Manufacturing Guidelines for Product Design
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Lecture-31
Induction Welding: Plastics

Namaskar friends, welcome to session 31 of our course on manufacturing guidelines for product design. So we have completed 6 weeks of discussion and we are left with 2 weeks of discussion on this very important topic. So, in the last 6 weeks what has been our target, our target has been to briefly review the manufacturing processes, to briefly review the engineering materials and then we have to establish a correlation between the materials and the processes.

And if you see today on the slides the title is induction welding and the material is plastics, so in our course in the very beginning during first week and second week of our discussion we focused primarily on the basic aspects of manufacturing and basic aspects of engineering materials, why because we have to combine the 2 things together. We have to take a material and then we have to select a process and accordingly we have to match the 2 things together to make a tangible product.

So, here we see that induction welding of plastics is an important topic why because plastics as we see are being used widely for a wide variety of applications and if maybe I can give you an assignment right now. You just look around you your visualizing or you are maybe listening to this session on your laptop or on a desktop or on your mobile phone. So, maybe one of the applications you can see as a cabinet of a desktop or a body of a laptop or a cover of a mobile phone.

And if you start looking around you, you will see n number of other plastic products and it is very difficult to make a plastic product as a single moulded part. Although it is our target that we must try to minimize the joining operations for the plastics but our target usually sometime is not met, why? because of the design complexity because the plastic may sometimes be required to be joined with other materials.

So, depending upon the design requirement we have to select a process for joining of plastics. So, I was just discussing that what we have already discussed in our course we have already discussed the course. We have already discussed the basic aspects of manufacturing and materials and then we have learnt some soft techniques like the design for manufacturing guidelines, we have see design for x robust design.

And finally we shifted towards the processes, we have seen that what are the various guidelines for various types of processes. If you can remember we have discussed the design guidelines for sand casting process or the products that will be made by sand casting. We have already discussed the design guidelines for the products to be made by die casting process, products to be made by injection molding, products to be made by compression molding.

So we have tried to see that how the product design must be changed in order to fabricate the products easily, that is what we have already understood by now. So, how to form the products then we shifted our attention towards how to machine the products and finally we shifted our attention towards how to join the different parts together to make a tangible product. And in that regard we have already finished 1 week of discussion that was a 6th week in which we first reviewed the various joining processes.

Then we discussed about the adhesive joining technique for joining of adherents, what are the design guidelines, what type of joints we must choose, what type of loading environments necessitate or specific type of joint design. We have already seen the mechanical fastening guidelines, we have already seen the guidelines for riveting. So we have seen that what are the standard processes for joining the different parts together to fabricate a product, when we are finalizing the design of our product.

We have to keep in mind that how the different parts that makeup the product will be joined together and we must ensure that joining process is trouble free. That joining process is easy, that joining process is a maybe we can say easily done. Already easy and easily done and maybe error

free, I wanted to use the word error free that there is no error during the joining process for 2 or 3 different components.

And for that reason we have already discussed that different processes are already there and if you take an example of the maybe again taking an example of the camera which is recording this session. So in the camera if this say I can easily see from here there are different parts maybe there are 25 to 30 different parts, some of them are made in plastic, others are made in metals, so, how to join all these parts together to make this assembly is a challenging task.

So, when we are designing the various parts of this camera, we have to take into account that how these parts will be joined together to make a final product which in this case is a camera. Therefore we must learn, we must know, we must understand that what are the various types of joining, processes and what are the guidelines that we must keep in mind while designing a parts. So, in that context only with that reference what we have already discussed we are carrying forward our discussion regarding joining.

Because joints are the most important parts in any product design and again I am repeating the thing that joints are the most susceptible to failure also. If we take an example of our body also whenever we have accidental fall always there is a chances that we may get injury at one over the other joint in the body. So therefore joints are most susceptible to failure and therefore they must be joined properly in order to ensure a trouble free life for the product in which we are using these joints.

