Manufacturing Guidelines of Production Design

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Lecture-26
Assembly Processes: introduction

Namaskar friends, welcome to the sixth week of our discussion on the topic manufacturing guidelines for product design. So, we have already finished 5 weeks of discussion and I firmly believe that this discussion might have added some value to your knowledge base, some value to the existing theories that we have understood or theories that we have studied related to the manufacturing processes.

Normally in our curriculum we talk about the process, we talk about the kind of raw materials it can process, we talk about the process mechanism how the material will be converted into the final product. But usually we lack a discussion regarding that what are the product design guidelines related to that process. That if the product has to be made by a specific process for example, say metal die casting or pressure die casting.

In that case what guidelines we must keep in mind when we are designing a product usually pressure die casting is taught the design of the die, the design of the ejector pins the cooling system the pushing mechanism for the metal the heating mechanism for the metal. So, all that is taught but sometimes we have very little discussion about the products that should be made by the pressure die casting process.

So, this course basically is focused on these type of guidelines and it is a very condensed course of 20 hours and we have try to include many possible processes that are used or that are maybe in that are employed for during the product development cycle. So, if you remember in the last 5 weeks we have been discussing the various topics and we have then started the discussion related to the individual process.

And the processes that we have already covered include sand casting, pressure die casting, compression moulding, extrusion, injection moulding. So, we have covered a lot many processes and if you remember towards the end of our discussion in the 5th week our topic was design for machining. That if the part has to be made by machining process what are the guidelines that we must follow.

Now you see that we know the guidelines for machining, we know the guidelines for making a product that is forming giving shape to a product either it is a metallic product sand casting or pressure die casting is used. If it is a plastic product we will be making use of you can very easily relate the processes now compression moulding, injection moulding, extrusion. So, we have seen that how to give shape to a product whether it is a metallic product or it is a plastic product.

And how to cut the product into the desired dimensional accuracy as well as the surface finish, now suppose in many cases the product is very complicated. So, in that case what we need to do, we need to breakdown the product into the number of subparts or subassemblies. And then we will make these individual parts or components and then assemble them together into the final product.

So, today our target is to understand the basic intricacies or the basic processes that are used for joining of the various parts or the processes that are used for joining of the product or assembly of the product. So, the word that we are using is the assembly processes, now what are these processes, the processes will be using an adhesive, we can have adhesive joining process, we can have mechanical fastening with the help of screws, bolts or rivets.

We can have welding in which we can have a fusion welding or we can have a diffusion welding. So, we can have different types of welding processes but all the 3 the adhesive joining, the mechanical fastening and the permanent joining in terms of welding will help us to realize a very very complex product. A product may be having a very complex geometry which is difficult to assembled, so which is sorry difficult to manufacture using any one standard process.

So, that product will be made in parts and these processes that we are going to discuss today will help us to assemble these parts or components to get the final product. So, one by one we will try understand the basics of the processes and in the subsequent sessions during this week we will see that how we must design our products. So, that it is easy to assemble that is part number 1, then if the product has to be made by adhesive joining what product design guidelines we must follow.

If the product has to be weld it together with the subassemblies have to weld it together what are the guidelines that we must follow similarly for mechanical fastening also. And if you remember in the third week of our discussion on this specific course we have discussed the various tools and techniques which help us to design the product in the most efficient and effective manner.

And there we have considered the concept of design for assembly which means that we must design our product in such a way that it is easy to assemble. And there were so many DFA guidelines which we must follow during the design of our product. Now what are these guidelines, these guidelines were related to the top down type of assembly approach, minimize the part count that is number of components must be minimized.

Then ensure modularity in design or ensure the modular design combine the parts wherever possible. So, there were number of guidelines which fall under the DFA, so what is DFA let us start today with our discussion for DFA. That when we are designing a product we must keep in mind that the product must be easy to assemble and when we have designed the product with minimum assembly operations.

Then how to do the assembly that is the subsequent part of today's session maybe by using a adhesive joining. So, where adhesive joining is applicable we will try to see, where mechanical fastening is applicable we will try to see, where welding is appropriate we will try to understand. So, before going to that where we will only follow the assembly or the joining processes wherever they are necessary.

First and foremost we must try to make the modular part where we have minimum requirement of the assembly, processes and that is in line with the design for assembly which we have already covered.

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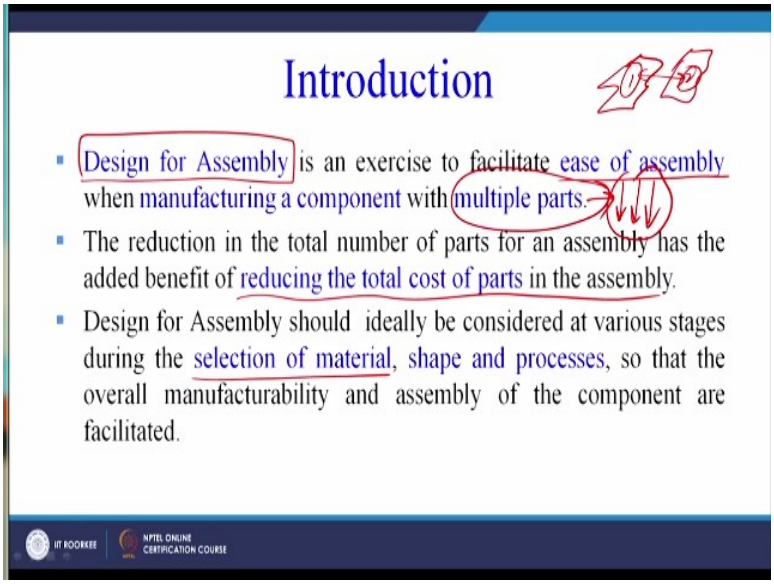

So, for in design of assembly what do we do, so DFA design for assembly is an exercise to facilitate ease of assembly. So, when we are designing a specific product for example we must try to design it in such a way that it is easy to assemble with the other part. So the design guidelines must be kept in mind during the design stage only. So, design for assembly is an exercise to facilitate ease of assembly between the different parts when manufacturing a component with multiple part.

