Weldability of metals

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Lecture-01
Understanding Weldability: Introduction–I

Hello I welcome you all in this presentation related to the subject weldability of the metals, in this subject basically will be talking about the ease of welding of the different metals. You know that the welding of the metals is very frequently carried out in manufacturing industry. In order to get that required size and shape of the components and primarily this simple shape components are welded together.

So that they can perform the intended function, for the welding purpose we use the variety of a approaches and based on the approach of the welding process the ease of the welding is significantly determined.

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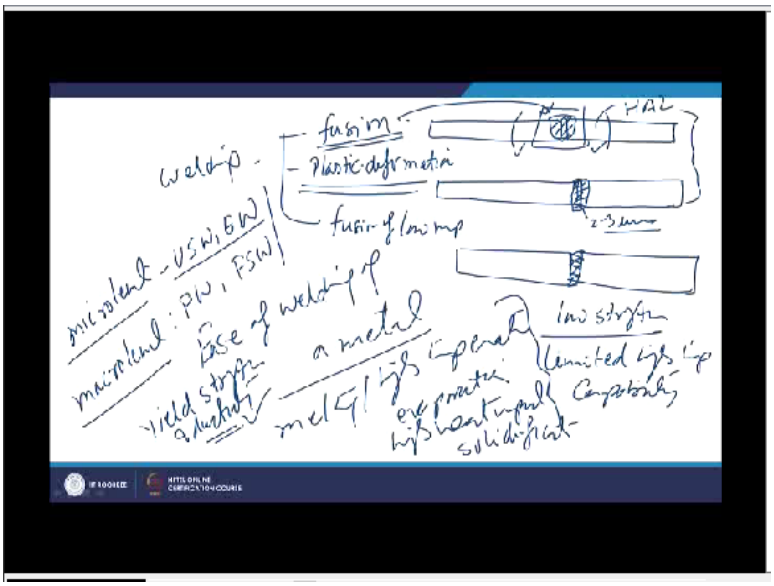

So, if we see for the welding purpose we may use basically 3 broad category of the processes, one is where the fusion of the components to be joined is realized. So, the components to be joined the edges of the plates are fused together and after the solidification we get the metallurgical continuity which can sustain the service conditions can take the service loads.

Another one is where only the localized plastic deformation is realized either at a macro level or micro level. So depending upon the process this deformation maybe very thin at micro level like in ultrasonic welding, explosion welding processes and thin layer of like say 2-3 micro meter is deformed both the sides and mechanical interlocking. And subsequently the metallurgical bonding results in the development of the joint.

And then there is allied category of the process where the fusion of the low melting point material is used and the base metals remains in the solid state. In that case the plates to be joined remain in the solid state and the low melting point metal is applied between the faying surfaces which after the solidification leads to the development of a joint. So, however these joints are of the lower strength and they have the limited high temperature capability.

So, we will be talking about the welding processes where in either the fusion or the plastic deformation based approaches are used for the welding purpose. And in light of those 2 category of the processes will try to access the ease of welding of a metal. Since the approaches are different like in one case is the fusion is realized, so melting of the metal the high temperature evaporation high heat input or the typical feature of such kind of the processes.

So, the molten metal will be leading to the solidification, so the cast structure of the weld joint. So, these are some of the features associated with the fusion welding processes, so the way by which metal response to the application of the high heat that will be determining the ease of welding of the metal, like few will be easier to melt than others few will be evaporating easily than others so.

Accordingly the soundness and the quality of the weld joint will be different since the heat it would is too high in the fusion based welding processes. So at least to the formation of the undesired zone in vicinity of the fused zone that is called heat affected zone. This zone is also wider, the changes which are taking place in the heat affected zone in form of the metallurgical changes or in form of the mechanical property variations.

These maybe favorable, these maybe unfavorable, so if these are unfavorable then it these will be leading to the reduced quality of the weld joint. And accordingly the reduced ease of the welding because we need more precautions, more specialized efforts for developing the sound weld joints which can perform the required function. On the other hand the plastic deformation based approach, the 2 broad categories of the processes which are based on the plastic deformation.