So in that regard our title today of induction welding is very important, so there are 2 aspects here 1 aspect is to just have a brief review of the induction welding process. And the second is how induction welding can be used for joining of plastic parts, although it can also be use for joining of the metallic parts also and is a well established process. So, whatever processes we have covered till now.

Such as the riveting, mechanical fastening, welding, all these processes are well established for metals, but it is difficult to weld the plastics using the standard welding processes. Such as the

electric arc welding or the gas welding why because the kind of temperatures that we see in arc welding and gas welding. In arc welding normally we get a temperature of 6000 degree centigrade depending upon the setting of the current and the voltage.

And in case of gas welding also depending upon the type of flame that we have produced we may get a temperature up to 3300 centigrade. Of course that will depend upon the type of fuel gas that we have selected depending upon the calorific value or the maybe that heat content of the maybe we can say the temperatures that can be achieved with a particular type of gas or the fuel gas.

The temperature is may vary but in general we can say round 3000 centigrade is achieved in gas welding. So now you can see 6000 degree centigrade in arc welding, 3000 degree centigrade in gas welding and our plastics cannot sustain those type of temperatures. So therefore we need to look for additional processes which can be used for processing of in general processing and in particular joining of the plastic parts.

So let us today revise the induction welding process for joining of plastics as well as try to look at maybe 2 or 3 or 4 guidelines which may help us to design the parts which are going to be joined for plastics or which are going to be joined for making the final product. Let us quickly I think the introduction has been a bit longer today, so let us now quickly jump to the topic because we are going to start this discussion for the complete week.

So, this introduction is not only for this particular lecture that is session number 31, but it is for the complete week starting session 31 to session 35. We will be looking at different types of processes which are used for plastics, today our target is induction welding tomorrow we may discuss vibration welding, ultrasonic welding or maybe microwave heating process for joining of plastics, so, we will cover all these topics in the subsequent session.

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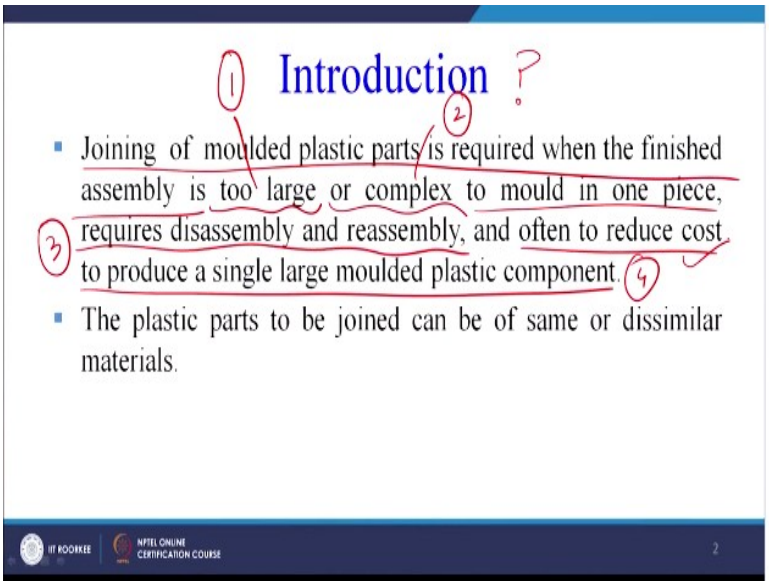

So, let us start our discussion now as we can see joining of moulded plastic parts is required when the finished assembly is. Now first we are trying to understand that why the joining of plastic parts is at all required. Already we have seen if we have gone through the sessions you may have seen that injection molding is 1 process for making the plastic part, compression moulding can give us even bigger parts there is a technique all rotational moulding, there is a technique called thermoforming.

So, we have so many processes which can be use for making the plastic parts, why do we need to join, we must directly make the plastic part. So, there have to be some reasons that why joining of plastics is required, so here we are trying to answer that question. That is a very very important question that why joining the plastics or why joining of plastic is necessary. So, joining of moulded plastic parts is required when the finished assembly is.

