Manufacturing Guidelines for Product Design
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Lecture-40
Product Design: Manufacturing Perspective

Namaskar friends, so finally we have come to the last session of our course on manufacturing guidelines for product designs. And as you are well aware that what we have covered in the course is now in your court means every information that has been covered is with available with all the learners. Now this is the last session and we have decided that in the last session we will try to summarize. We will try to finalize that what all we have learnt.

And what kind of information is available we have taken glimpses from the various sessions. So, that as concise form we are able to produce may be one particular session which can act as a guideline for learners who are just listening to this particular session, for our learners we have registered for the course and who have undergone all the sessions may be this session may not seem that relevant.

But sometimes there are sessions may be this session can have a standalone viewers also. That viewers were only listening to the particular session. So, this session will act as a guideline, will act as a source of very concise, very brief, very clear cut information that what kind of information is available, what kind of data basis are available, what kind of guidelines are available, what kind of rules and regulations are available, emphasizing on the manufacturing perspectives when the product is being designed.

And if you remember in the very first session of our course we have seen that the product design process. What we have seen there, when we analyze the product during the design process. We try to focus on 4 important analysis or 4 important characteristics. Now what are these 4 important points, the first one is the marketing aspects. The second is the product characteristics in terms of the functional aspects, operational aspects, durability and dependability aspects as well as the aesthetic aspects.

The third broad analysis point is the economical analysis or the economic aspects and fourth is the production aspects. So, when we are designing a product we have to analyze it from 4 important aspects and out of which however focus primarily is on the manufacturing or the production aspects of the product. And therefore the title of the today's session which is a summary session for this course on manufacturing guidelines for product design is product design from the manufacturing perspective.

That when we are analyzing our product that how it is going to be manufactured, what are the various guidelines that we must keep in mind, what are the important factors that are going to influence the manufacture ability of our product, that is basically what we are going to cover today. We will try to take a case study also in which we can see that if we redesign the part may be to at get the same type of functions to get the same type of operational aspects.

But may be the product may become light weight, the product may become easy to a sample. The product may become easy to disassemble, the product may become easy to maintain, easy to service. So, there can be advantageous accrued across various dimensions, so we can get different types of advantageous whereas the product is definitely satisfying the functional scope for which the product has been designed.

So we will try to take one case study also in today's class, so may be let us start revising our course in totality. So we can see that we have try to classify the various manufacturing process is, now you can see on your screen only one term is coming that is the manufacturing processes.

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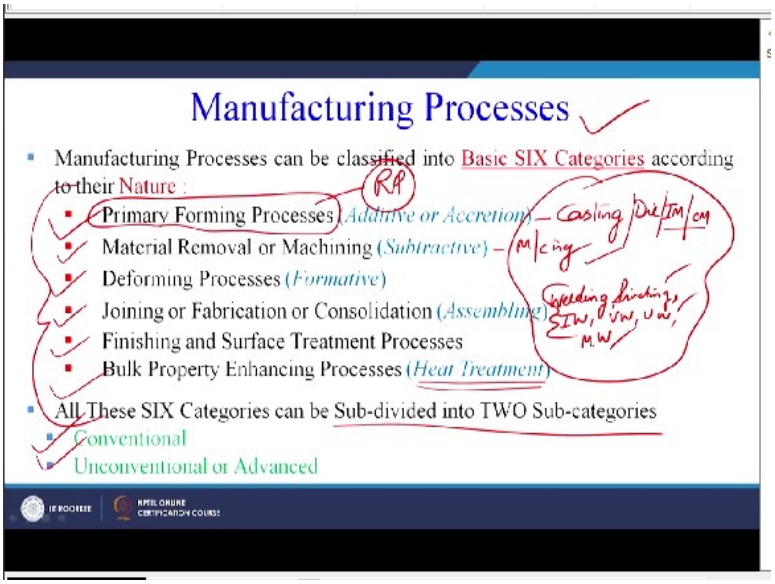

So, the learners who have gone through this course must be able to emphasize that how we can classify the various manufacturing processes. And for new learners I will just click and show what are the various processes?. Now the various processes can broadly be classified into 6 categories. And these are the processes which we have seen in the very beginning may be during the first week of our discussion on this course on manufacturing guidelines.

So basically we can have the primary forming processes as you can see on your screen the primary forming processes. And in our course our focus primarily has been on casting which is sand casting and die casting, also we have seen injection molding, compression molding for plastics. So we have seen the primary forming processes, what are the various guidelines we will quickly revise may be one or 2 guidelines for each of these processes.

Then we have seen the material removal processes, in this we have seen the machining process what are the design guidelines foe machining? and if you remember we have also seen the hole making operations also, so we have seen that how to design a product what must be the distance between the holes, what must be the distance between the hole and the edge of the plate, where the hole has to be made?.

So, all that we have covered in the material processes similarly deforming is another category of the processes. And we have not much focused on the deformative processes but in joining our focus has been on a large number. Because most of the products again I am coming to the example of the video camera there are so many parts which have been assembled together. So, even the most simplest of part if I take about example of my pen.

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There are still 4 or 5 different **7** parts which have been assembled together to make this simple product. So for making this simple product we have seen how the various assembly operations are required, when we open it there are a gripping mechanism here and which is coming and fitting here with this click, so this is one joining technique it is may be a screw type of fastening arrangement here.

So we have a joining technique here also and this metallic part is fixed here at the top. So, for a simple product also we can see so much of joining strategies are required. So, for a very very complicated product there are different types of joining strategies that are required. So joining and fabrication we have seen and we have tried to list down the guidelines for welding, we have to try to list down the guidelines for riveting, for mechanical fastening than for plastics we have seen different processes like induction welding.

We have seen vibration welding, we have seen ultrasonic welding, so different processes related to joining have been seen, then we have also seen another process which is microwave joining of materials. So, different processes we have tried to cover in the overall summary of this course or in the overall domain of this course. So, primarily the processes can be divided as primary forming processes, material removal processes, deforming processes, joining or fabrication processes, finishing and surface treatment processes and bulk property and enhancing processes such as the heat treatment.

This is the broad classification of the processes whatever we have covered in the course very broadly is listed here. Then coming to the 6 categories which can be further sub divided into 2 categories what are these conventional and unconventional processes. So specifically for joining we have seen that welding, mechanical, fastening, adhesive joining or simple processes conventional processes. Then may be the micro wave joining of materials can be clubbed as a unconventional process.

And in between we have ultrasonic welding, induction welding, vibration welding, so these can be in between the 2 not very conventional but not very advanced also. So, we have try to cover broad categories in primary forming if we remember casting is one process where we melt the metal and then we pour it into the mould to get a desired shape of the product in sand casting process.