So wherever multiple parts are there we must design the product in such a way that it is easy to assemble. First and foremost we must also try to reduce the multiple parts by redesigning a product. The reduction in the total number of parts for an assembly has the added benefit of reducing the total cost of parts in the assembly. So we will reduce the cost of parts when they are going to assembled together if we are able to if as I have already mentioned here.

Reduce the number of multiple parts that go into the assembly, design for assembly should ideally we considered at various stages during the selection of material. So when we are selecting the material we must be very cautious regarding the DFA guidelines. Because the parts have to

be finally assembled into the final product shape and processes that we are going to use, so that the overall manufacturability and assembly of the component are facilitated.

So overall our objective is to make the product with the minimum manufacturing cost and for that we have to keep in mind all the guidelines. The design for manufacturing guidelines, the design for assembly guidelines, the design for safety, design for reliability, design for production, design for manufacturing manufacturability and assembly. So, there are number of different types of and I must add the word conflicting guidelines, why conflicting.

Because of one of the guidelines are by following one specific guideline we may be transgressing into or we may be violating some of the other guidelines. For example if we religiously follow the design for manufacturing guidelines we maybe violating some aspect of design for assembly guidelines. And if we religiously follow design for assembly guideline we may be violating some of the basic principles for design for assembly which we have already understood during our 3rd week of discussion.

So, overall to ensure the manufacturability of our product we must keep in mind that the joining processes must be limited to a very less number. Because if we have lot of joining processes to be done the cost of the product will definitely go high. And therefore you will see that in most of the design these days we talk about modularity. We talk about modular designs with minimum requirement of assembly.

So the first and foremost thing that we must keep in mind is that we have to minimize the number of parts which need to assembled together to get the final product. And in case of the assembly operations are required what are the processes that we are going to study in the subsequent slides.

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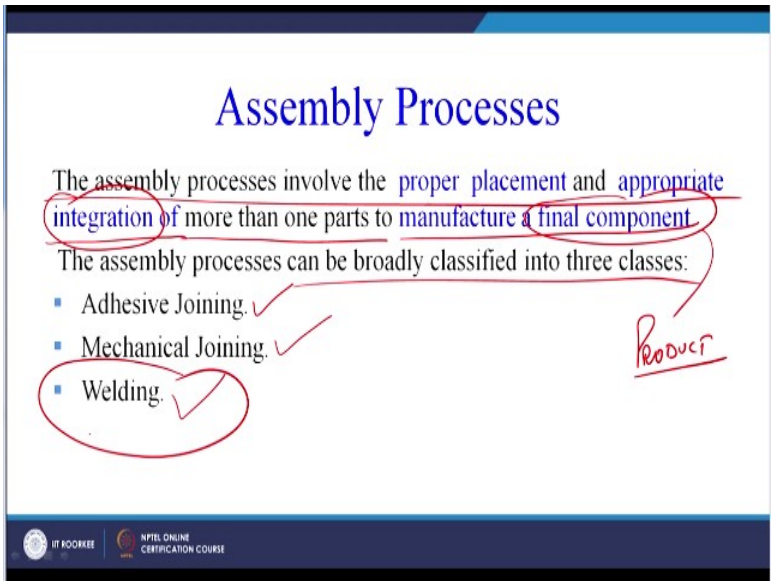

So, the assembly processes you can see, the assembly processes involve the proper placement and appropriate integration of. So, we have to ensure that the 2 parts which need to be joined together or place properly and appropriate integration of more than one parts to manufacture a final component. So, our final component is the final product that we plan to produce, so assembly processes will involve the proper placement and integration of more than one parts.

Now this word integration if in mathematics also we see we add up, so integration means we are trying to integrate 2 or 3 different parts together. So the assembly processes can broadly be classified into 3 classes, so we can see adhesive joining, mechanical joining and welding. So, most commonly we see from mechanical engineering point of view and joining of metallic parts we take different types of welding processes.

So, if the product has to be manufactured and if we talk about usually I take the examples from our day today life. If we talk about the camera that is recording this video or may this is recording this session. The camera is a highly complex part and there maybe 100 or 150 parts that I can see which may have been assembled together to bring this overall product into picture, so the overall product is our camera.

But number of assembly operations have been done, number of different parts of different materials have been joined together, assembled together to make this product. So, we cannot

undermine the importance of assembly operations specifically in case of product design. So, when we are designing a product we must ensure that how the product is going to be finally assembled, what are going to be the subparts and how these subparts have to be integrated.

And many a times we may not be really interested that the user maybe able to see the joints. So, we need to sometimes camouflage or sometime cover the joints in such a way that the user is not able to comprehend that how the product has been joined together. So, the joining approach or the joining methodology that is going to be adopted is very very important and it cannot be just like that we design a product and when we start assembling the product we are not able to assemble it properly why?.

Because we have not understood the complexity in the assembly as well as we have not given due attention to the joining processes. During the product design process and therefore understanding these processes is very very important, what is the versatility of the process, how it can be applied, what are the specific areas where this can be applied. So, all that we need understand, so today is an introductory talk about the assembly processes.

And in subsequent sessions we will talk about in detail that what are the product design guidelines for the specific processes.

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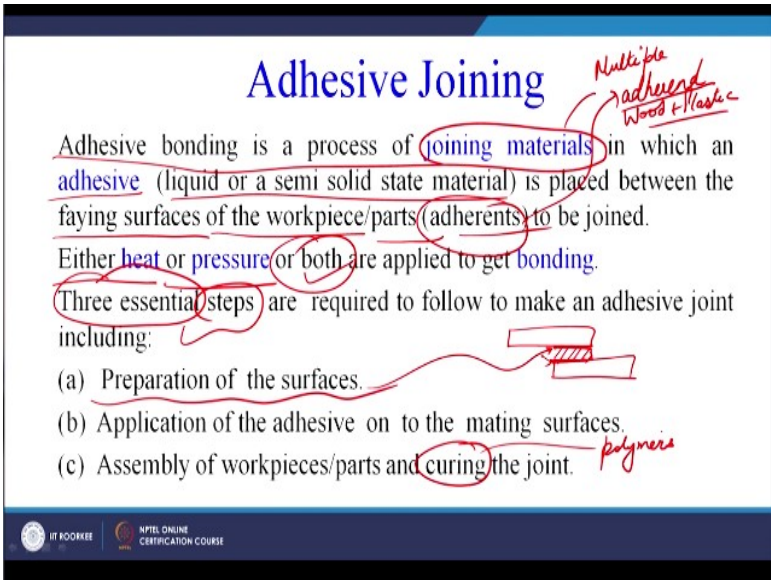

So, the first one is the adhesive joining and again I am going to take an example from our day today life. In our daily life for our children if a toy is broken we usually try to fix it using any standard adhesive which is available in the market. So, we go and buy a adhesive bring the 2 parts together do some surface preparation and apply the adhesive leave it for maybe a day the product is joined or the product that in this case is a toy is joined.