First reason is joining assembly is too large or the product is too large or second is it is very very complex, the design is such that it cannot be made to an near nut shape using any one of the plastic forming processes. Such as injection moulding or compression moulding, so it is complex part, it is very large part to mould in 1 piece as I have already told near nut using a standard plastic forming process it is difficult to make.

So, 2 things 1 is it is very large, large assembly second one is complex shape complexity is there, third requires disassembly and reassembly to facilitate the maintain and sometimes we may have to disassemble the parts, so that to facilitate that we require joining of parts. And often to reduce cost to produce a single large moulded plastic component, so the cost is equally important.

So, what is coming out of here there are 4 major there can be minor factors also what 4 major factors that necessitate the joining of the plastic parts, 2 large assemblies, complex geometries facilitate the maintenance or serviceability using disassembly and assembly again. And finally the cost of manufacturing a large single part usually forces us makes it necessary for us to make the plastic parts in small components and then join them together to make a complete assembly of the product.

So, I think this sentence clearly establishes the importance of joining for the plastic parts, this is same as in case of metals. The plastic parts to be joined can be of the same or dissimilar materials, so you may have a thermoplastic part and thermosetting part you may require to join them. You may require to join as we will see in today's lecture only, there is applications of induction welding of plastic where we will see a plastic is joined to a metallic part.

So all those things maybe the materials that we are joining together maybe similar or they maybe dissimilar also. So thermoplastics as I have already told there are 2 categories of plastics basically broadly thermoplastics and thermosets.

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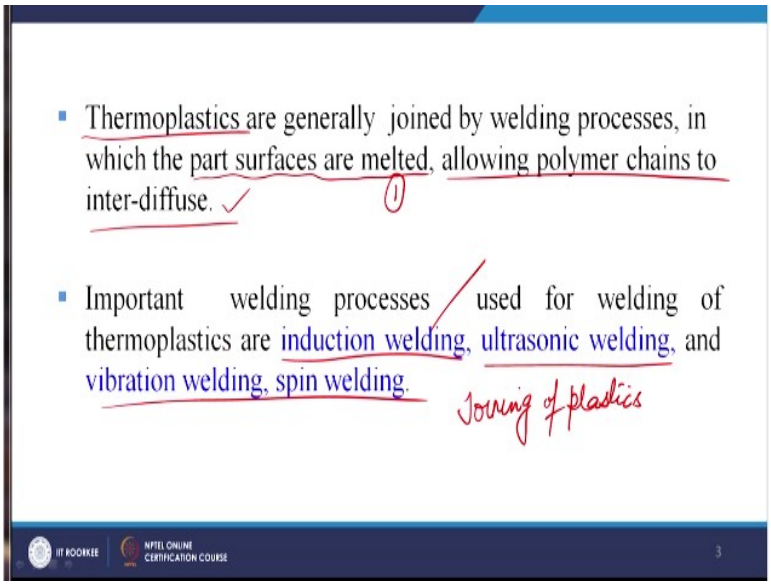

So, thermoplastics is the category which can be joined by this welding processes. So, thermo plastics are generally joined by the welding processes in which the part surfaces it will showing the procedure for welding or joining. So part surfaces are melted first step allowing polymer chains to inter-diffuse, so when you melt the parts at their interface, the polymer chains inter-diffuse and make a joint.

So, that is basically the mechanism of joining of the thermoplastic polymers or thermoplastic parts. Important welding processes which we will be trying to cover during our discussion. This is the first one induction which we are trying to cover today, ultrasonic we will try to cover in the next session, then vibration welding and spin welding. So, these are the welding techniques which can be used for the process of joining of plastics.

And as we have already seen that the plastics maybe joined among themselves also or they maybe joined to the other materials also. So, let us now quickly revise the induction welding of plastics.