One is where the micro level plastic deformation of the faying surfaces take place like ultrasonic welding, explosion welding. And there is a another category of the process where macro level plastic deformation of the faying surfaces is required friction welding, friction stir welding. Since in both these processes the plastic deformation is involved in order to facilitate the required metallurgical continuity and the development of the joints.

So the mechanical properties like yield strength and the ductility of the metal significantly governed the ease of welding. For example the metals of the high yield strength will be difficult to deform plastically, so they will be imposing more difficulties associated with the welding processes based on the macro or the micro plastic deformation. Another important mechanical property affecting the plastic deformation based processes is the ductility which indicates the extent of deformation which can be realized without cracking without fracture.

So in order to facilitate the joining or the welding through the micro or macro level deformation it is necessary that metal should have reasonable level of the ductility. So, that the plastic deformation can we facilitated in order to develop the required joint. So now we have to see since the approach is being used in the welding processes are different. So the important properties of the metal that will be affecting the ease of welding.

They will also be different, in light of this now we will systematically try to understand the weldability the factors which will be affecting the weldability, the factors which are used to assess the weldability of the metals. So here if we see if you want to weld a metal system the best possible option will be that the 2 components are simply joint together without doing anything.

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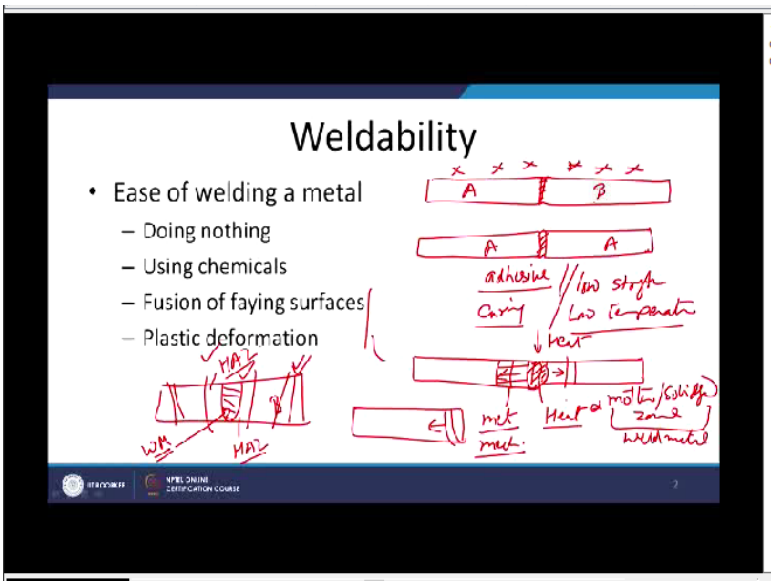

So, if the joint is obtained without doing anything this will be the best possible situation like A and B are just broad together and joint is formed which can take the service load and the service condition. This is the best possible situation because in that case there will be at least uniformity in terms of the properties from one zone to another across the joint. But since this is not a fusible this is not the workable approach, so we need to do something for developing the joint in that case.

So another somewhat easier approach to develop the joint is like between 2 components we apply some chemicals so connectivity or the joint between the 2 components to be joined is realized. In order to required size and shapes, so that they can confirm a perform the intended function, so in this case basically we use the adhesives. And the process in that case is called adhesive joining.

So, like typical products like M-shield or the phenolic resins are as a commonly used for developing the joint through the application of the chemicals. In this case after the application of the joint curing is normally performed, so that the required joint a strength can be achieved yeah. So curing helps to realize the required strength but the adhesive joints do not offer very high strength and they do not passes.

The ability to with stand at a high temperature and that is why these are you can say of the low strength joint and the they can perform under the very low temperature conditions means not at a high temperature conditions. At high temperature like 100 degree centigrade above the adhesive will decompose and the joint will be lost. Another approach which is more commonly, a last approaches are more commonly used for developing the joint wherein the components to be joint or subjected to the application of the heat.

