Manufacturing Guidelines of Production Design

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Lecture-32
Ultrasonic Welding: Plastics

Namaskar friends, welcome to session 32 of our course on manufacturing guidelines for product design. So currently we are in the 7th week of our discussion on this important topic and in the 7th week we have started to discuss the important joining techniques for plastics. And the last session if you remember in session number 31 our focus was induction welding of plastics.

So, some of you may be wondering that how this is related to our topic which is manufacturing guidelines for product design. Now basically when we are deigning a product what are the important things that we have to keep in mind. And if you remember in the very beginning we have seen a triangle in which the product quality is dependent upon 3 important things. Now these 3 important factors are the materials that are used for making the product.

The manufacturing process that is adopted to manufacture the product as well as the design of the product. So all these 3 things or 3 sides of a triangle are important to ensure the quality of a good product or to ensure a good quality product. So, that is the basic premise which helps us to focus on these important areas, now suppose we have selected a plastic material for our product and we have seen in the previous session that why do we need to join the various plastic parts together.

And we have seen that there are 3 or 4 important reasons which help us to justify the joining of plastics. Now what are these 3 or 4 reasons, the first reason was that the traditional or the processes that have been commercialized for making of plastic parts such as the injection molding process, the compression molding process, the rotational molding, thermoforming, extrusion.

These processes are not suitable for making very complex large size plastic products, so therefore we need to develop the product in smaller parts and then we need to combine them together to make a bigger or larger assembly. So, therefore the joining becomes important, so the first maybe justification for joining of plastics is that when we develop bigger large size products it necessitates the process of joining, first justification.

Second justification is that many a times we need to disassemble the product in order to ensure the maintenance or the serviceability. And for that purpose also we require to join the parts, so that it is easy to disassemble them moreover cost is the last parameter which is very very important for making a very big size plastic part the mold also has to be bigger than the product and to justify the cost of a bigger mold we must produce a large numbers.

So, we must have large number of parts to be manufactured then only the cost of the mold or the die can be justified. So, it is better than we can make the product into smaller parts using less tooling cost and then assemble the product to get the final assembly or the final product. So, therefore the joining of plastics is an important area, so therefore it is related to our context of product design also.

That when we are designing a product the material we have already selected that it is going to be a plastic material we must know that how this parts or these parts are how this product is going to be assembled. So, that is the most important justification of covering this topic in our course that the material selected is plastic, the product design has to be modified to ensure that this plastic parts are assemble together and therefore we focus on the manufacturing technique.

So, 3 triangles will ensure a good quality product the plastic the design has to be modified and the joining has to be ensured. So, that we are able to produce a good quality product and for that purpose only in this week our focus is primarily to identify that what are various processes which are widely being used for joining of plastics, what are the salient design guidelines that we must keep in mind when we are designing the products which are to be made by plastics.

And finally try to see the good quality plastic products based on these guidelines, so the joint configuration or the joint designs are almost similar. We have already discussed the various joining techniques like adhesive joining, mechanical fastening, welding, brassing, soldering. So, most of the joining techniques we have already covered in the previous week and the various design guidelines also have been covered in detail.

So, most of the joint configurations remain same but there are some specific guidelines as we have seen towards the end of our previous session in induction joining or induction welding of plastic that there are few specific guidelines which are specifically relevant to the induction welding process which we have seen yesterday. And today also we will divide the complete discussion into 2 broad parts or 2 broad classifications that is initially we will try to see the fundamental aspects of ultrasonic welding of plastics.

And then we will switch our attention to the next stage that is what are the important design guidelines related to the parts which have to be joined by using the ultrasonic welding process. To start with let us see that what is the ultrasonic welding and how it is relevant for the plastics.