So, that is a very simple example of adhesive joining, normally we do, we take our shoe the sole has come out we take it to a cobbler the cobbler applies the adhesive and then fixes the 2 parts together that is an example of adhesive joining in our day today life. But adhesive joining is also use for engineering structures for engineering products. And what is the adhesive joining if you have understood the example I do not feel that you will feel any problem understanding what is given in this slide.

So, you can see that adhesive boding is the process of joining materials, now materials can be multiple materials also. So, we use the word adherent for the material that is to be joined, so the adherents can be of different materials. You can join wood plus another part can be made in plastic or it can be metal or a wood. So, you can have different types of adherent, so adhesive joining is a process of joining materials in which an adhesive which I have already told a kind of polymer that we use for joining the 2 parts together which can be in a liquid or a semisolid state material.

If you go to the market and you buy an adhesive to join the toy which is broken you will see that it will be in a semisolid or a viscous state. So, liquid or a semisolid state, so the adhesive is placed between the faying surfaces, the surfaces to be joined together of the workpiece or the parts which is given here adherents to be joints. So, this is the word that I have already mentioned here, so these are the adherents that we need to join together.

Now either we will apply the heat or we will apply the pressure sometimes when we have to join the 2 pieces together we put the adhesive we join them and then we keep some weight on top of this 2 layers that we have joined, why do we keep the weight. So, because that is applying the pressure and in some cases we may supply some heat also. So, either heat or pressure or both are

applied to get the perfect bonding between the 2 workpieces or the 2 adherents that we want to join together, 3 essential steps are required to be followed to make an adhesive joint.

Now these are the 3 step process and specifically the adhesive joining first one is preparation of the surfaces. The surfaces may not be that smooth suppose this surface I want to join with this surface, this is my overlap area where I want to apply the adhesive. Now these 2 surfaces that I am joining may not be ready to be joined together. So, first thing is we need to do the preparation of these 2 surfaces, application of adhesive on the mating surfaces.

So, we have to apply the adhesive here as I have shown with the thicker line, assembly of the workpiece part and curing of the joint. Now curing is the process for the polymers in which they become solid from the semisolid state, so that is the very basic definition of curing process. Otherwise if you want to understand curing you have to understand it from the chemical or the chemistry point of view or the chemical engineering point of view where we talk about thermosets we add a hardener into it.

And there is a reaction and then the 3 dimensional molecules are formed or network of molecules is formed which lead to the solidification of a polymer. So, we are not going into that much detail but we are going to understand that there are 3 steps which a product designer must keep in mind when the product is designed. So, that surfaces can be prepared to be joined by adhesive joining, so this is these are the 3 steps which is absolutely clear preparation of the surface.

Sometime surface is very very smooth, very difficult to join using the adhesive. So, you will increase the surface roughness by rubbing the sand paper on the surface. So, first and foremost we have to prepare the surface, we have to second is apply the adhesive, third is apply the pressure or sometimes the heat maybe supplied and curing of the joint will take place and then the joint will be formed, so these are the 3 steps.

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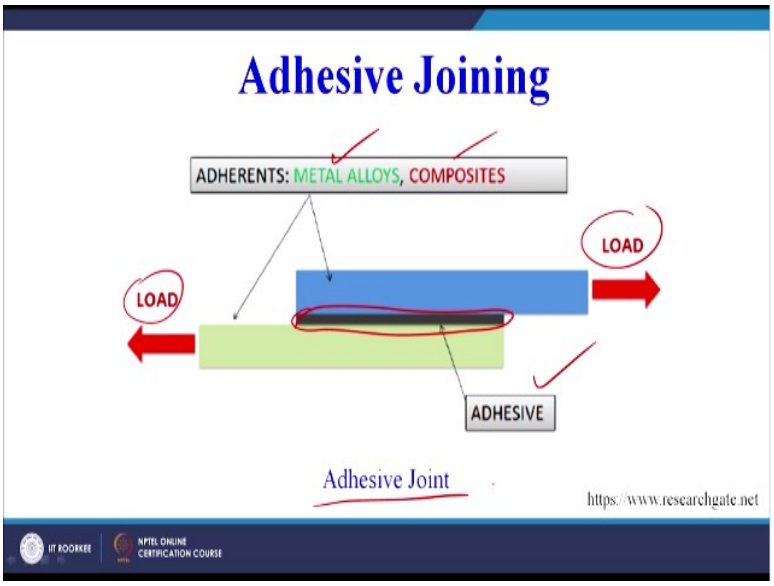

Again this is explained here we can use metal alloys also that adherents, composites can be used. This is the load that is being applied, this is the joint a black portion and this is the adhesive which has been used, this is the adhesive joint. So, we can see very easy process, very simple process, no expertise is required maybe little bit of training can help you to make the adhesive joints.