So, heat application first of all will be heating the faying surfaces up to the melting point and there after the further application of the heat will be causing the fusion of the faying surfaces. And after the application of the heat once the heat source is removed or taken away the solidification the heat loss will be leading to the solidification of the molten metal to produce the metallurgical continuity and to produce a weld joint.

In this process since the heat is applied significant in large quantity to facilitate the fusion of the faying surfaces. Since the metals are also of the heat conducting, so some amount of the heat is transferred to the underlying base metal. So all the amount of the heat is transferred to the base metal greater will be the extent up to which the changes in the base metal properties will be taking place.

For example if the heat limited amount of the heat is supplied limited amount of the heat is transferred to the underlying base metal then it will be causing the limited change in the metallurgical and mechanical properties of the base metal which has not been brought to the molten state. So, the fusion based approach leads to the development of first molten and then solidified zone.

Since the solidification conditions are different than the conventional casting conditions, so the properties of the solidified zone which is called weld metal or found to be different from the base metal and depending upon the type of the metal the properties maybe greater than the base metal properties maybe lower than the base metal or inferior than the base metal. At the same time since lot of heat is decapitated to the underlying base metal or the base metal which has been heated to the high temperature.

But has not been brought to the molten state that zone will also be experiencing the changes in the metallurgical and the mechanical properties. So, since the zone which has been heated to the high temperature enough has experienced the changes in metallurgical and mechanical properties. So, it will be offering the difference set of the properties different kind of the performance, performance in terms of the tribological properties in terms of the corrosion resistance in terms of the ability to carry the load.

So, it is not just the base metal and weld metal properties it is not just the weld metal properties or the base metal properties that will be important in the weld joints. But also the properties of the heat affected zone will be equally important. And they will be determining the ability of the metal to sustain the service conditions to carry the load to with his standard high temperature to with his standard under the corrosion conditions.

And we know that the strength of a component or an assembly is determined by the weak link wherever the weak link exists that will be forming that will be leading to the failure or that will be the cause of the failure. So, in this case if the base metal weak as compared to the heat affected zone and the weld metal then the base metal will be the weak link. And if the heat affected zone is weaker than the failure will be occurring from the heat affected zone.

And if the weld metal is a weaker as compared to the heat affected zone and the base metal then the weld failure will be taking place. So in the weld joint the ease of the welding will be determined by both the factors associated with the heat affected zone as well as the weld metal, it is not just the weld metal characteristics. But for a given set of the conditions how the heat affected zone properties are been compromised that will also be determining the ease of welding significantly.

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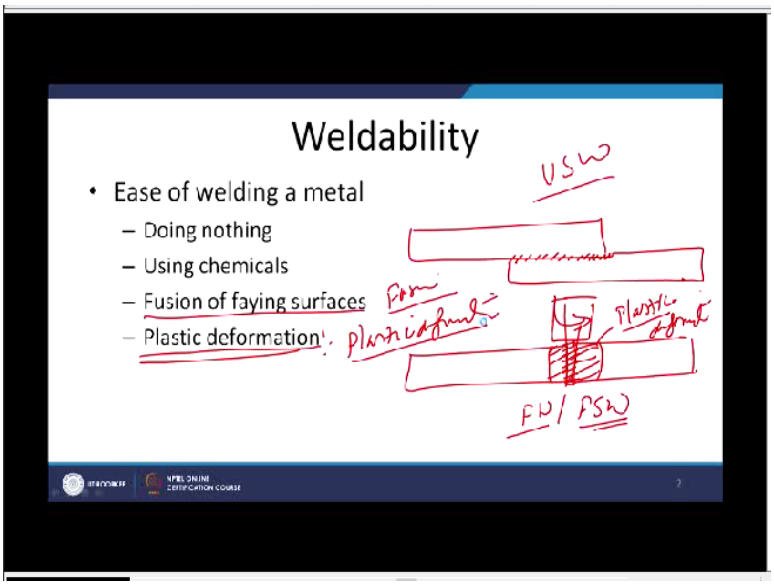

Now another approach is the plastic deformation approach which as I have explained earlier like there can be any kind of the joint configuration like there can be a lap joint or there can be a butt joint. Lap joint configuration is typically used in the ultrasonic welding and here micro level plastic deformation is realized in order to achieve the weld joint. Similarly in the processes like diffusion bonding, micro level plastic deformation is realized.

