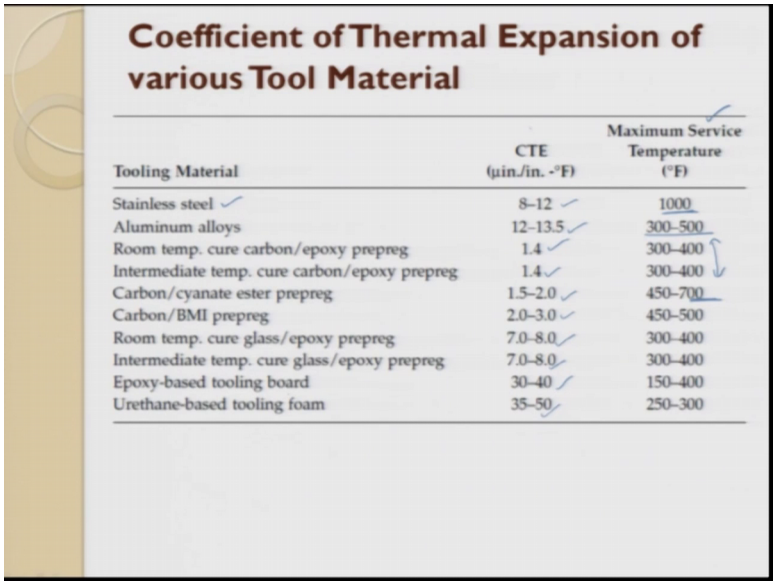

So, the coefficient of thermal expansion what I was talking to you about various mould. So, if you look at steel, steel the coefficient of thermal expansion is 8 to 12 microns micron inch per inch for degree Fahrenheit, aluminium alloy it is 12 to 13, then at room temperature cure carbon epoxy prepreg it is 1.4 look at the difference. So, how it is very clear that we are it is better to use a composite material for making a master pattern so,that you take care of the coefficient of thermal expansion. Intermediate temperature cure carbon epoxy prepreg is 1.4, then carbon ester prepreg it is 2, then carbon BMI prepreg is 3, room temperature curing glass fibre prepreg is 8, then intermediate is 8 epoxy based tooling board is 30 to 40 microns, urethane based tooling foam is all around 50 microns.

So, here are the servicing temperatures are given. So, if it is really a very high temperature like thousand degrees we degree Fahrenheit we always go for stainless steel anything else slightly lower half of it we go for aluminium alloy, then if you look at it epoxy are also used up to 300 400 degree Celsius. So, cyanide carbon ester can go up to 700. So, service temperature is important and the coefficient of thermal expansion is important to have a proper quality control over the finished product. So, this is an important property for making the master pattern. So, this is what we were discussing

here, the master pattern could be an existing part such that a boat hull automotive fender or a hatches cover or could be made by machining a block of metal wood plastic foam etcetera.

So, with this we come to an end to the chapter on process selection, process selection is very important and I repeat in manufacturing nothing is called as an universal solution depending upon the cost, depending upon the strength, you need you can choose processes to your requirement.

So, thank you very much.