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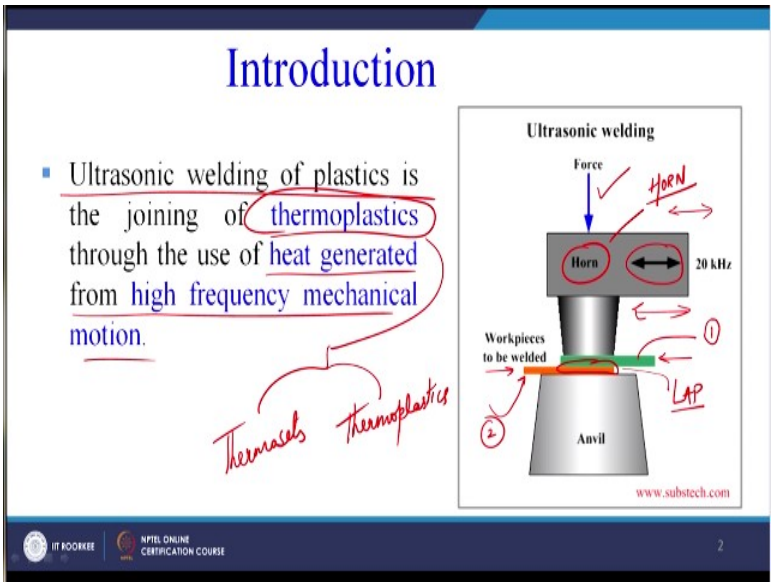

So, let us see this is a very simple diagram on your screen here we can see this is a horn if it is not clear I can write it again. This is the horn, so this is given a vibration ultrasonic frequency we can see the force is applied here already it is shown there is a force here. So, basically this load

will ensure the 2 parts are in contact. Now what are the parts that we are joining this green portion is our first part and the orange portion is our second part.

So, these are the 2 adherents that we want to join together like this and what is this joint configuration known as all of you know we have already seen it is a lap joint configuration. So, the 2 parts that have to be joined together have been placed like this.

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And on top maybe like this and on top there is a force that is acting, a force has be applied on top of this. So, the 2 parts under lap configuration are in constant contact, now there is a ultrasonic vibrations given in this direction it is clearly shown here. So, in this direction at 20 kilo hertz are more, so you give the ultrasonic vibration the 2 pieces rub against each other and a heat is generated at the interface between the 2 adherents.

One of the adherents is represented by green color the other adherent is represented by the orange color here. So, when we produce the heat between the 2 adherent a joint is produced, so ultrasonic welding of plastics is the joining of thermoplastics it is written clearly thermoplastics. All of you know that polymers can broadly be classified into 2 categories, 1 is thermosets and the other category is the thermoplastics.

So, this is well known to all the learners and here we have highlighted that the ultrasonic joining of plastics is most suitable for joining of thermoplastics. So, ultrasonic welding of plastics is the joining of thermoplastics through the use of heat generated by high frequency mechanical motion. So, there is a mechanical motion between the 2 adherents as is shown here in this direction, direction is clearly indicated and this continuous mechanical motion between the 2 parts produces lot of heat.

And if you see that in joining normally 2 important parameters have to be controlled we must try to understand that and yesterday also I defined the welding process again today I will speak about welding for a minute or 2. Now welding is a process of joining 2 similar or dissimilar materials with the application of heat with or without the application of pressure. So, the heat is an important input for any joining to take place and here the source of heat is the relative motion or the mechanical motion between the 2 adherents which have to joined together.

In our previous we have seen when we were trying to join the 2 plastics together using the induction heating mechanism. So, the source of heat was the electromagnetic induction heating, prior to that in brazing and soldering we have seen that we melt the alloy and the alloy penetrates with the help of capillary action between the 2 adherents or the 2 metal pieces which we want to join together.

In electric arc welding the source of heat is the electric arc, in case of gas welding the source of heat is the gas or the fuel gas that we use or that we burn for producing the flame. So, different types of joining processes have 1 commonality that is they have a source of heat and here the source of heat is the mechanical motion or the friction between the 2 adherents. So, the heat is generated from the high frequency mechanical motion between the 2 adherents.

So, if we have understood that what is the process of ultrasonic welding of plastics we can very easily be able to appreciate the kind of design guidelines that we must keep in mind when we are designing parts which have to be joined using the ultrasonic welding technique. And specifically the plastic that we are designing which needs to be joined using the technique which is the

ultrasonic welding technique. Now let us see the next stage or the things that I have already try to explain from the diagram.