But in that process in addition to the plastic deformation the diffusion of the atoms comes across the interface helps in development of the joint. But in the processes like friction welding, friction stir welding, large skill plastic deformation is realized. And that will be leading to the development of the joint, for example in friction stir welding the tool pen is inserted at the faying surfaces at the weld joint line and the entire tool is rotate.

Metal is transported from the one side to another in order to realize the metallurgical continuity, so the movement of the metal from one side to another involves lot of plastic deformation. So, the material should be able to get deform under the given welding conditions in order to produce a weld joint using the plastic deformation approach whether it is the FSW or friction welding. So, if you see in case of the fusion based approach.

It is the fusion which is important in case of the deformation based approach it is the plastic deformation or the conditions that will be affecting to the plastic deformation will be determining

the ease of welding. So depending upon the kind of the process which is being used the way by which we should look into the weldability that will be different.

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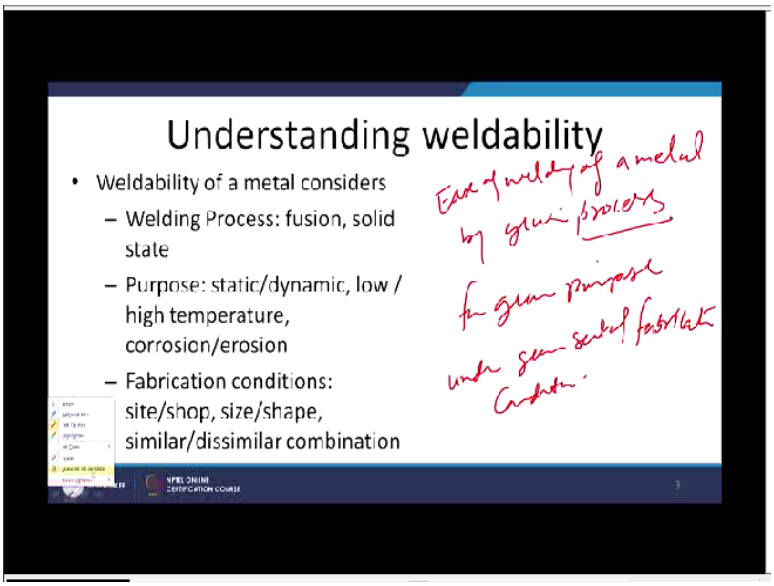

Now what are the different aspects that we need to consider for assessing the weldability of a given metal. So like the weldability is defined as ease of welding of a metal by given process for given purpose under given set of the fabrication conditions. So this is how it is defined and to understand this each of the point is to be taken separately like if you take any metal system like metal A is taken.

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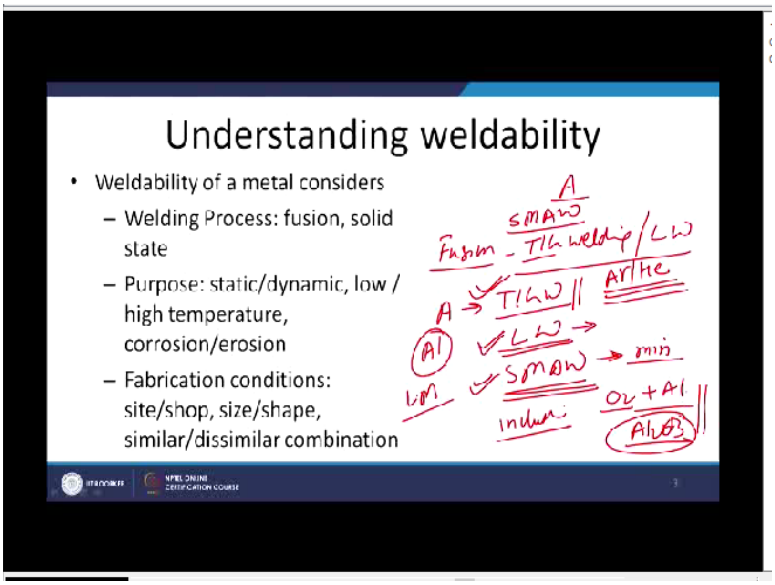