Similarly we have seen a process called pro-typing in which we are able to produce product or a pro-type by may be diffusing the powder or may be depositing the material layer by layer like in case of laminated object manufacturing, powdered material is entered in selective laser centering sometime liquid photo polymer is cured to get a final product in case of repeat prototyping strategies.

So those all are also falling as the advanced form of primary forming processes that is rapid prototyping which we have already covered in this course in the last week that is the 8th week. So, these are the this is the summary of the manufacturing processes that we have covered we have seen the guidelines for most of these processes.

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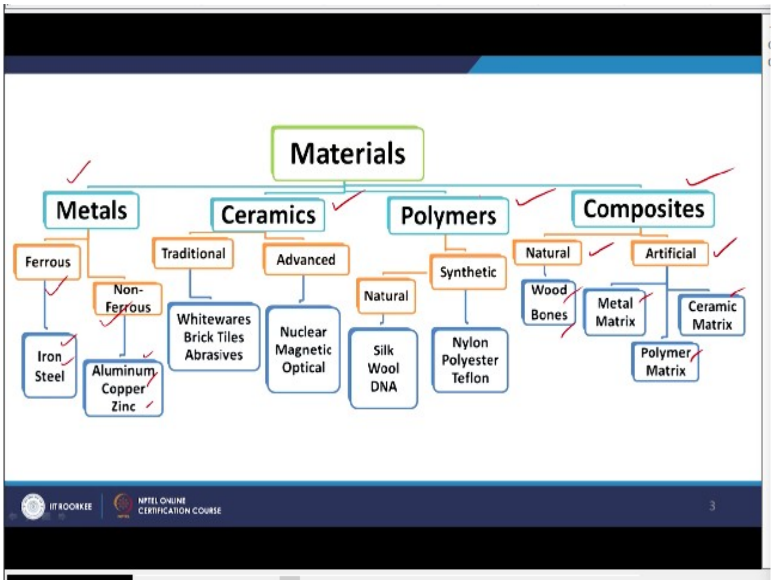

Then we have focused on materials also how this can be classified we have seen with this, can you classified as metals, ceramics, polymers and composites. So within metals we can have ferrous metals, non-ferrous metals, in ferrous metals we can iron steel, non-ferrous aluminum copper zinc. Similarly for composites naturally occurring composites and artificial composites, metal matrix composites, ceramic matrix, polymer matrix.

Naturally we can have wood and human bones are may be the bones similarly for polymers and ceramics, so we have tried to list down or explain or discuss the processes for different types of material. So if you can see that there is a wide variety of combinations possible, now there is a long list of manufacturing processes there is a long list of engineering materials. And when we combine these two together we are getting a complete table that which process can be use for which type of material and for that we have this summary table.

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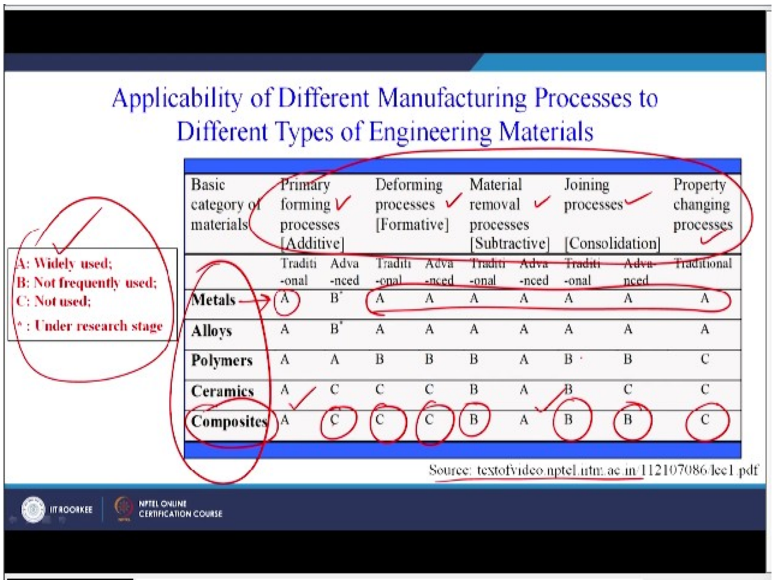

This is also available on the NPTEL website, so applicability of different manufacturing processes 2 different types of engineering materials. So, we can see A means widely used, B means not frequently used and C means not used. So, let us take 2 extreme cases here these are the processes various processes which we have just seen. These are the various materials that we have just seen, so 2 previous slides here we are combining the 2 together.

So, we can see we can have primary forming processes deforming material removing joining and property changing processes. Let us take the case of metals A, so we can see almost all are the A and what is the ranking for A, A means widely used. So, which means for metals most of the processes are well established and are being commercially used. Now let us take the case of composites C C C and one more C here.

And one B here B here B here only one A here and A here which means that our conventional processes which are well established for converting the metallic raw materials into the metallic products are very well established and are commercially being used where as all these processes cannot directly be duplicated in case of composite materials which means that we need to look for advanced processes new processes for making the composite material.

So, this way we can see that the product design when we are doing a new product design and we decide and we select the material for that product we have to do all these analysis that which particular process will be use for making this product since it is being made by material X. So, for material X first, so for material X first we need to list down what are the processes that are possible. Whether these processes will be able to produce this product in the most efficient effective both from the feasibility point of view also from the cost effective point of view also.

So, this diagram is very important, so we can very easily see and locate that which processes is applicable to which type of materials. So for all product designers they can have a look at this type of data basis this type of information which is available and take their decisions more judiciously. So that at the latest stage there are no design equations required when the product goes into manufacturing.

So we have select our processes, we have to select our materials and there are standard guidelines for that and this matrix that we have seen in the previous slide we that can be clubbed as a process material matrix.

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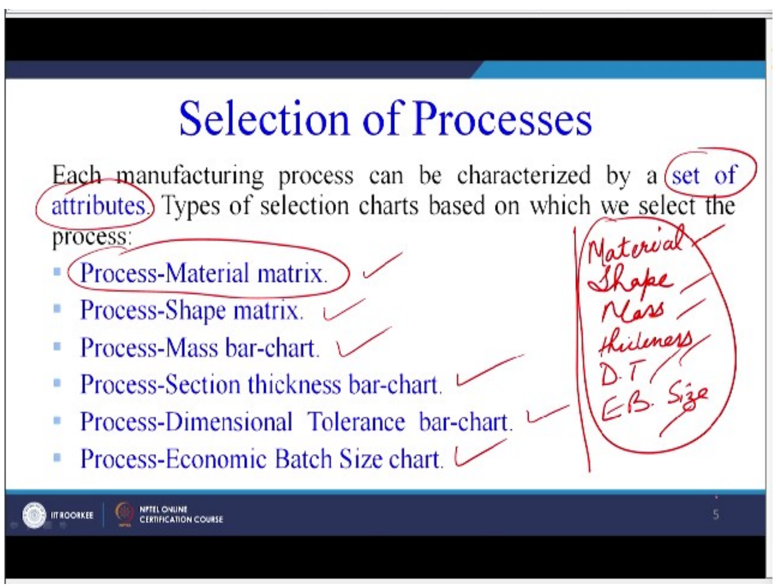

Because the processes where there in the various columns, the materials where are there in the different rows and there was a correlation between the 2 in terms of which for which material which processes widely used. So each manufacturing process can be characterized by a set of attributes type of selection of charts based on which we select the process are easily available.