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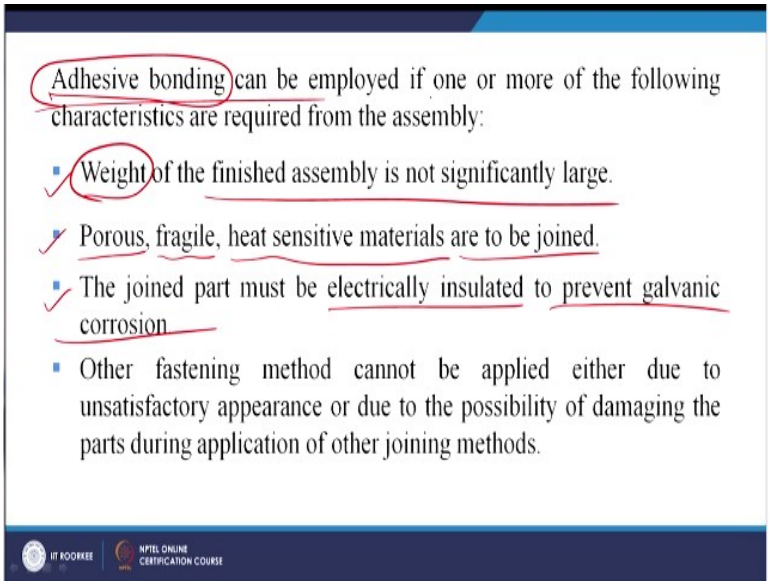

Now adhesive joining can be employed if 1 or more of the following characteristics are required from the assembly. Now when we have done assembly we are going to do the assembly or 3 or 4 different parts together what are the essential characteristics that are there in the assembly that

will ensure that we can make use of adhesive joining there. First characteristics is weight, weight of the finished assembly is not significantly large.

So, if the weight of the assembly is less we can easily go for the adhesive joining approach or adhesive bonding technique. Then if the parts are porous or they are fragile or they are sensitive to heat they are to be high heat sensitive materials are to be joined. So, when these type of material which are porous, fragile, heat sensitive, in that case also we can go for adhesive joining.

The joined part must be electrically insulated to prevent the galvanic corrosion, so when the galvanic corrosion has to be prevented or avoided and the joined parts has to be electrically insulated in that case also adhesive joining is used. Other fastening method cannot be applied either due to unsatisfactory appearance or due to the possibility of damaging the parts during the application of other joining methods.

So, if we are applying a joining method maybe you are trying to make a hole and then you will use a fastener to make the assembly and in that hole making operation you are damaging the part. In that case you may not be able to use the mechanical fastening technique, so you will very easily go for adhesive joining technique where the other joining methods are not possible. So, there also you can apply the adhesive bonding or adhesive joining technique.

So, in summary light weight, porous, fragile, heat sensitive materials as well as where electrical insulation is required wherever the galvanic corrosion is an issue, in all those cases you can very easily use the adhesive bonding technique. So, as a product designer now we can keep in mind all these points that in these cases we must suggest we must design our part in such a way that these parts can be easily joined using the adhesive bonding technique.

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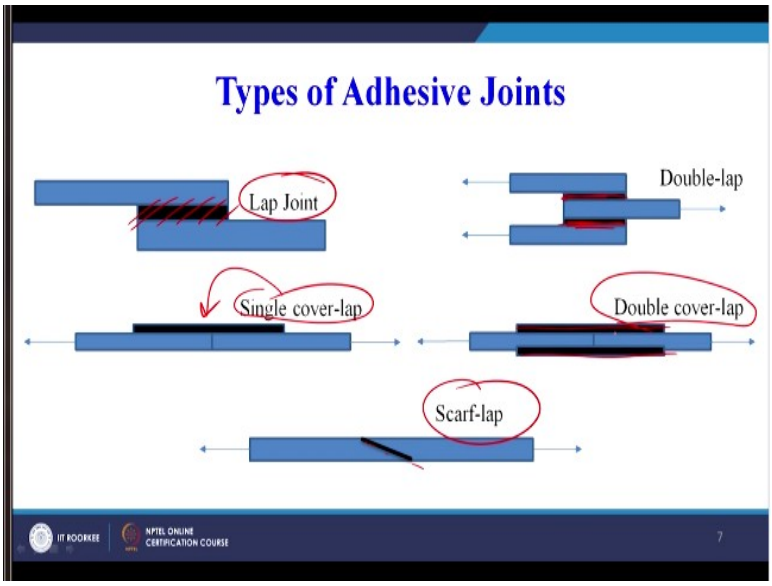

Now different types of adhesive joints can be there one is a lap joint, this is the joint area or the joint interface. Then double lap this is one adhesive bonding, this is second then double cover lap joint we can see this is double cover is there, this is the overlap area here. Then the scarf we can see this is a scarf joint, this is single cover lap, cover lap is on one side only here it is on 2 side.

So, you can your product that what type of joint will be able to help you to join the 2 parts together. So, different joint configurations you can select there is a wide variety even you can design your own joint configuration only thing is the 3 steps will remains same that is preparation of the surface, application of the adhesive and finally curing of the adhesive under heat and pressure. So, these 3 steps remains same, the joint configuration you can design as per your requirement.

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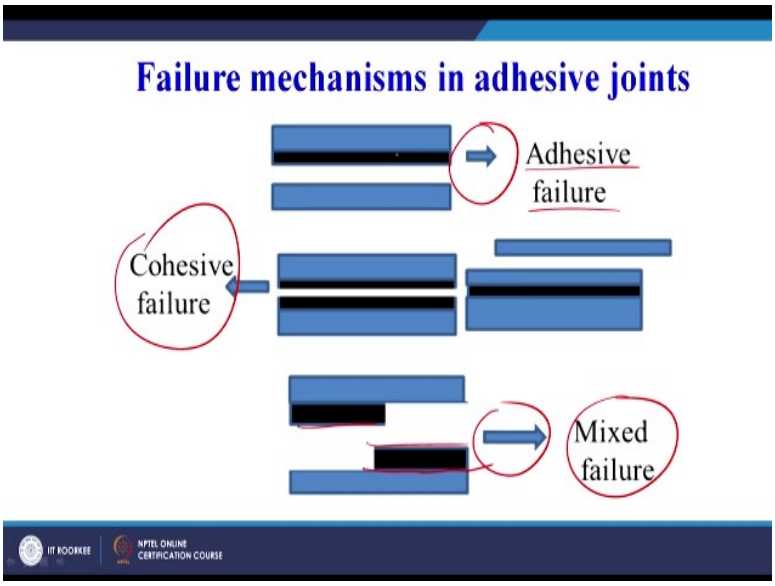

Now these are the failure mechanisms likely we are going into the depth now, these can be adhesive can fail, adhesive failure. There can be mixed failure this can get de-bonded from here and the adhesive has also failed from here then there is a cohesive failure here. So, different type of failure may take place when the product is loaded under the different types of loading environments it can be compressive load, it can be tensile load here we are showing tensile only.