And when it is a welded by one type of the process like fusion welding approach say for like TIG welding or laser welding. Then the metal A will be responding in a particular fashion or simple shielded metal arc welding. So, metal A will show us a one kind of the ease of welding or the weldability for the TIG welding the weldability for the laser will be different and for the SMAW will be different like say if you take aluminium the weldability of the aluminium alloys by the shielded metal arc welding process will be minimum.

Why because the protection of the aluminium during the welding will be limited in case of the SMAW process a protection is minimum is, when aluminium is brought to the molten state. Oxygen from the atmosphere interacts with the aluminium to form the alumina Al203 which is of high temperature does not melt it forms the refractory oxide layer which mixes with the molten metal or because of the almost similar density.

And that is how it will be leading to the formation of the inclusions, even it imposes the difficulty in melting of the base metal. So the welding of the aluminium by shielded metal arc welding if performed it will offer very limited weldability. Because it forms the alumina, so despite of having the low melting point high affinity of aluminium with oxygen during the welding by SMAW process will be leading to the limited weldability.

On the other hand if the same aluminium alloy is welded by the gas tungsten arc welding using shielding gas of like say argon or helium. It will offer for the excellent weldability because the formation of the Al2O3 is avoided by effective protection from the argon and the helium as a shielding gas. On the other hand if the argon and helium as a shielding gases are used during the laser welding of the same aluminium alloy it will offer the best weldability.

But if we consider the cost aspect that probably the laser welding will be costlier as compared to the TIG welding and the cheapest one will be the SMAW. But since the SMAW is not able to develop the weld joint GTAW can develop the weld joint at lower cost there is another problem like when laser welding of the aluminium is performed. Because of the high reflectivity most of the laser is reflected and very limited power of the laser is utilized for the fusion.

For each process given metal will be imposing the different kind of the difficulties or metal when welded by the different processes will be offering the different kind of the ease of welding.

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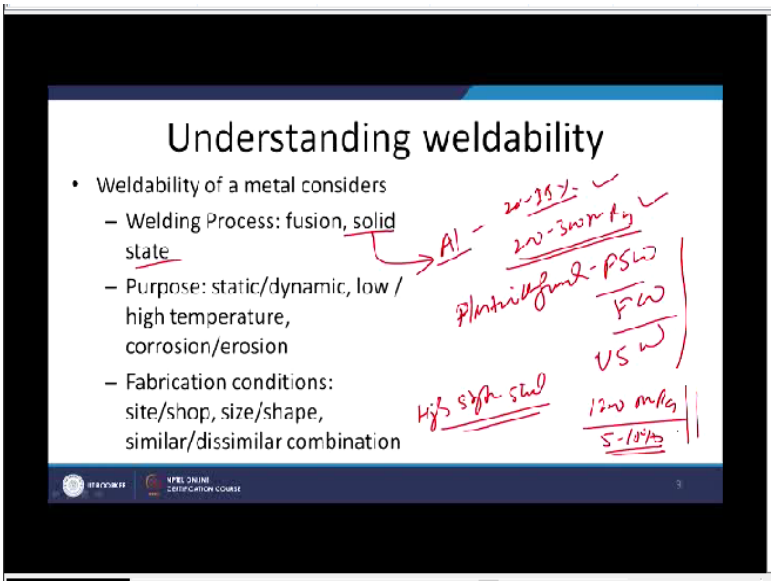

Similarly if we take the aluminium alloys which is showing very high ductility likes say 20 to 25% offering very low yield strength of 200 to 300 MPA probably it will be easier to perform the plastic deformation waste welding process like FSW or friction welding or ultrasonic welding. Because the metal the aluminium alloys in general offers the lower yield strength and higher ductility.