So, process-material matrix are their process-shape matrix is there process-mass bar chart is there.

Process selection thickness chart is there, process-dimensional tolerance bar-chart, process economic batch size chart. Now what are the attributes which are written here set of attributes, now these attributes can be material as is given here shape it can be mass of the material, it can be thickness achieved by a different processes. Then the dimensional tolerance and the economic batch size or the number of parts that we want to produce.

Now these can be the attributes when we are designing our product that what is going to be the material?, what is going to be the shape of our part?, what is going to be the mass?, thickness dimensional tolerance, economic batch size, and accordingly then we have to see that, which is the process which is satisfying all these set of attributes. And accordingly we will select our process, so this already we have covered in our session in the beginning of our course.

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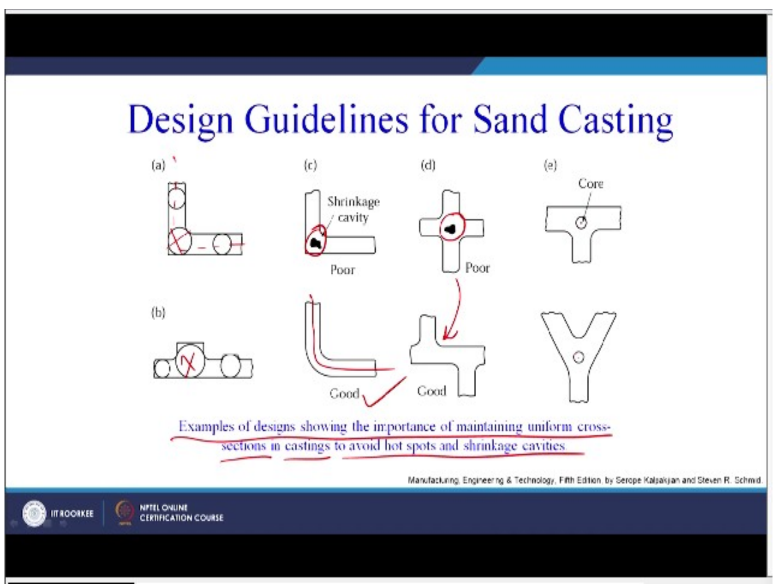

Now these are the may be once we have selected the process, for example we selecting casting process then this type of information is available as you can see on your screen. So, the design guidelines for sand casting, so we have seen these are the examples of designs showing the importance of maintaining uniform cross-sections in casting to avoid hot spots and shrinkage cavities this is the shrinkage cavity here shrinkage cavity here.

So, here we can see large volume of part is there, so usually we try to maintain a uniform cross-section. So, this is the good design where we are able to maintain a uniform cross-sections, so we can avoid the shrinkage cavity. Here also there are chances of formation of shrinkage cavity, so we can avoid these types of shrinkage cavities by maintaining a uniform cross-section or by modifying the design also.

So, here we can see if possible we can modify the designing such a way shrinkage cavity is avoided or we can place the course here or modify the design. So, that the shrinkage cavities are not form. So these type of guidelines are this is just an example to summarize what we have already covered. Now these type of guidelines are there for sand casting, these can be there for other forms of casting also, for example investment casting or slush casting or CO_2 mould casting.

There are different types of casting roots and strategies and for each type of casting strategy there will be certain guideline. So a product designer when he or she specify may be investment casting as the casting process for manufacturing the product must look at these kind of guidelines while designing the product or while doing the detailed design of the product. So, that we do not face or encounter problems during the manufacturing of our product which is manufactured by the process which has been specified by the designer.

Similarly we can see design guidelines are available for die casting also in previous cases we can modify the design of our product we avoid the formation of shrinkage cavities. Similarly in die casting also we can modify the design, in order to avoid the defects.

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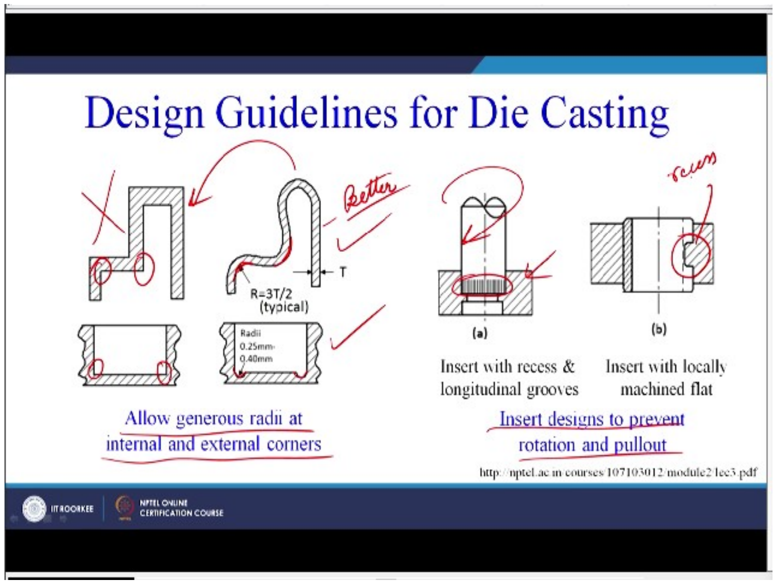

So, one of the guidelines is allow the generous radii at internal and external corner, so we can see here there are sharp corners and here it is a rounded corner again sharp corner rounded corner. So, this is may be a better design as compared to this design, so this is not recommended for die casting this is recommended for die casting. Similarly here also sharp corners are there, here there are radii provided a better design for the die casting point of view.

Similarly insert designs to prevent rotation and pullout, so here we can see this threaded portion will avoid the rotation of this part. When it is fixed in this part similarly this type of in recess can help us to provide locking arrangement to avoid the rotation of the part, insert with locally machined flat. So, this is a locally machined flat here which will avoid the rotation of the part or movement of the part up and down.

So, insert designs to prevent rotation and pullout, in this case it is going to avoid the pullout. And in this case it is going to avoid the rotation of the relative or the 2 members among each other. So, therefore we can modify our designs, so that they can be easily manufactured using the die casting process, similar type there are may be long list of guidelines that do exist when we are designing the product we must take into account this guidelines.