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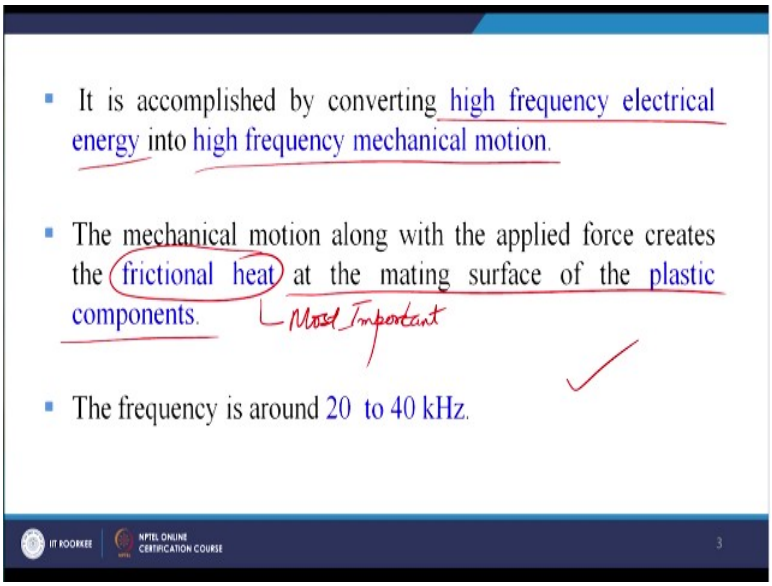

It is accomplished by converting high frequency electrical energy given to the horn into the high frequency mechanical motion. So, the 2 parts rub against each other under the applied force, so the mechanical motion along with a applied force creates a frictional heat. Already I have discussed this word, so this is the most important source of heat in case of our ultrasonic welding, so this is most important.

So, when the our electrical energy which is supplied to the equipment is converted into the mechanical motion at high frequency between the 2 adherents to be joined when they rub against each other heat is created. And this frictional heat is use to join the 2 thermoplastic parts together at the mating surfaces of the plastic component. So, this frictional heat which is generated at the mating surfaces of the plastic components maybe at the joint interface localized maybe joint is formed at the lap interface.

So, this is the movement between the 2 pieces and at the joint interface localized maybe melting and re-solidification of the thermoplastic may take place forming a joint between the 2 plastic parts. The frequency 20 to 40 kilo hertz, so the frequency as we have already discussed is in the range of 20 to 40 kilo hertz.

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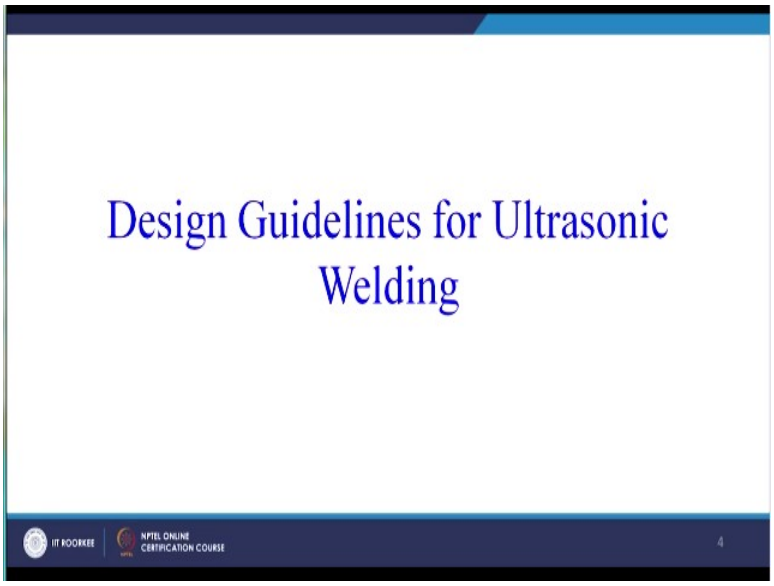

Now let us see that what are the various design guidelines that we have to follow when we are designing parts which are made out of plastics and which we plan to join using the ultrasonic welding technique. Now what are these guidelines one by one we will try to see and with the help of the diagrams we will try to understand that how we must design our joints, so that they can be in mechanical motion under the frequency which is just mentioned. So, that frictional heat can be used to produce a joint between the 2 mating parts, now we can see on your screen.