But it can be under compression under shear under different types of loading environments the failure might be different depending upon the kind of bonding that has been developed between the 2 adherents. Now what are the advantages of the adhesive joint fast and cheap I will just read.

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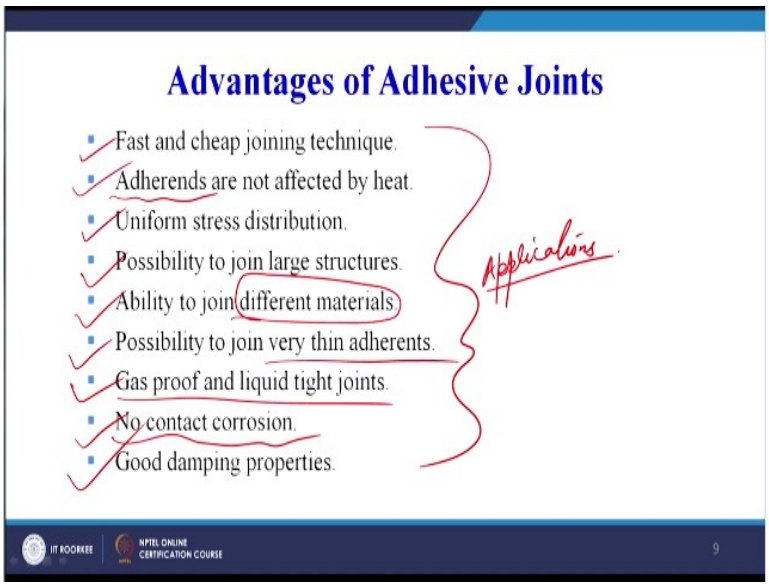

If you have understood the adhesive joining it will be easier to understand fast and cheap joining technique, adherents are not affected by heat maybe adherents are not effective. But if lot of heat is there the adhesive may get affected by the heat if in service you find lot of heat. Uniform stress distribution, no stress concentration is there uniformly the stress is distributed over the whole adhesive area, possibility to join large structures, ability to join different materials.

Different materials as we have seen the adherents can be of different material, possibility to join very thin adherents which is otherwise very difficult. Gas proof and liquid tight joints can be made, no contact corrosion, galvanic corrosion is also avoided, good damping properties. So, we can see a long list of applications where the adhesive joints can be easily used, so these are the areas where a product designer can think of using the adhesive bonding or joining techniques.

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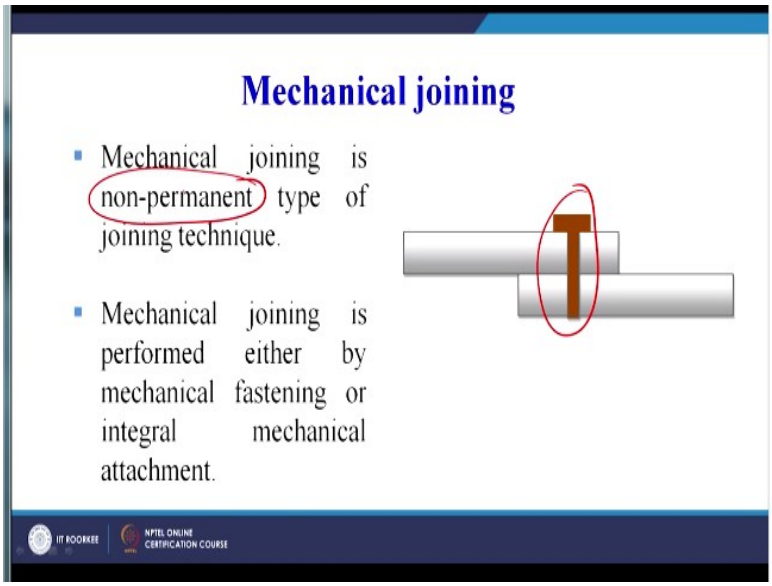

Now coming onto the mechanical joining all of us have seen number of application areas of the mechanical joints. So, mechanical joining is a non permanent why it is non-permanent because we can always unbolt the joints. So, mechanical joining is a non permanent type of joining technique, mechanical joining is performed either by mechanical fastening or integral mechanical attachment.

So, you can do maybe a fastening using a fastener or it can be a integral permanent attachment of mechanical type. So, you can permanently use a mechanical fastener in your assembly, so fasteners we can see.

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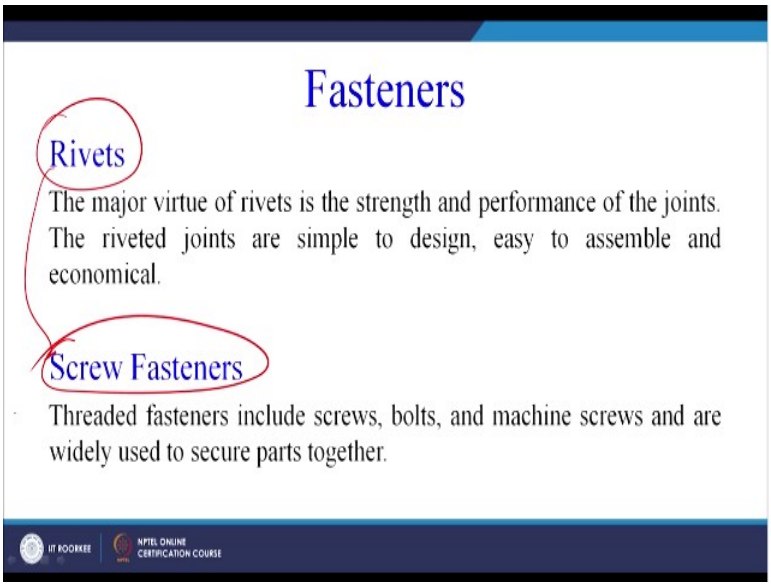

We have 2 types rivets as well as your screw fasteners, so what are rivets the major virtue rivets is the strength and performance of the joints. The riveted joints are simple to design easy to assemble and economical, screw fasteners threaded fasteners includes screws, bolts and machine screws and are widely use to secure the parts together. So, 2 types of fasteners are used rivets and the screw fasteners.