Similarly we have discussed about the polymer processing also, in polymer processing manufacture process used with polymers to take advantage of the unique viscoelastic flow properties of the polymers.

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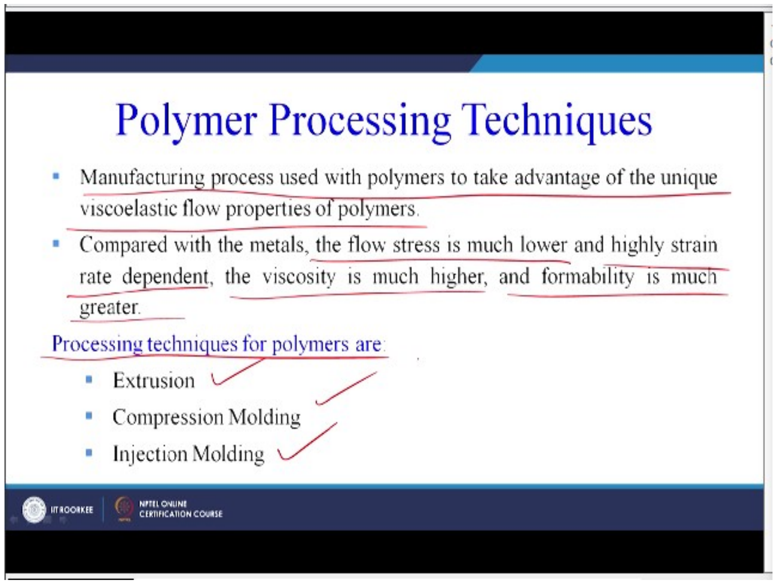

Now compared with metals the flow stresses much lower highly strain rate dependent the viscosity is much higher and formability is much greater. So, this is basically different techniques are used extrusion, compression molding and injection molding.

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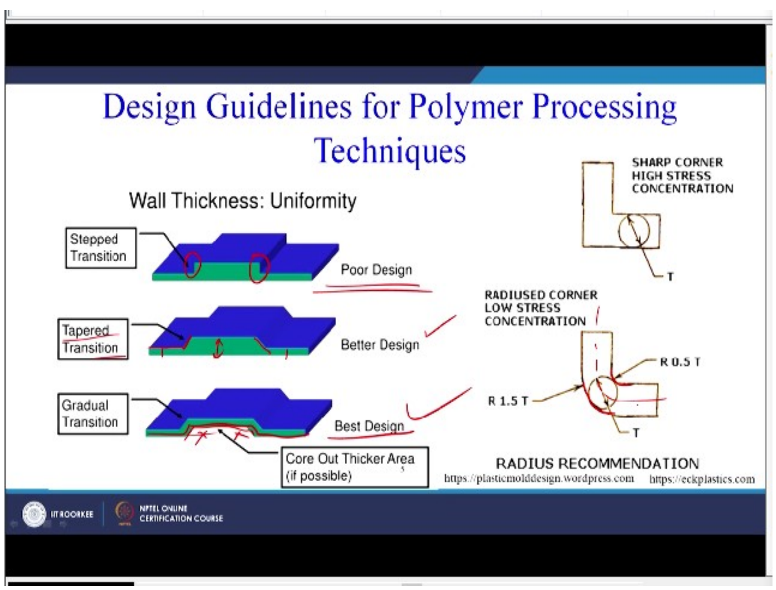

So, these are some of the design may be in the previous slide just a summary that what are the important characteristics of the polymer processing techniques. And we have seen injection molding, compression molding and this type of guidelines we have already covered for the polymer processing techniques. So, here we can see sharp corners are there, so it is a poor design, so if we make this as a slanted corners are tapered transition of this corner.

It is better design but still here we see the cross-section is different, so gradual transition plus we are coring out this thickness this extra thickness from here. And then we are maintaining a uniform thickness across the length, so this is the best design. Similarly here we are seeing sharp corners are there. So, we are maintaining a uniform cross-section by giving a radius here. So, when we are designing a plastic parts we can take into account these type of guidelines. So, that our manufacturing becomes easier faster and effective.

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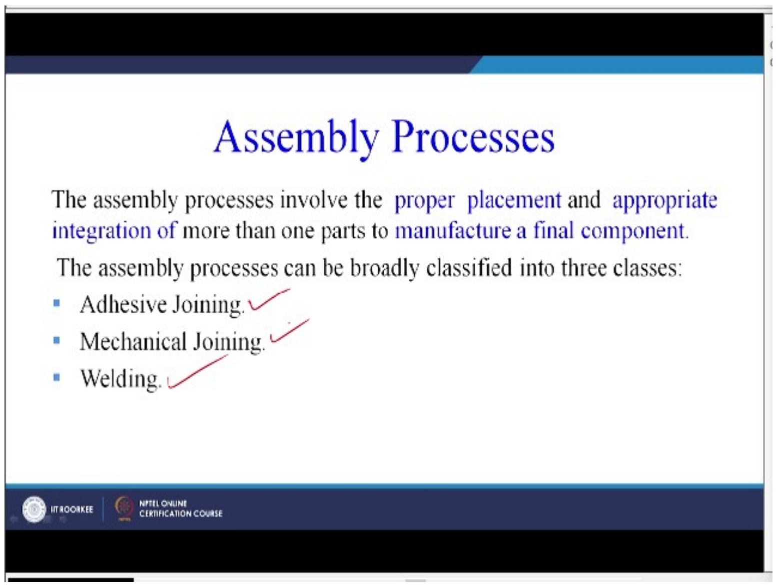

Then we have also discussed the assembly processes, the assembly processes involve the proper placement and appropriate integration of more than one parts to manufacture a final component. I have already explained it with help of a pen, so many assembly processes have to be included in the final manufacturing of the product or final assembly of the product. So, we have different types of joining we have seen adhesive joining, mechanical joining, welding.

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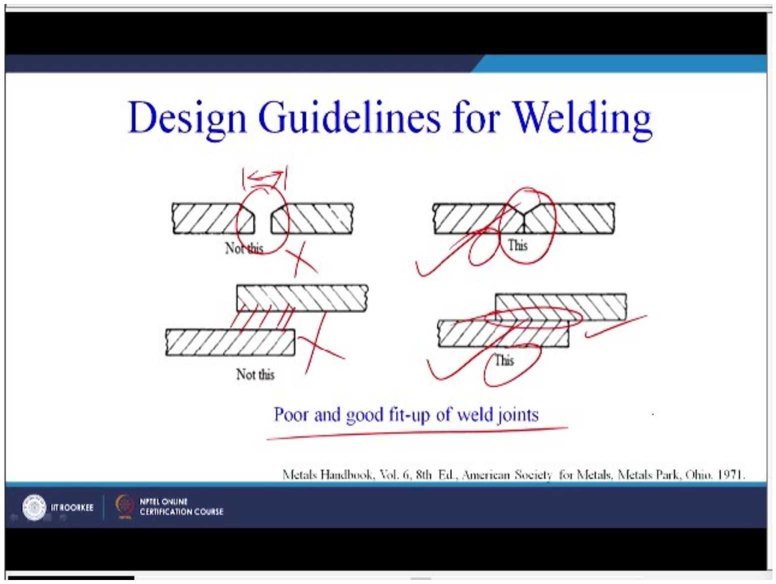

Now these are the design guidelines for welding this is not recommended lot of distance between the 2. So, this is better joint preparation here also lot of gap, so may be a better gap management here. So, this is recommended and these 2 are not recommended poor and good fit-up of the weld joints. So, this also not only this we have seen a lot many designs or design modifications suggested by the engineers and scientist which help us to make good joints.