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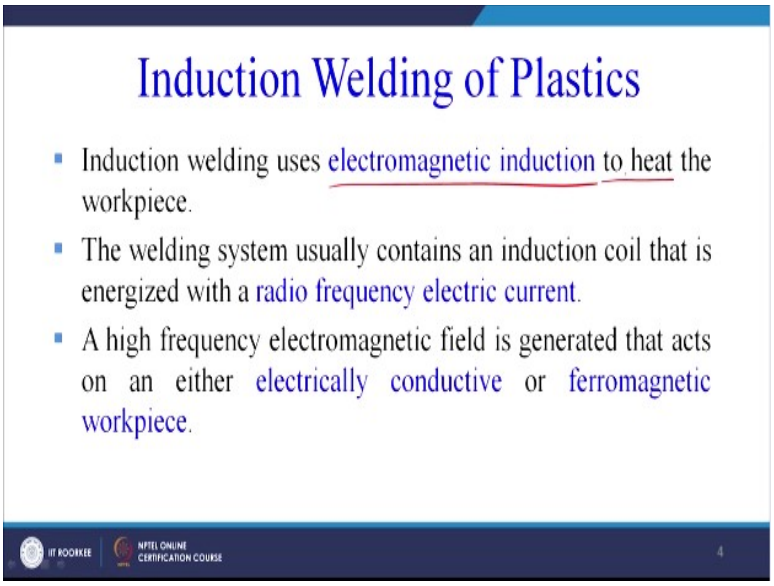

So, induction welding uses electromagnetic induction to heat the workpiece, so as you know in any welding process as we have defined welding as a process to joint 2 similar or dissimilar materials with the application of heat with or without the application of pressure. So, here also heat is an important integral element for joining the 2 plastic parts. So, induction welding uses electromagnetic induction to heat, so the heat source is in case of induction welding is the electromagnetic induction.

So, it will through electromagnetic induction, we will put the workpiece in the coil and through the induction welding electromagnetic induction effect it will get heated. And because of the heat we will be able to form the joint, so the welding system usually contains an induction coil as I have shown. This is the induction coil and we place our workpiece inside. So, it usually contains a induction coil that is energized with a radio frequency electric current.

So, we pass that current through the coil, so that in order to produce the electromagnetic induction effect. A high frequency electromagnetic field is generated that x on either the electrically conductive. Now our workpiece may be either it maybe electrically conductive or it maybe ferromagnetic. So, suppose we take an example of a coil and we place our workpiece inside the coil, so this workpiece must either be conductive or this workpiece maybe a ferromagnetic material.

So, that the electromagnetic induction effect can be introduce, so there can be different sources of heating the workpiece in case of arc welding we use an electric arc to heat the workpiece. In case of gas welding we use the flames produced by the fuel gas to produce the heat in case of maybe vibration assisted welding, we will use the vibrations to produce the heat in case of friction welding we use the principle of friction to produce the heat between the 2 surfaces to be joined together in induction welding.

We use the electromagnetic induction effect to produce the heat in the workpiece, so the source is of heat may vary, but the basic aspect is that we have to form a solid joint between the 2 parts. And these 2 parts maybe plastics this can be metals or metal to wood or metal to plastic different types of material combinations maybe use to form the joints. So, we have seen the basic here by electromagnetic induction effect will be used to produce the heat between the 2 surfaces to be joined together.

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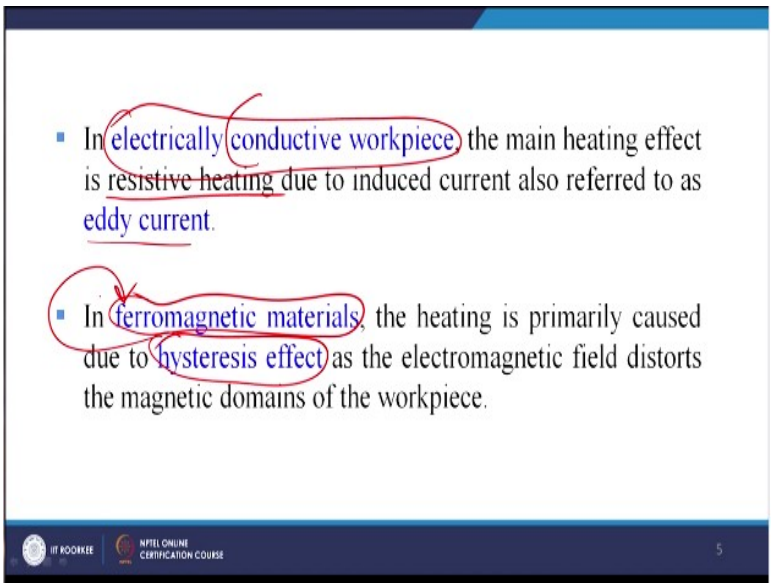