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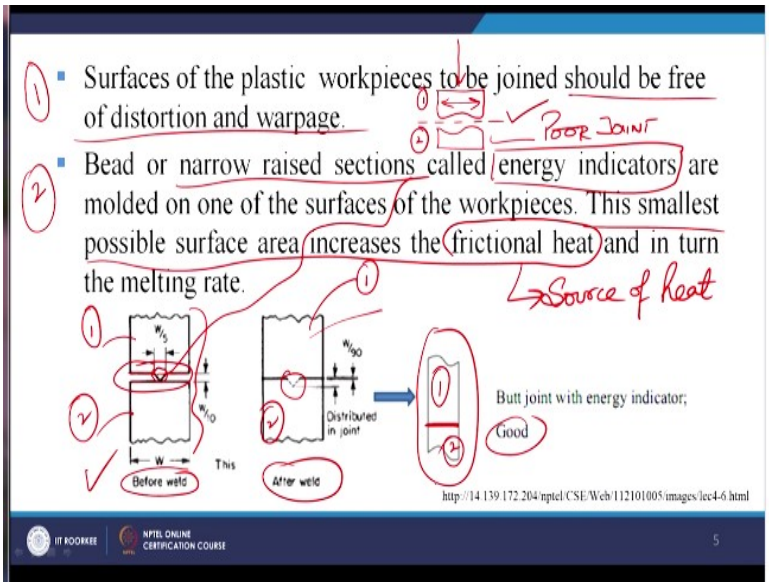

This is our first part, this is our second part and we want to join them at this interface, so the width is also given w. Now let us see now what is written on the screen surfaces of the plastic

work pieces to be joined should free of distortion and warpage. This is first requirement should be free from distortion and warpage. So, very very important why you can see here, for example this is my 1 surface and this is the another surface.

And as we have seen when we want to join them together we apply a force here and then we create a mechanical motion between these 2 parts, this is the first part and this is suppose a second part. When the surfaces are not aligned properly there is distortion or warpage at the joint interface we will not get a good joint. Therefore we have seen that the surfaces must be straight as indicated here and we will discuss what is the need of putting this indicator here maybe in the next sentence.

But first thing we must ensure that the surfaces of the plastic workpieces this is workpiece number 1 and workpiece number 2. So, surfaces of the plastic workpieces to be joined should be free from distortion and warpage this clearly helps us to highlight the importance of the preparation of the surfaces which have to be joined using the ultrasonic welding technique. So, this will lead to a poor joint because the surfaces have distortion and warpage.

Now coming to the second guideline which is given on this screen bead or narrow raised sections. So, this is the narrow raised section which is shown here, so this is a narrow raised section which is after the welding this is the after the weld, this is before the weld. Now bead or narrow raised sections these are called the energy indicators, what is the need of these energy indicators, energy indicator are molded on one of the surfaces.

So, when we are making our 2 parts or designing our 2 parts this is our part number 1, this is part number 2. So, when we are designing these 2 parts we will try to mold a energy indicator during our primary forming process only. Now this primary forming process can be anything it can be compression molding, it can be injection molding, it can be maybe thermoforming, so any process we are using for making these 2 parts and then these 2 parts have to be joined together.

So, during the molding stage only we will put this energy indicator and this energy indicator why it is required. So, the energy indicators are molded and one of the surfaces of the workpiece, this

smallest possible surface area increases the frictional heat and in turn the melting rate. So, this smallest possible surface area of the energy indicator increases the frictional heat as I have already indicated the frictional heat is the source of heat which is required for joining the 2 plastic pieces.

So in turn it improves the melting rate as I have already told when localized mechanical motion takes place between the 2 surfaces, there is a frictional heat that is produced**.** And the localized maybe melting of the plastic in that area and then fusion of the 2 adherents together after the melting of the plastic in that area maybe the reason for the joint being formed. So, we need to understand because that will vary depending upon the type of thermoplastic that we have selected depending upon the range of frequency that we have selected.

Depending upon the load that we are applying on the joint that we are making, so depending upon a lot of parameters we will be able to establish that what is the mechanism of the bond that is formed between the 2 workpieces which are of plastic material. So, the mechanism in general will be localized heating, melting and solidification in general but specific needs to be investigated and established.

So here we can see that in order to join the 2 plastic pieces there is 1 design guideline that energy indicator or maybe a very small raised section can help to increase the rate of heating and that of the and then increase or accelerate the melting rate at the surface where the joint have to be formed. So this is the initial stage, then this is the second stage after the weld and this is the final butt joint with energy indicator.