So, in our 6th and 7th week of discussion we have already seen a lot of guidelines like this. Now joining of thermoplastic we can have different strategies for joining of thermoplastic for joining of metals we can use welding, riveting. In case of joining of thermoplastic we can use process like ultrasonic welding, vibration welding, spin welding, induction welding.

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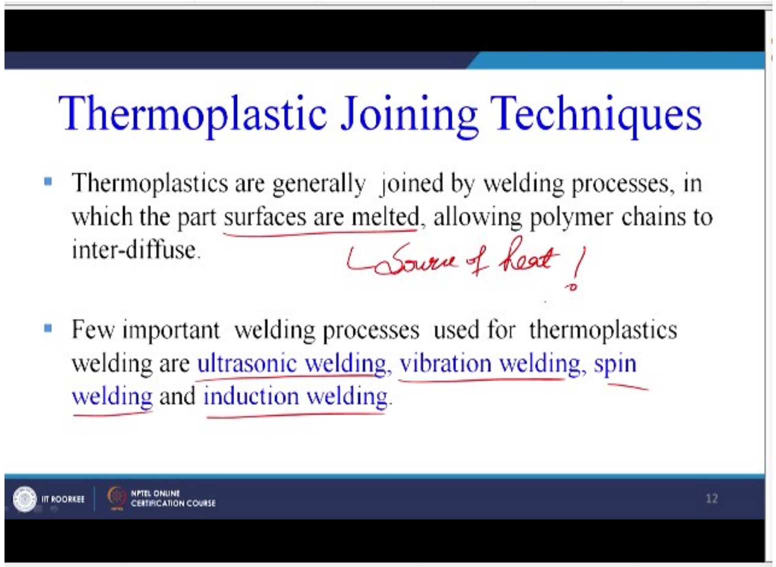

So, few important welding process is use for thermoplastic welding or already listed here and we have already discussed them in detail in our discussion during 6th and 7th week. So, thermoplastics are generally joined were welding process in which the parts are surfaces are melted allowing polymer chains to inter-diffuse. So basically how the surfaces are melted the source of heat may vary and based on the source of heat different processes are used.

So we can see that for metals there are specific set of processes and for polymers also there are specific set of processes and some of the processes can be use both for metals as well as for the polymers.

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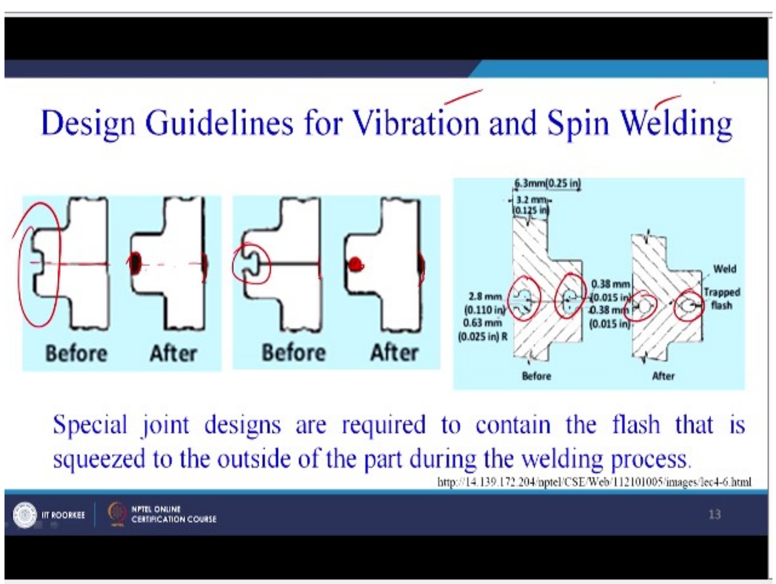

Now these are the design guidelines for vibration and spin welding all of us know that when we are joining the 2 plastic parts. And in the previous slide we have seen that there is a melting of the plastic at the interface. So, there is a tendency of this plastic to move out as a flash when it is in the molten state and when we apply or certain amount of pressure. So, when under that pressure the molten plastic may come out at the edge and form of flash.

Now how to avoid the flash this is the design modification if we make the 2 edges to be joint here like this. So the flash whatever is generated at the joint will move out but will fill this section similarly here additional flash is there. So, here we can see the flash that is formed in this design is accumulated here. But this side we have no modifications, so the flash is coming out of the part, so similarly these are the with the dimension that how much dimensions must be given in order to avoid the problem of flash.

Special joint designs are required to contain the flash that is squeezed to the outside of the part during the joining process during the vibration or the spin welding.

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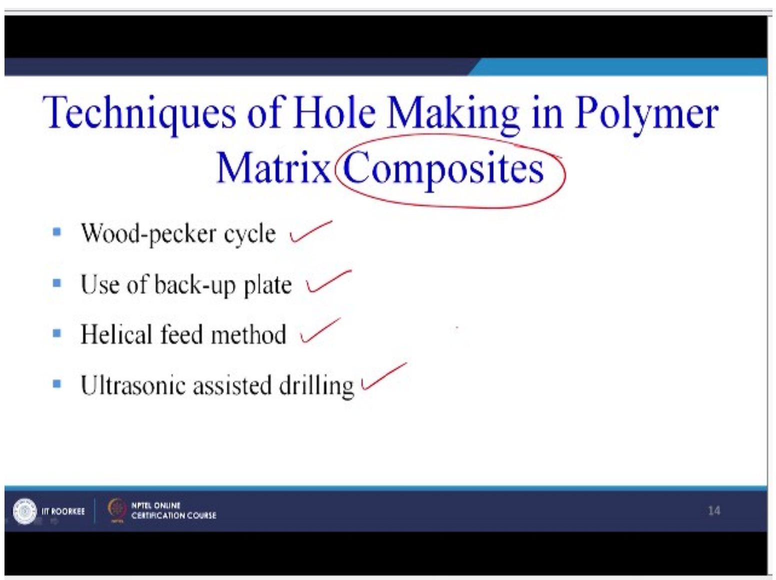

Then we have also discussed in our course the techniques for hole making in polymer matrix composites. So, we have seen there are different types of materials may be metals, ceramics, polymers, composites. So, for composites we have seen there are number of problems associated, so for hole making techniques we have seen. We can use wood-pecker cycle, back-up plate can be put below the composite plate helical feed method, ultrasonic assisted drilling.