Now in electrically conductive workpiece this is just simply trying to explain the mechanism that if the workpiece is electrically conductive how the joint will be formed. And if the workpiece is ferromagnetic how the joint will be formed, let us try to understand that with these 2 sentences in electrically conductive workpiece the main heating effect is resistive heating due to induced current which is also referred to as the eddy current.

So, resistive heating is the mechanism for electrically conductive workpiece and for ferromagnetic workpiece the heating is primarily caused due to the hysteresis effect. So, the hysteresis effect is the reason for producing heat in case of the ferromagnetic materials as the electromagnetic field distorts the magnetic domains of the workpiece. So, you can understand that 2 different types of workpiece material we can use electrically conductive pieces as our workpiece material in induction welding process.

Or we can use ferromagnetic materials to make a weld using the induction welding process. Now this is very easily explaining the process of induction welding.

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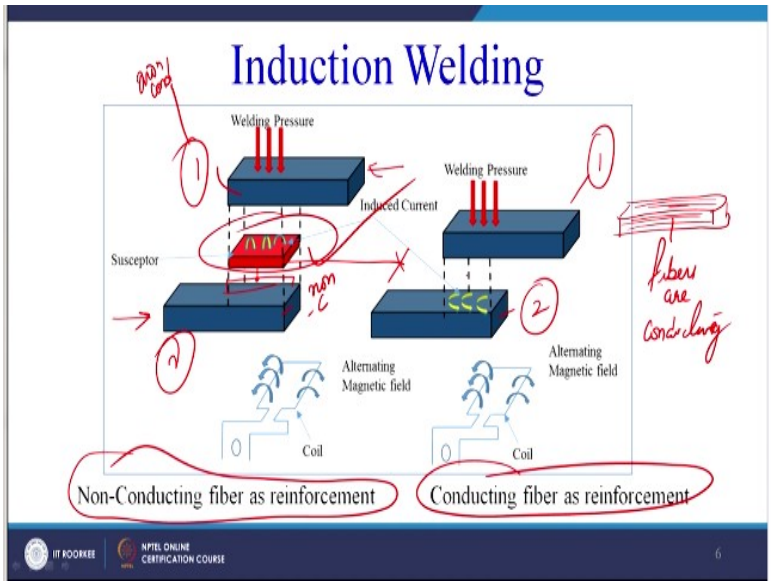

So, suppose this is the workpieces we can see these are the 2 plates, plate number 1, plate number 2 and this is the susceptor materials. Sometimes in order to facilitate the process of welding we may use a susceptor, so this is with the help of a susceptor this will be pressed down the susceptor will come here in this reason. And we will be able to form a joint between the first and the second workpiece and this is the coil which will produce the induction effect.

And here we can see that the conducting fiber as the reinforcement, so this is first part, this is second part they have to be joined here. So, this is an important part that why the susceptor is required and here there is no susceptor why because in the previous slide we have seen that

either the workpiece must be electrically conductive or the workpiece must be a ferromagnetic material.

So, suppose my point number 1 is non-conducting and this also is non-conducting, so we do not have a electrically conducting workpieces. So, when these workpieces are not electrically conducting then in that case we will use a susceptor material to introduce the induction effect. And specifically when we talk about the polymers they may be electrically non-conducting, conducting polymers are very few and or in many of them are still in the research stage.