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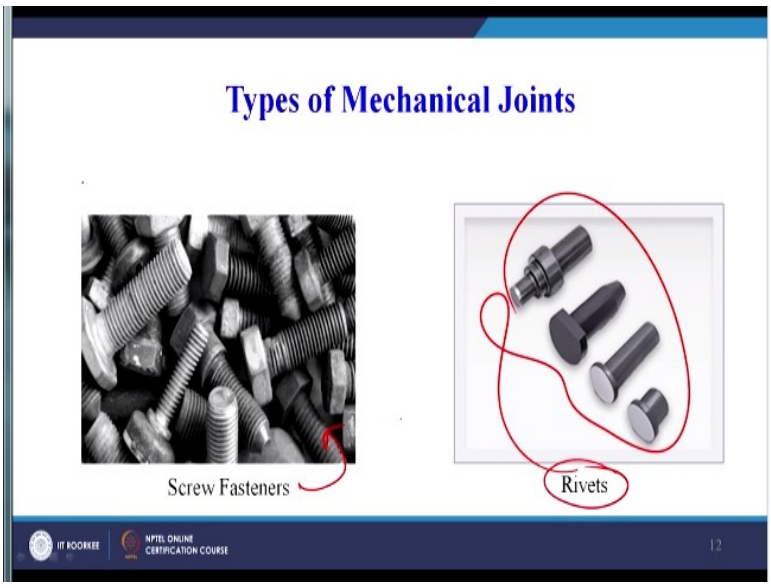

Now these are the types of mechanical joints you can see the rivets here, different types of rivets are there and these are the screw fasteners or the threaded fasteners.

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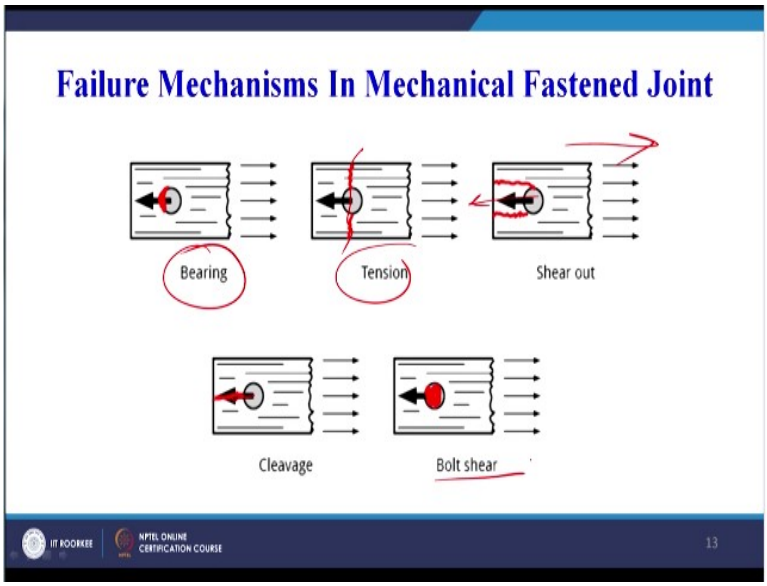

Now failure mechanisms in mechanical fastened joints we can see here, we can have bearing type of failure under tension. This is the type of failure which may take place, shearing out we are applying the load in this direction and this may shear out in this direction. Then cleavage can be formed it is shown here, it is a bolt shear can also take place, the bolt may also fail, the workpiece may fail or the bolt may also fail in some cases.

Depending upon the type of loading environment, depending upon the material of the bolt that we have selected depending upon the material of the adherents that we are using, different failure mechanisms may take place during the loading of the mechanically fastened joints. Now what are the advantages of mechanical joints.

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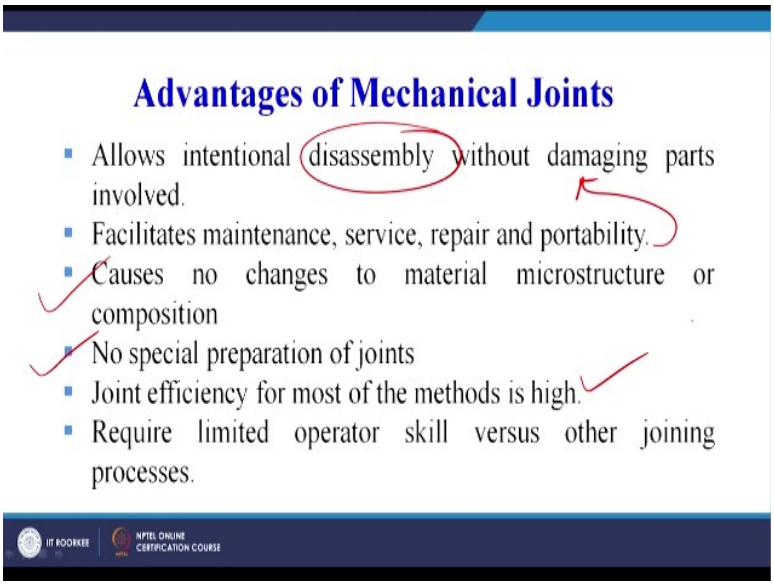

This allows intentional disassembly without damaging the parts involved, this is as we have seen it is not a permanent joining techniques. So, we can disassemble the structures also where mechanical joints or mechanical fasteners used. Facilitates maintenance, service, repair and portability which is a direct reflection of the first point. If you can disassemble your structure you can easily do maintenance service repair and portability.

This causes no change to the material microstructure or composition which is in contrast to the adhesive joining technique as well as the welding where the microstructure may take place. in adhesive joining also we do the surface preparation, so the surface morphology is affected in case of adhesive joining. But here no such problem is there, no special preparation of joints is required, joint efficiency for most of the methods is high.