So a good joint here we can see this is the joint which has been formed, so this is our part number 1 and the part number 2 that we have joined using the ultrasonic welding technique.

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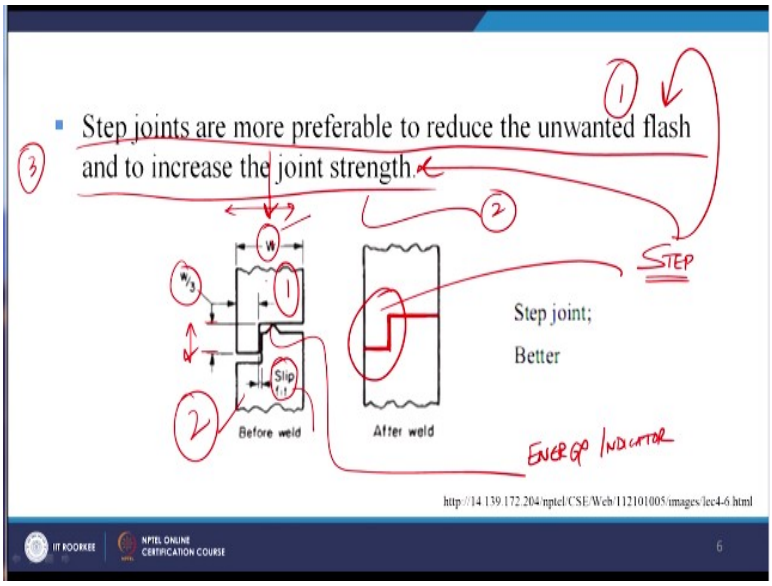

Now here we can see the step joints, this is the third guideline, so if we go back to the previous slide and try to see what are the guidelines we have seen. There must be no warpage or distortion in the surfaces that you want to join, secondly energy indicators are little molded portions at the surface during the molding stage can help to increase the frictional heat as well as the melting rate.

So, the third guideline is step joints are more preferable to reduce the unwanted flash and to increase the joint strength. So 2 important advantages are there with the step joints, 1 is unwanted flash can easily be avoided and it increases the joint strength. So it is always our endeavor, so it is always our aim, goal, objective to achieve the maximum joint strength whenever we are joining the 2 parts together.

So, step joint help us to achieve our objective of a very high joint strength, let us see now what is the step joint. Here we can see again there is a energy indicator, so we can use these guidelines in synergic manner also that w can use a energy indicator also as well as the joint configuration can also be changed to take advantage of both the guidelines. So, this is an example of an energy indicator which is mentioned here or which is depicted here.

And now this is our first part, this is our second part, so these 2 we want to join together and how they will be joined together this is the width of the workpieces, again we will apply load in this

direction and the vibration can be given. And then because of the relative motion mechanical forces will act frictional heat will be produced and that frictional heat will help us to get the joint and this is the joint which has been achieved.

This line red line now indicates the final joint which has been achieved and this is what we are calling as the STEP. So, this STEP joint will give us better joint strength and as well as will reduce the unwanted flash which can otherwise be generated. So, we can see here there is a slip fit also which helps that to join the 2 parts together. So, basically the guidelines are also given that what must be this w/3 this area is given here.

And then what must be the STEP size here which is also indicated, so this is in terms of the w parameter which is there already known to us from the dimensions of the plastic part that we want to join. So, from the dimensions of the plastic part that we want to join, so from the dimensions of the plastic part very easily we can calculate what must be the STEP size, what must be the slip fit and accordingly then we apply the vibrations or the ultrasonic vibrations.

And accordingly because of the frictional heat we will be able to produce a quality joint. So, if we take into account all these parameters when we are designing the plastic part they will help us to design the parts in a better manner, so that their joining is also effective and efficient.