So, when our polymers or plastics are non-conducting we may like to put a susceptor which will facilitate the joining at the interface. So, non-conducting fiber as reinforcement, so we will use, so in case of composites we have fibrous reinforcement also. So, if our fiber also I think we have already discuss the concept of composites in this course as in the very beginning in engineering materials we just introduce the concept of composite.

So, what is a composite, in a composite there maybe fibers and polymers and we call it as a polymer matrix composite. So, if the polymer is non-conducting it is not electrically conducting as well as the fiber that we have introduced in the polymer is also non-conducting. Therefore it will necessitate the use of a susceptor but suppose in a composite material if we have a conducting fiber.

So, in this case if I draw it again and try to understand the concept of fibers, so there are continuous fibers that are running in this and these fibers are what? they are conducting. So, if the fibers are conducting in that case what we will do, we this use of susceptor is not required we can directly join the 2 pieces which have the conducting fiber as the reinforcement specially in case of composite material we can join them together.

So, the basic summary is that we can join the electrically conducting or ferromagnetic material using the concept of induction welding and polymers usually are poor conductors of electricity and therefore we need to use a susceptor to join the polymer parts or plastic parts. Now here we can see the applications of induction welding of plastics.

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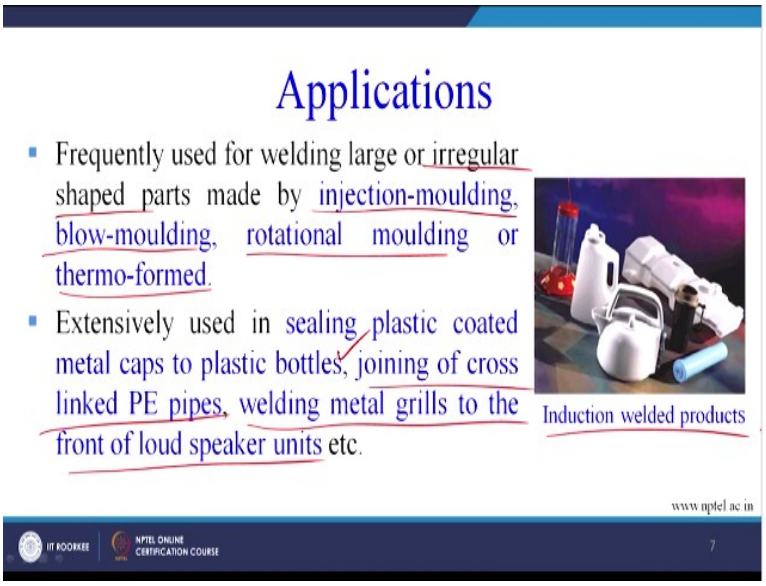

Frequently use for welding large or irregular shaped parts made now we can see irregular shaped parts when the shape is not regular therefore we need to produce them in 2 or 3 different parts and which we need to combine together. So, these parts individual parts maybe made by injection-moulding, blow-moulding, rotational moulding or they can be thermo-formed. So, we can use any of the plastic forming process to make the individual parts.

And then we can combine these parts using the process of induction welding to make a complete product. Now where are the applications, let us see extensively used in sealing plastic coated metal caps to the plastic bottles. So, this is 1 example how the plastic coated metal caps are put on the plastic bottles, joining of cross-linked PE pipes. So, polyethylene pipes can be joined together using the induction welding process.

Then welding metal grills to the front of the loud speaker units, so you have a loud speaker unit and you have a metallic front grill it can be welded to the body using the induction welding process. So, this we can see different induction welding parts, so many times 1 plastic part we want to put concentrically on the other we can have a induction coil on the top and heat it locally and form a joint, so we can use induction welding process for joining of plastic parts.