On the other hand if we take of the high strength steels offering like strength of 1200 to 1500 MPA, ductility is 5 to 10% elongation. Then because of the limited ductility higher yield strength their plastic deformation will be difficult. So, they will be offering the greater difficulties associated with the welding of solid state based approach means solid state welding processes will be offering the greater difficulty in welding of the high strength and the low ductility metals.

So for a given metal if we change the process is of the welding changes like solid state welding process, lower strength metals, lower strength and can high ductility metals can be easily welded using the solid state joining process as compared to the high strength and low ductility metals.

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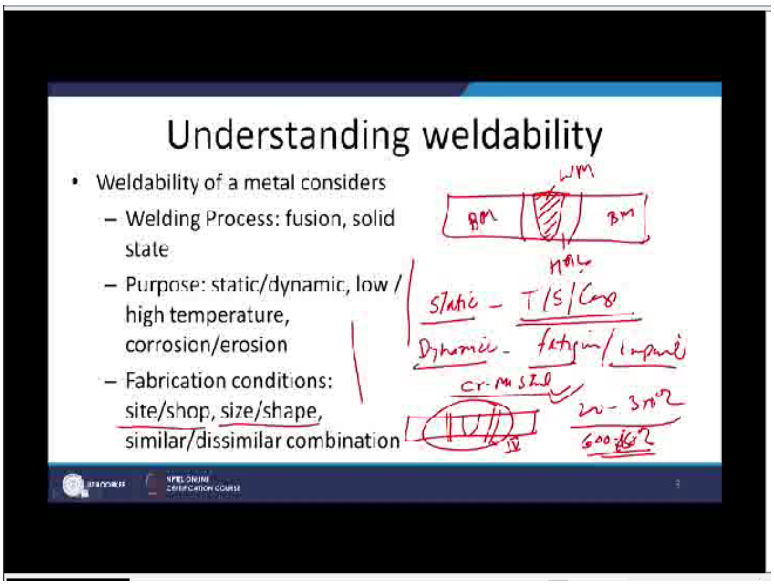

Likewise we have also to consider the purpose, like we have got a very good sound weld joint by selecting a suitable process and the process parameters, like this the joint is sound, of course it will have one heat affected zone and one weld metal and one base metal but whether the joint will perform equally good under all the set of conditions or not. Because whatever the joint is being made that should serve the purpose.

If the joint is not able to serve the purpose then the weldability of the metal will be considered low despite of forming the desired sound joint. For example like if the service conditions of the joint is subjected to the static loading like whether it is tensile or shear or compression. Then probably the discontinuities in the weld joint and the extra stages present in the weld joint may not be contributing much role towards the failure.

But if the joint is subjected to the dynamic conditions of the loading like the fatigue loading or the impact loading. Then definitely we need to consider the properties of the weld joint must suit to the service conditions. Because the extra stages in form of the high stress concentration at the 2 of the weld or the weld is continuities or the limited the toughness of the metal. These will be deteriorating the capability of the weld joint to perform under the given set of the conditions.

So, one weld joint may be able to perform successfully under the static conditions but the same may perform very poorly under the dynamic conditions. So, we considering the purpose for with

joint is being made we need to see that a given metal is welded in such a way that it is able to perform the required function. Despite of forming the sound weld joint if the joint is not able to perform the intended function is not able to serve the intended purpose.