So, as compared to adhesive joining the joint efficiency is better in case of mechanically fastened joint, required limited operator versus other joining processes. So, for adhesive joining also minimum skill set is required whereas in adhesive joining minimum skill set is required. In mechanical fastening it is still easier, easily a person can do the assembly operations most of the time it is done manually.

Now coming onto the last process we are also running out of time, so welding is a very very important process and it has been dealt in much more detail there are courses available under

MOOC's scheme focusing on welding. But we will just try to highlight to our learners what is welding, so that when you design a product you understand the basic intricacies involved in the welding process.

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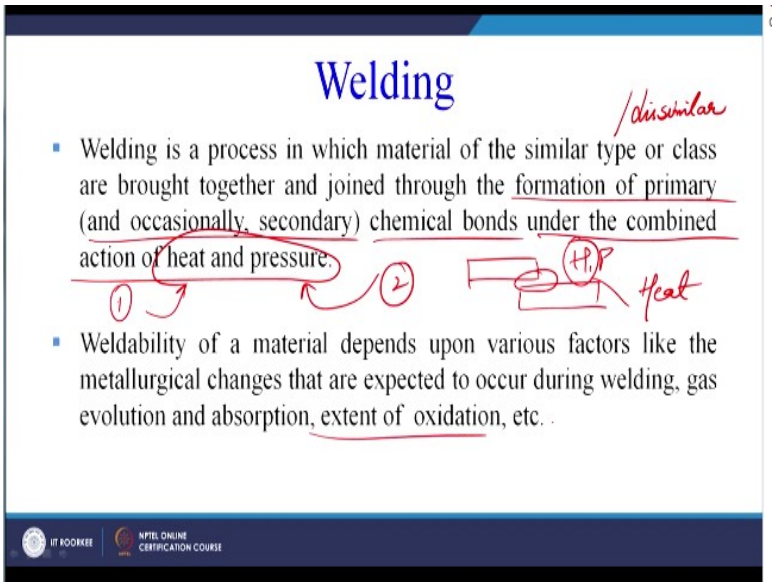

So, welding is a process in which material of a similar type or a class are brought together and joined through the formation of primary and occasionally secondary chemical bonds under the combined action of heat and pressure. So, one thing I would like to suggest here in this definition it is a little change welding is the process in which material of similar type or class. So, these days we have processes where we can use dissimilar materials also.

So, we have a welding technique maybe an advanced welding technique where dissimilar materials can also be joined. So, we have to join the 2 materials together either by formation of primary or secondary chemical bonds under the combined action of heat and pressure. So, these are the 2 important inputs heat and the other input is the pressure. So, we have to join the 2 pieces together at forming a joint here by the application of heat and pressure.

Weldability of a material depends upon various factors like the metallurgical changes that are expected to occur we have seen that in mechanical fastening no changes occur at the metallurgical level. But in welding metallurgical change of the microstructure of the 2 metals which were joining together is definitely going to change. Because here one of the inputs is heat,

so when you heat the material above it is melting point and then you allow it to solidify certainly certain metallurgical changes are going to happen.

So, the metallurgical changes that are expected to occur during welding will definitely govern the weldability of the material, gas evolution and absorption, extent of oxidation. So, usually we say aluminum oxidizes very easily. So, maybe the materials that we are going to welded the characteristics like oxidation, evolution and absorption of gases, metallurgical changes expected are going to affect the weldability of any material.

So, when we are selecting a material for our product and we feel that later on it has to be welded to another part in order to get our product. In that case we must be very careful and study that what kind of metallurgical changes can happen during the welding process which may affect the performance of our product. And welding is a very diverse field a very exhaustive field.

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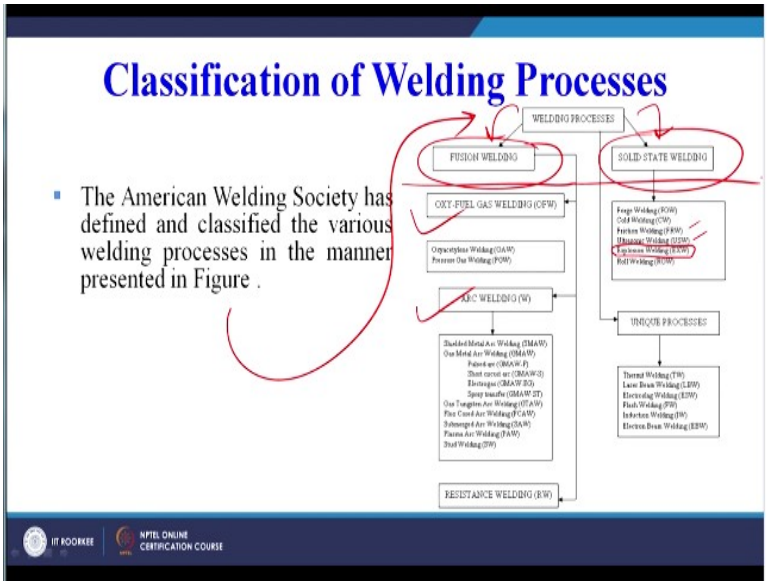

And the welding processes are basically you can see classified into 2 major categories, we will not go into the detail of each one of this. So, the fusion welding and the solid state welding, so the American welding society as defined as classified the various welding processes in the manner presented in the figure. So, this is the figure you can see major classification is fusion welding and solid state welding and in solid state welding we have an explosive welding technique, ultrasonic welding, friction welding.

And in fusion welding most common oxyacetylene welding, oxy-fuel gas welding or oxy fuel gas welding and arc welding. So, generally we use oxy fuel gas welding as well as arc welding and arc welding has further classification like gas tungsten arc welding, submerged arc welding, plasma arc welding, stud welding. So, we have different types of welding techniques available, so as a product designer I must have a basic idea that when I am designing a product and it has to be welded during the product fabrication stage or during the product assembly stage.

I must take care of the choice of materials, the type of design, the geometrical features that I am putting in the product. So, that it is easier to assemble at a lateral stage and for welding there is a wide variety of processes which are material specific which are heat input specific which are metallurgical changes specific. So, depending upon the various factors that influence the weldability of materials we must choose the material as well as we must choose the appropriate or the specific process.