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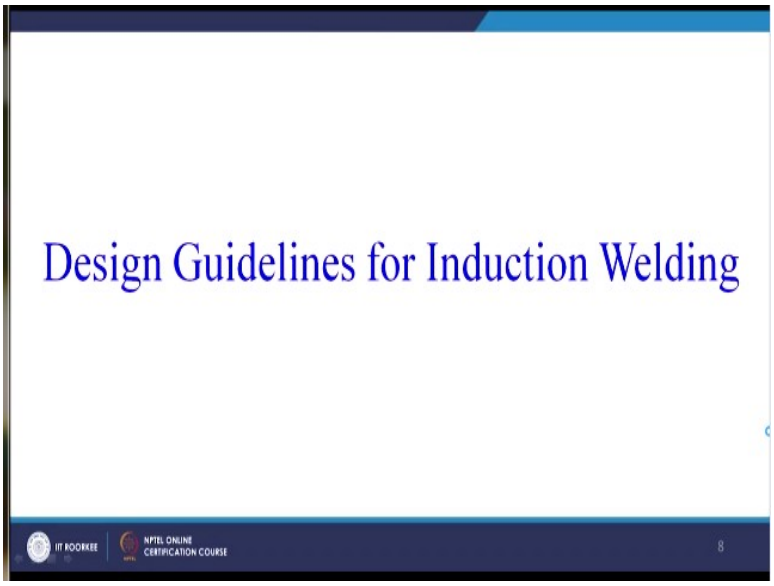

Now let us see few design guidelines quickly, there are not many available in the open literature some of them are under the patent or IPR production. But whatever is available in the general literature that we will try to understand, now what are the design guidelines.

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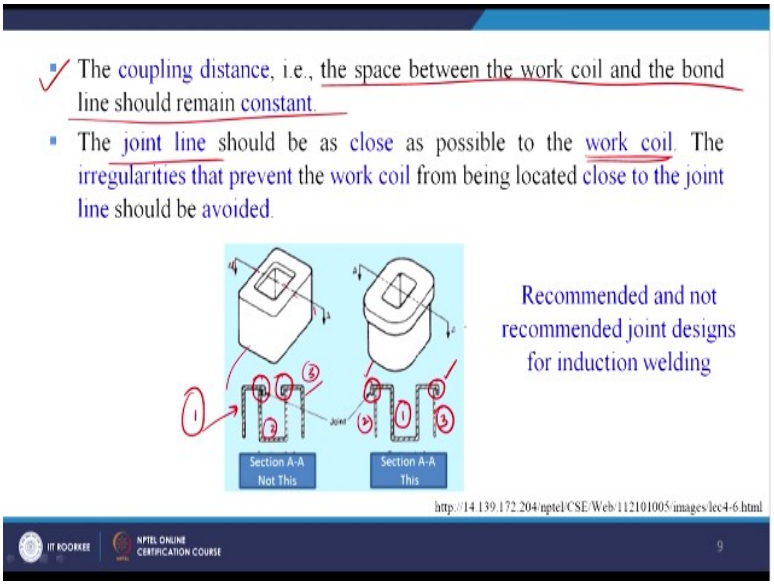

Now let us see first important design guideline is the coupling distance that is the space between the work coil and the bond line should remain constant. So, suppose this is my coil and then we put our workpiece inside the coil to heat it and once we are heating it the joint line should remain at as constant distance from the coil. So, the coupling distance that is the space between the work coil and the bond line should remain mostly constant.

Secondly we can see the joint line should be as close as possible to the work coil. So, we can see the work coil is going to produce the electromagnetic induction effect. So, our joint line where our 2 parts are going to join together this joint line must be close to the work coil. Because we need to heat at the joint interface to produce the joint, so therefore it must be close to that work coil.

The irregularities that prevent the work coil from being located close to the joint line should be avoided. So, we must have redesign our part if there are few features which forces to keep the work coil away from the joint line. All those design features must be modified in order to ensure that the work coil is close to the joint line or the bond line. So, let us see try to understand this important guideline with a help of an example.