So, all these techniques are improvised version of the conventional drilling technique in order to avoid the drilling induced damage in composite materials.

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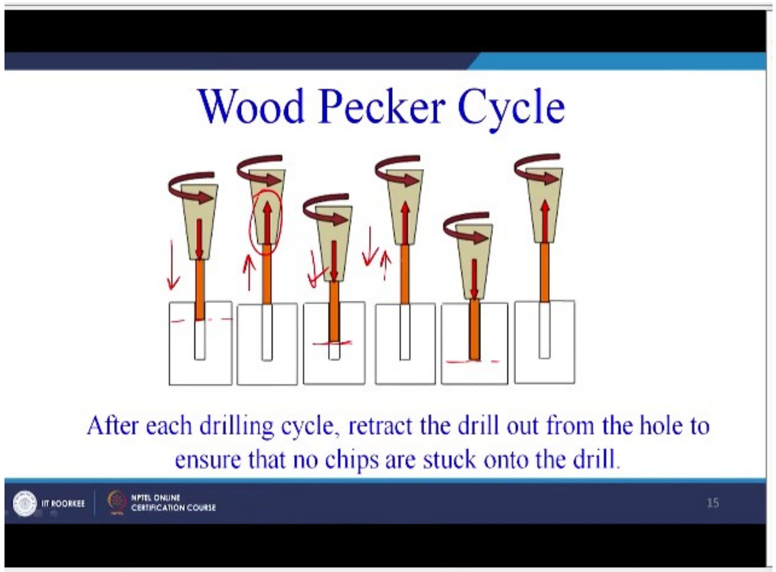

And this is just one technique the drill goes down then it comes up it is shown here again it goes down to a further depth initially it goes down to this depth. Then the depth increases then again the depth increases, so this down and up motion of the drill is like the wood-pecker makes a hole in the tree, after each drilling cycle retract the drill out from the hole to ensure that no chips are stuck onto the drill.

And more over the feed rate also we controlled in the subsequent steps which is a important cause oppose down type of delamination that is the lower layers of the composite try to push down during the action of the drill. So therefore this type of helical feed method can avoid the push down type of delamination, when we are making holes or when we are drilling holes in case of laminated composite materials.

Then towards the end of our discussion we have also seen the design for environment that whatever materials, whatever process we choose must be environment friendly.

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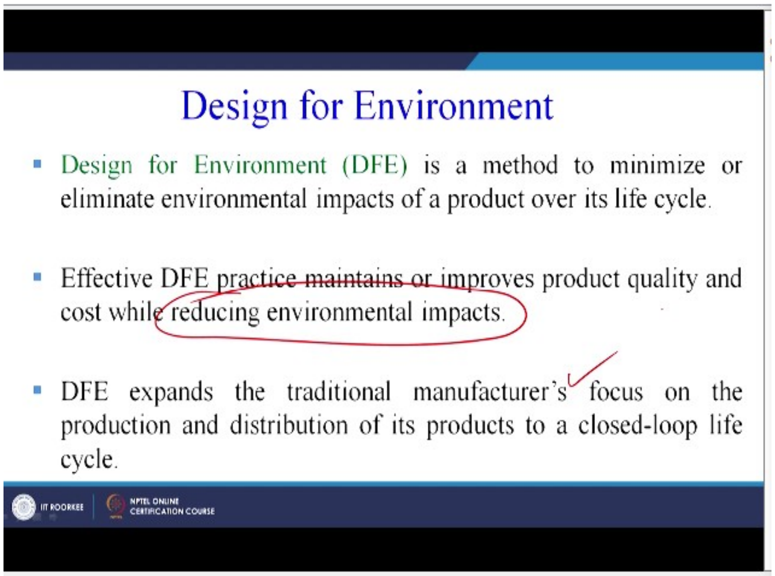

So, design for environment is a method to minimize or eliminate the environmental impacts of a product over its life cycle right from conceptualization of the idea to the end of life of the product finally to the recycling or disposal of product into the environment. We must make a environmental impact assessment of the product at its various life cycle at its various stages of the life cycle, effective DFE practice maintains or improves product quality and cost while reducing the environmental impact.

So, that is very important we want to reduce the environmental impact of the product. DFE expands the traditional manufacturer's focus on the production and distribution of its products to a closed-loop life cycle. So, this point already I have explained in the last or the 8th week of our discussion in session number 36 and session number 37. So, we have seen that how the view point of traditional manufacturer must change if he or she wants to be successful.

Then we have also covered the concept of product architecture that when we have to design the product finally we need to design it as different modules. Because sometimes we may like to take advantage of the expertise of a particular company which has developed a particular module and that module can directly be integrated into our product. So, we can make our product into different modules and for some modules we can have the expertise.

And for other modules we can out source them into finally combine all the modules to finalize or fabricate or assemble our product. So that is arrangement of functional elements into physical chunks which become the building blocks for the product or product family of product.

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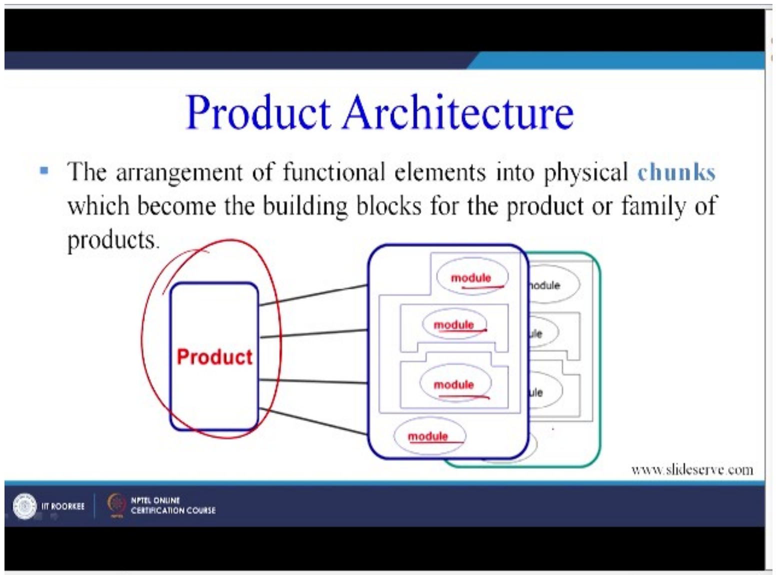

So we can see overall product, it can be divided into 2 different modules module1, module2, module3, module4 the some of these modules we can try to develop. Some of these modules we can try to outsource we have seen that what type of product architectures are usually in practice 2 of them are shown here. We can have a modular architecture we can have a integral architecture.