Then it will be considered as of the low weldability for example like the joint of the chromium molybdenum steel can perform successfully 200 300 degree centigrade without any difficulty. But when the same joint is performed at 600 to 650 degree centigrade the especially heat affected zone of such kind of the weld joints shows the cracking in the heat affected zone. And this is typically known as the type IV cracking.

So, we need to ensure that a right from the welding procedure to the application of the welding procedure for developing the sound weld joint. So, that it can really perform the intended function not just at low temperature or room temperature but at the temperature of the target service conditions. So, if type IV cracking is occurring at 600-650 degree centigrade of the chromium molybdenum steel.

Then we need to see how it can be avoided what precautions we need it may require proper pre-heating, it may require post weld heat treatment and all those additional steps may be needed to avoid such kind of the cracking during the service. So, if the joint is develop but if it is not able to perform the intended function then the weldability of the metal will be considered low for and the third one is the fabrication conditions.

We need also to see the fabrication conditions like the ease of the welding is it also a or determined by the conditions like under what situations the welding can be performed whether a given metal can be welded easily in site or it will required the control conditions of the shop floor. So, the site welding is considered to be easy as compared to the shop floor because the heavy structures many to be installed at the site

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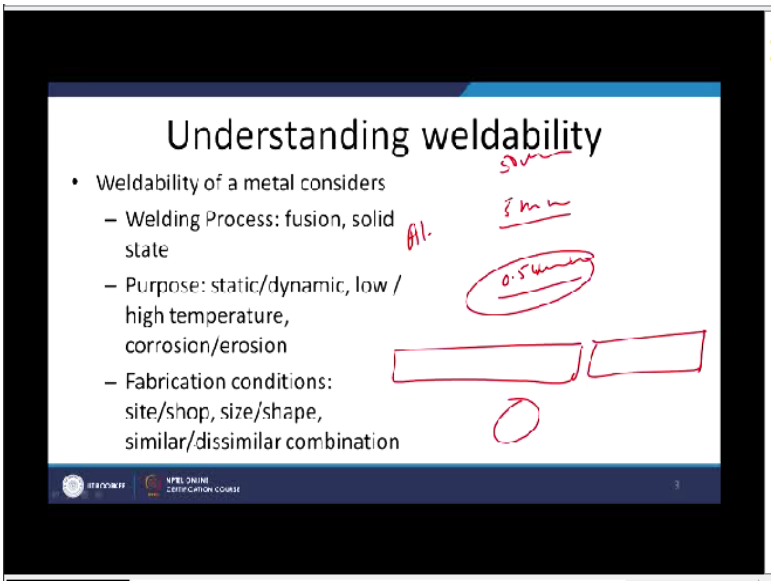

Size and shape really are very important and very crucial for determining the ease of welding, for example aluminium of 5 mm thickness plate can be easily welded as compared to that of the 0.5 mm. Because there will lot of the fluidity issues the rapping distortion is use, so not very thin not very thick plates can be welded easily but if the welding of the 50 mm thick plate is carried out or 0.5 mm thick plate is to be carried out.

Both will be imposing difficulties, similarly the welding of the plates will be easier as compared to the typical configurations like in form of the thin walled pipes and tubes and other complex geometries like which are typically used in the automotives and the car panels and the car bodies. If the shape is complex then welding will be difficult similar or the dissimilar combinations.

If similar metals are found easier to be welded as compared to the dissimilar metal combinations because the dissimilar metal combinations will be having the different mechanical properties, different physical properties, different chemical properties. So there can be lot of metallurgical issues, so while accessing the weldability of the metals we consider that weldability of a given metal for a given process for a given purpose.

And when the welding is performed under given set of conditions then we can say the weldability of a given metal is good or it is poor or it is reasonable. So, it is a very qualitative way of assessing the weldability now will be looking other aspects related with the weldability

like what we can see if you have to assess the weldability and how the metals what are the various metal properties which will be affecting the ease of welding or the weldability.

So, in this presentation basically I have try to explain the importance of the weldability and how can we understand the various aspects related with the weldability, thank you for your attention.