Now here we see we are trying to form a joint here, now this joint is in this total assembly is of 3 parts this is part number 1, this is part number 2 and this is part number 3. So, we are making the joint here section A, so this is the situation at section A-A, coil will be somewhere around this. So, we want to redesign this part, so that we are able to satisfy our guideline number 2, the joint line should be as close as possible to the working coil.

Now it can be redesigned, we can see it is still made in 3 parts but the part number 1 that design has been now changed. This is my part number 2 and the joint we are going to make is here and this is a part number 3. So, here we can see our joints from the inner periphery have gone to the outer periphery, the joint is now being done here which maybe close to the work coil. So, recommended and not recommended joint designs for induction welding are shown in this picture.

So, in this way this is just one example we may redesign our parts, so that we are able to satisfy this requirement and similarly I think this clear I need not repeat it again. The parts remaining same only the design of the parts has been changed in order to satisfy the design guideline.

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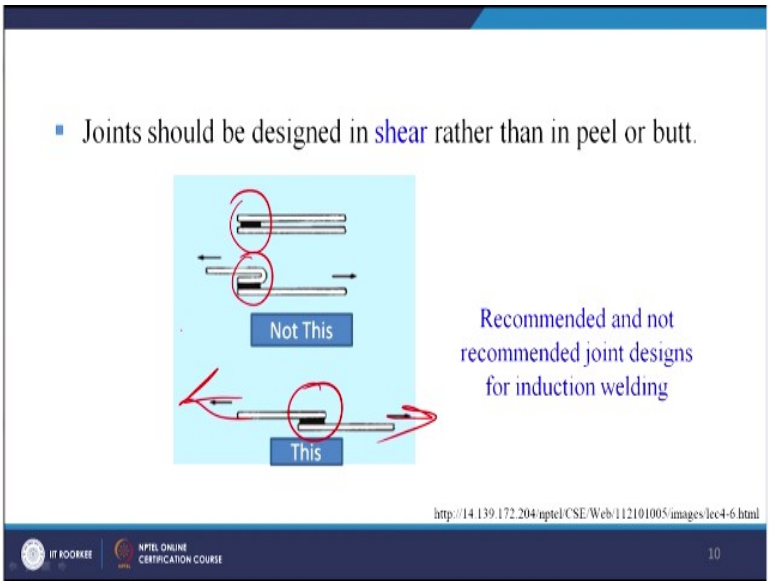

Now this is another design guideline, joints should be designed in shear rather than in peel or butt. So, whenever we are designing a joint which has to be made by the induction welding process especially for plastics they maybe designed for shear. Now this is the design for shear load ejecting in this direction and in this direction whereas the other 2 joints that we see here these 2 joints these are not in shear maybe they are in peel or butt mode.

So, that is what we can say that we must avoid the joints which are going to be loaded under the peeling forces or under the tensile forces. We must try to try design the joint, so that they are under shear for joint should be designed in shear rather than peel or butt mode. So, recommended and not recommended joint designs for induction welding are shown in the figure. So, these are few guidelines which we must keep in mind when the plastic parts are being joined using the induction welding process.

So, 3 things we have tried to address today, the first thing is the induction welding process because this may also sometime not be commonly taught to the learners at the UG level. Second is that induction welding can be successfully use for joining of thermoplastic parts, there we have already tried to see the application areas also that it is not only that it will join the 2 plastic parts only it can be use for joining plastic part to a metallic grill also second.

And third thing we have tried to see very small or maybe 2 or 3 guidelines only that we must keep in mind when we are joining the parts or when we are designing the parts which are going to be joined using the induction welding process especially for plastics. So, with this I think a basic information has been generated maybe learners I will again suggest you there is lot of literature available very good books available on design for manufacturing.

So, you must look at the various books and may try to find out, may try to look out for the other guidelines which maybe followed when you are designing a plastic part which is to be joined to a similar material or to a different material using the process of induction welding. In our subsequent sessions our target will be to learn the other guidelines other processes that are used for joining of plastics.

So, this week our focus primarily will be to learn the various joining strategies for different types of engineering materials, thank you.