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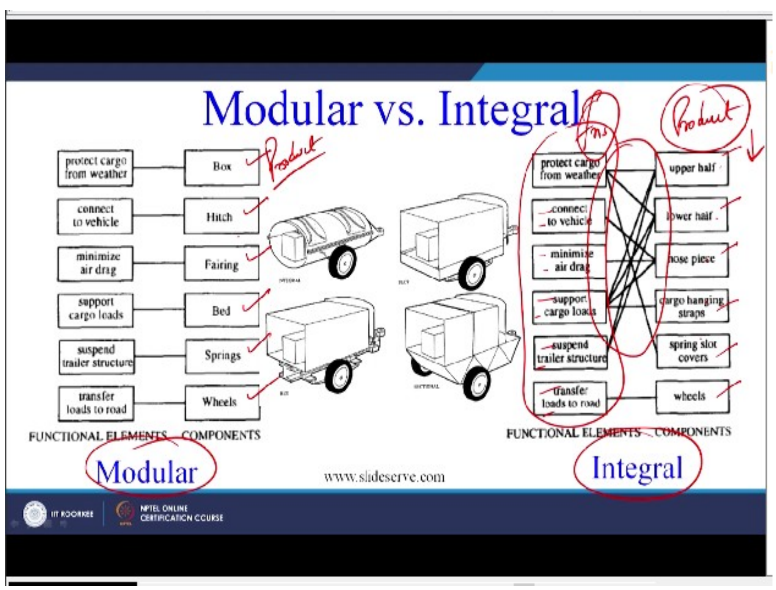

So, we will not be able to going to the details of this but in modular architecture each part box, hitch, fairing, bed, springs, wheels or may be independently satisfying a particular function or their satisfying the functional requirement independently, whereas in case of a integral we can see that there is a inter-relationship among the various parts the upper half, lower half, nose piece, cargo, hanging straps, spring slot covers, wheels.

So we have different parts of the product, here this is a product, so we there are different modules or different modules in the product. But here there is a integral designs, so there is a interface among the various module and the function that they are satisfying. These are the functions that are satisfied and if you go back to the functional definition usually we use the very crisp 2 word functional definition that is verb and noun. So, here we can see minimize air drag, connect to vehicle, support cargo loads, suspend trailer structure transfer loads to road.

So, these are the functions which have to be satisfied by the product this is the product which is listed here and these are the various parts of the products. So, here in integral product architecture we have inter-relationships among the various parts of the product and the various functions that are satisfied where as in modular each and every module has got very very specific function to be achieved. So, this also we have covered in our section in the discussion then we have also covered one section on rapid prototyping.

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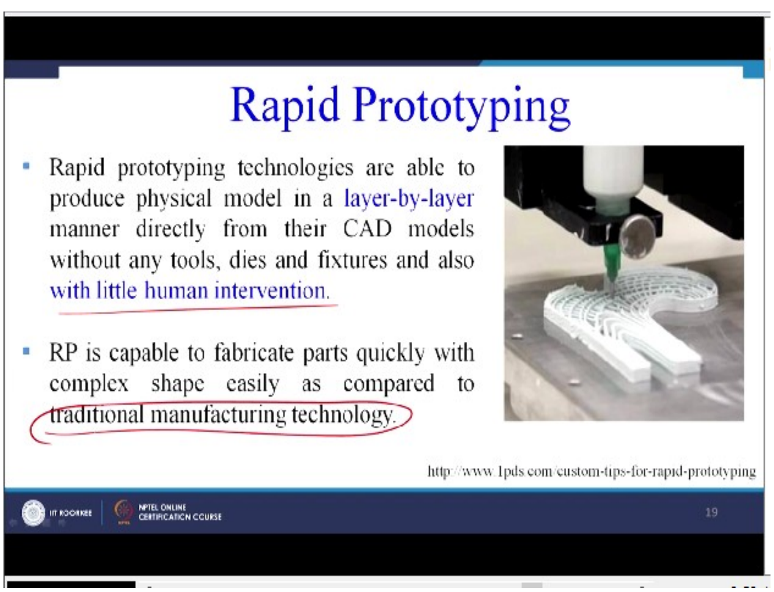

So, rapid pro-typing technologies are able to produce physical model in a layer-by-layer manner directly from the CAD models without any tools, dies and fixtures and also with little human intervention. So most of the rapid prototyping processes are automatic in nature, RP is capable to fabricate parts quickly with complex shapes easily as compared to the traditional manufacturing technology.

So whatever we are covering in today's session is the summary of what we have already covered in the 39th sessions which have already been recorded and are now available with you. So, we have tried to now focus all the latest strategies and all the thought processes that are product designer must keep in mind when he or she is designing a product. So we have seen that we must focus on product architecture we must focus on product design process.

We must focus on the product analysis, we must focus on the design guidelines for various products that are manufactured by the various processes. So, this is a amalgamation of all the various aspects that must be kept in mind during the product design process. So, that the design that we finalize is easily acceptable by the manufacturing community. They are easily able to manufacture that product and then it finally it becomes a profitable product in the market.

Customers are happy to use that product because the functions for which they have bought the product are easily being satisfied without causing any trouble or any without requiring any trouble shooting. So we have tried to cover all these topics in the course.

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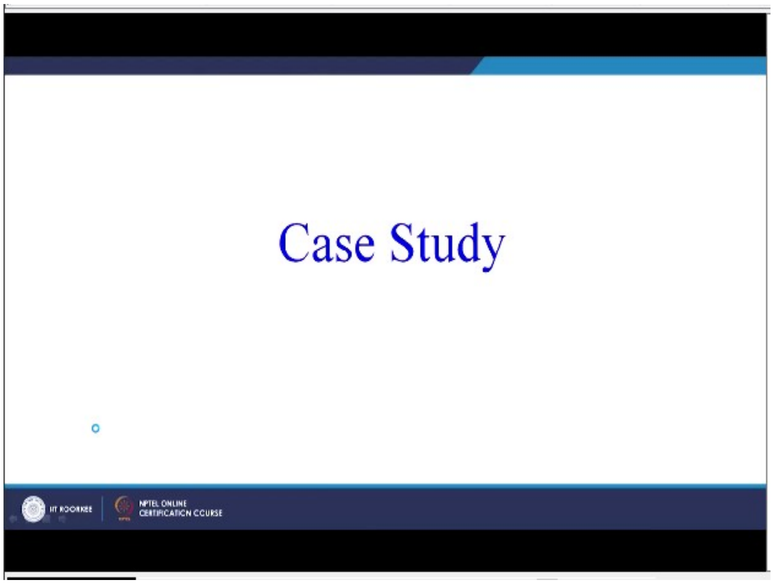

Now let us take the case study now we have seen beginning from the design of the product then manufacturing analysis of the product. Then pro-typing of the product we have learnt that we can derive that complete product design into the various modules. We can have a modular type of product architecture, we can have a integral type of product architecture, now once we have pro-typed we have checked that now our product is ready.