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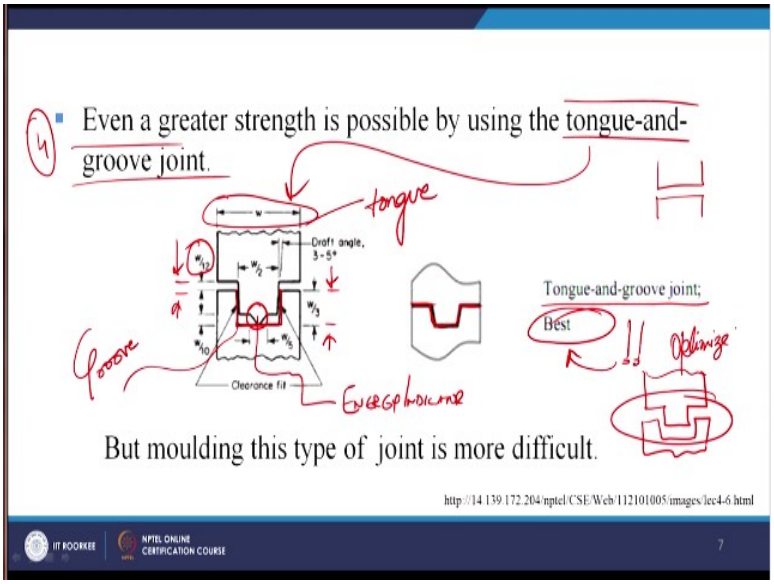

Now the fourth guideline we can see here 3 guidelines already we have see even a greater strength is possible by using the tongue and groove joint. So, previous was the STEP joint what were the 2 advantages it will minimize the flush it will improve the joint strength another guideline the joint strength can further be improved if we can use the tongue and groove joint. So, what is this tongue and groove joint it is shown in the diagram again the parameter geometrical parameter for our plastic part is given w.

And all other parameters are in reference to w only this is w/12 this dimension and this is w/3 the depth up to which our tongue is going. So, this maybe we can call this top portion as the tongue and the bottom portion where we have this slot, this slot can be called as the groove. So, we have tongue and grove type of joint here and again you can see there is a what is this the by now you must be easily able to identify which we have already covered.

This is an energy indicator, so when we will form the joint here the joint will be formed like this after the ultrasonic joining. So, tongue and groove joint gives us even better strength as compared to the previous joint which was the STEP joint. So, this is the tongue and groove joint which is most of the times called as the best joint for joining the 2 plastic parts together using the ultrasonic welding technique but molding this type of joint is little bit difficult.

So, because initially we need to make this part and the corresponding part which have to be joined together. So molding of these parts maybe slightly difficult in comparison to molding the straight surfaces. So, maybe with little difficulty if we can optimize this process or this design we can very easily get very high joint strength using the tongue and groove type of joint.

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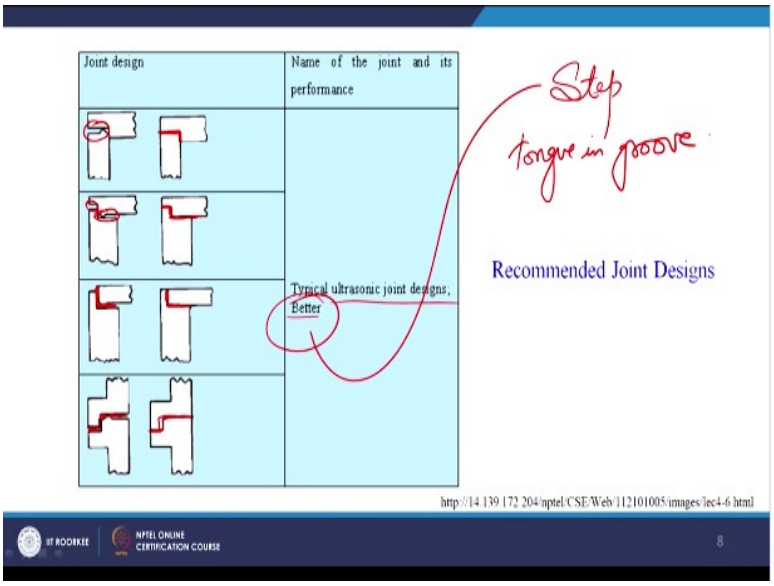

So, these are the recommended joint designs for ultrasonic welding of plastics we can see what are the types of joints you can see here, this is the joint we are getting after ultrasonic welding maybe it can be called a L type joint. Then this is another we can have joint line here and a joint line here which is final form this shown like this you can see then again we can have a joint line here and a joint line here which is shown here the 2 parts are joined.

After joining this is our joint line and similarly we can further redesign the part to get a this type of joint. So, these are some combinations of the joint configurations which can easily be adopted for ultrasonic welding of the plastic parts. So typical ultrasonic joint design, so these are better designs previous to this we have already seen 2 types of design which one was STEP another one was tongue and groove.