So, in fusion welding we will try to understand because in the previous slide we have seen 2 major categories are there fusion welding and solid state welding and then there are subcategories to this.

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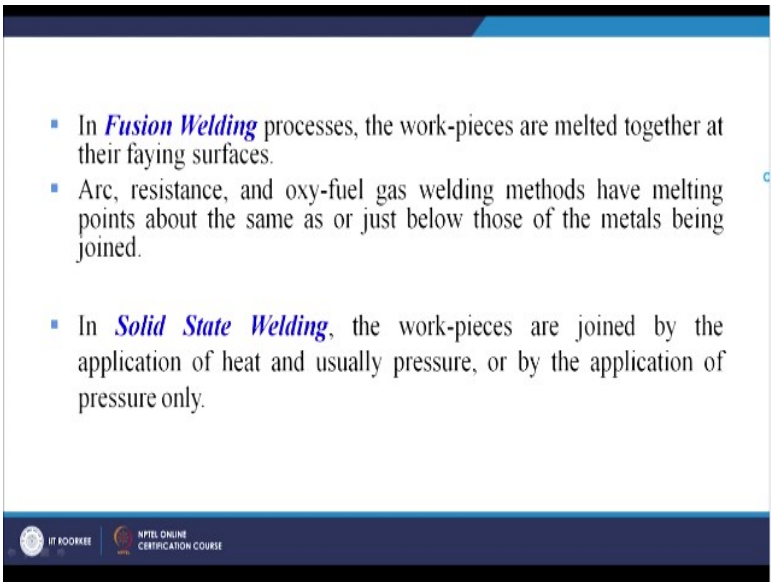

So, fusion welding, in fusion welding processes the workpieces are melted together at their faying surfaces. Arc welding resistance and oxy-fuel gas welding methods have melting points above the same as or just below those of the metals being joined. In so we will heat the metal, we will try to melt the metal and then fuse the metal together to form the joint, examples are given.

In solid state welding the workpieces are joined by the application of heat and pressure or by the application of pressure only. For example forge welding or friction welding, so these are 2 broad classification of the welding processes.

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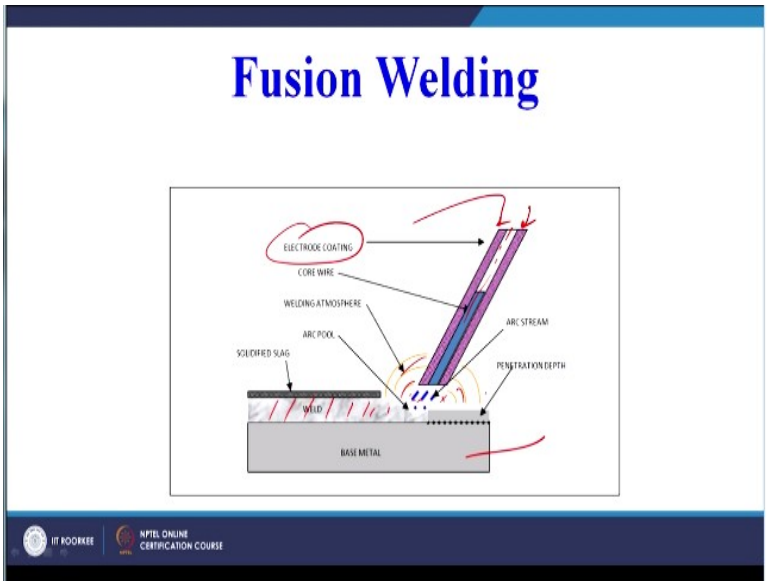

Now this is an example of the fusion welding process, we do it this is the base metal, this is the weld that we are depositing, this is the electrode, it is a coated electrode, electrode coating is shown here. This is the coating and inside we have an electrode wire, so we have a core wire or the electrode wire and this is the welding that is taking place here. So, this is a simple example of an electric arc welding process.

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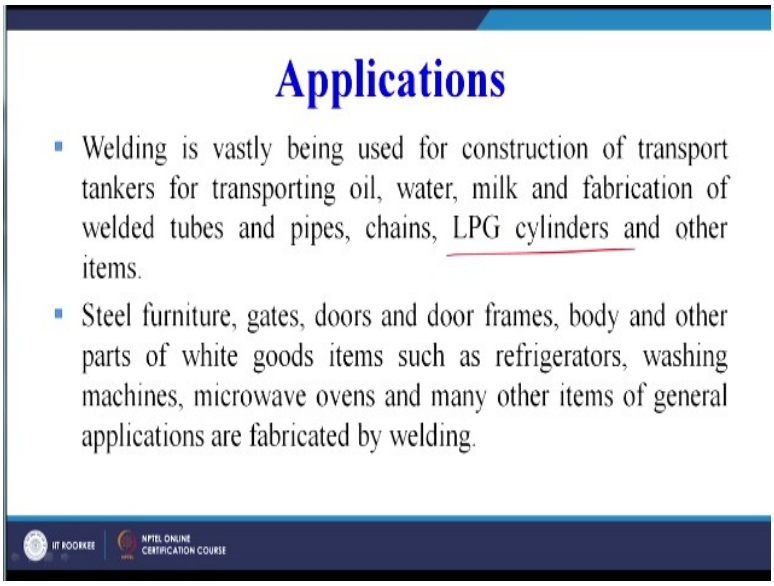

Now what are the applications of welding, welding is vastly being used for construction of transport tankers for transporting oil, water, milk and fabrication of welded tubes and pipes, chains, LPG cylinders and other items. So, you can see one of the application that we see in our day today life steel furniture, gates, doors and door frames, body and other parts of white good items such as refrigerators, washing machines, microwave ovens.

And many other items of general applications are fabricated by welding. So, I must summarize that welding is a most important joining process which we see around us for the products that we see around us. So, with this we conclude the today's session, this was just an overview of the various joining processes. So, now subsequently one by one we will take a process each and try to see that what are the various guidelines that are established for designing of various parts which are to be made by the joining processes.

Thank you.