It can be sent for manufacturing we can think of the benefits or savings that we can accrue and this case studies only to help to you understand the magnitude of savings that we can get if we follow all the guidelines that we have covered in the previous session or in all the previous sessions.

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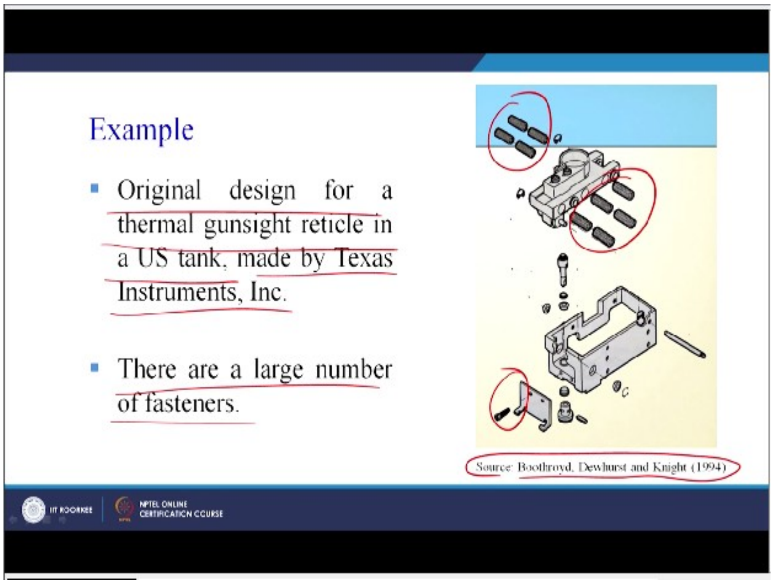

So, this case study taken from that book Boothroyd Dewhurst Knight published in 1994 product design for manufacturing and assembly. So, example is this is original design for a thermal gunsight reticle in US tank made by Texas Instruments. There are large number of fasteners here we can see large number of fasteners are there.

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So, when the company modified the design it was a modified design is again shown here. Redesigned thermal gunsight reticle simple to assemble and less to go wrong, so you can see here we have less number of fasteners that are required the product design has been change, the number of processes required will also change. The number of material required will also change as well as the type of processes that will be used to manufacture this product will also require to be change. So, when the company launched a new design you can yourself see what are the improvements that has been achieved.

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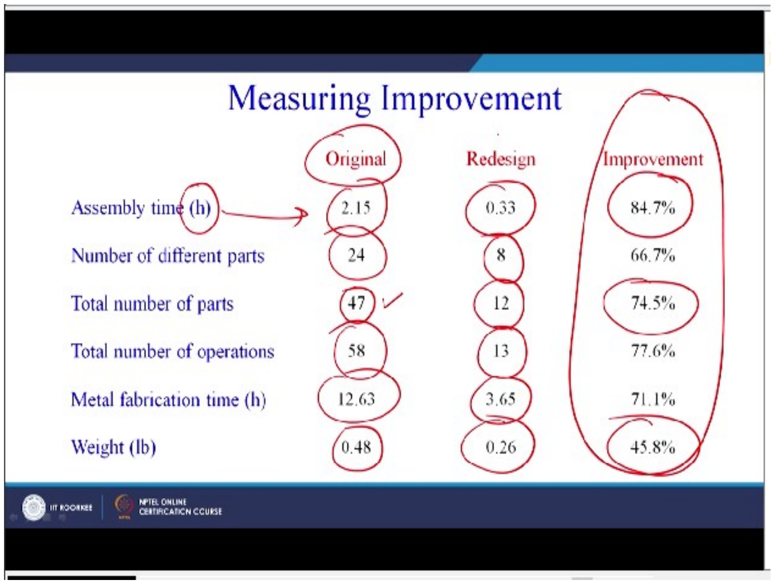

So, the assembly time for the original design which was initially used was 2.15, in the redesign only 0.33 was the time units those were used. So, basically our target is to look at the improvement, so the time as we can see in hours is written here 84.7% improvement is there in the assembly time, number of different parts initially 24 different types of number of different parts were used.

Now it is only reduced to 8 total number of parts initially 47 parts were there, 24 different parts may be one part may be used in 2 numbers or one part may be use in 4 numbers or 6 numbers, total number of parts were 47. But finally the total number of parts were 12 only significant improvement, total number of operations from 58 were reduced to 13. Metal fabrication time from 12.63 hours to 3.65 hours, weight 0.48 pounds to 0.26, 45.8%.

So you can see lot of improvements are there only by modifying the design by changing the design by keeping a manufacturing focus on the design but looking at the design from the manufacturing point of view we can see the kind of improvements that have taken place, so friends if we look at the designs that we have seen for various products around us. And try to figure out that how this design can be modified without compromising with the functional scope of the product.

We may come up with very innovative designs and once we have the design ready with us if we focus on that how it is going to be manufactured, what can be the best manufacturing process for this product, what can be the material that can be selected for this product we can go to the rapid prototyping stage. And once we are able to make a pro-type very easily we can lead that product or design into the actual full scale manufacturing.

So, with this we conclude our course on manufacturing guidelines for product design. In today's session we have summarized, we have given a manufacturing perspective about the product design that once we are designing the product where our focus must be or what is the kind of information that is available in the open domain which we must make use of while designing our products. So that the products that we design are easy to manufacture, easy to assemble as well as once they are easy to manufacture and assemble.

We have to also ensure that their maintainability, their serviceability is also easy their durable also their dependable also. So, basically we have look at a large number of factors when we are deciding the materials and the manufacturing processes that are going to be used for manufacturing of our products. I sincerely believe that the last 40 sessions that we have interacted will be useful to all of you.

And it will give you a new thought in the direction of combining or complementing your knowledge from the manufacturing as well as from the industrial engineering into a broad area of product design. So basically what we target is that we must create number of innovators, number of product designer, so that we come up with designs of products which are going to satisfy the needs and requirements of our society.

So, I wish all the product designers a very bright future and I wish the course must have been helpful to you in some form of value addition related to the combined effect of the 2 streams of P and I engineering that is a production as well as the industrial engineering. In case you have any doubts you are most welcome to write at the discussion board we will be more than happy to answer to all your queries.

Thank you.