So, various types of joint configurations can be adopted the basic principle that we have to keep in mind is that we apply a force then we keep the 2 adherents together joined together and then we apply a high frequency mechanical force between the which generates frictional heat and this heat is the source of joint or the joining between the 2 plastic part. Now depending upon our product design whatever possibilities exists we if we have the idea about different types of joint configuration.

We can select the best joint configuration which can give us a high strength least or minimum warpage least or minimum flash. So, accordingly we can join the 2 parts together according to our design, so during design only we must keep into account or keep in mind all these design configurations which are possible for ultrasonic joining of plastics, now this is a last slide for today.

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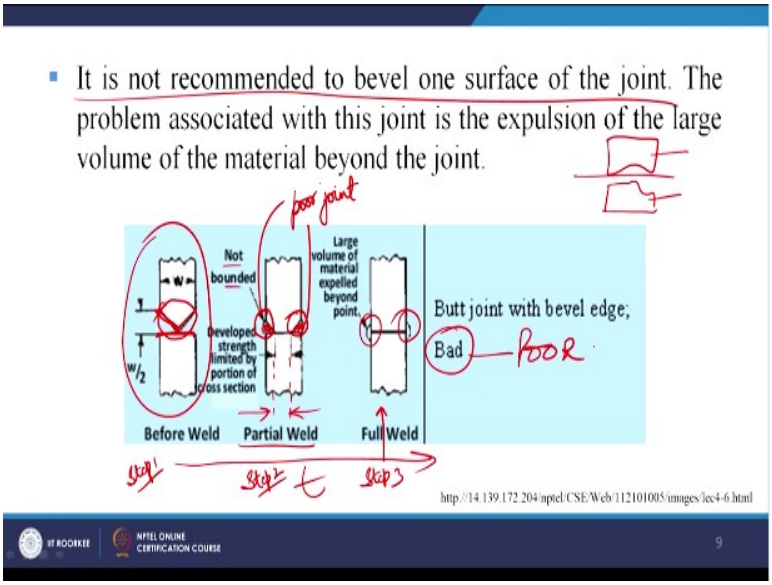

So, it is not recommended to bevel 1 surface of the joint, another important guideline this is related in fact to the first guideline that we have seen. That when we have 2 parts with warpage or distortion we may not get a good joint. Similarly if we in this, this is an higher order case of this type of joining or this type of problem. Here we have bevel here you can see, so it is not recommended to bevel 1 surface of the joint.

So, this is a flat surface of the joint, this is the bevel surface of the joint, so it is not recommended why because when we do the ultrasonic welding there are chances of bonding not occurring in these 2 regions. So, these are poor joint characteristics, so not bounded, no bounding has taken place in this region and in this region. So, developed strength limited by the portion of the cross-section, now what is the portion of the cross-section.

This is the portion of the cross-section where actual bonding has taken place and outside there is no bonding which has taken place why because of the bevel nature of the one of the adherents or

one of the plastic parts which is joined to a flat surface of the other plastic part. So, another problem is large volume of material expelled beyond the joint, so this is another problem full weld, so this is a partial weld, so this is before weld.

So, we are moving in this direction in terms of time, so initially this is the case maybe we can called it as step 1. Then after these when we start the process this is our step 2 in terms of time and this is our step 3 which is the final or the full weld. So, the butt joint with bevel edge this is not a good design it is a poor design, so we must avoid a bevel type of surface when we plan to join the 2 surfaces one being flat another being bevel.

We will not be able to get a good joint strength even after adopting the ultrasonic welding technique. So, with this we can conclude the today's session what we have tried to understand today we can broadly classify the understanding into 2 parts. Initial one is the basic fundamental of ultrasonic welding of plastics we have seen a diagram how ultrasonic welding is done and finally we have switched our attention towards the various joint configuration that we must keep in mind when we are designing our product.

So, in our product if 2 or 3 plastic parts are there and we have to join them together using the ultrasonic welding techniques we must plan, we must select our joint design judiciously. So, that we get a good quality joint, in our next session our target will be to focus on another welding technique or joining technique which is use for joining of plastics with this we conclude the today's session.
Thank you.