Weldability of Metals

Prof. D K. Dwivedi
Department of Mechanical and Industrial Engineering
Indian Institute of Technology-Roorkee

Lecture-02
Understanding Weldability: Introduction–II

Hello I welcome you all in this presentation related to the subject weldability of the metals and in the previous presentation I have talked about the way by which we can define the weldability and we can try to understand the weldability of metals. What we have seen is like for assessing the weldability of a metal we need to see.

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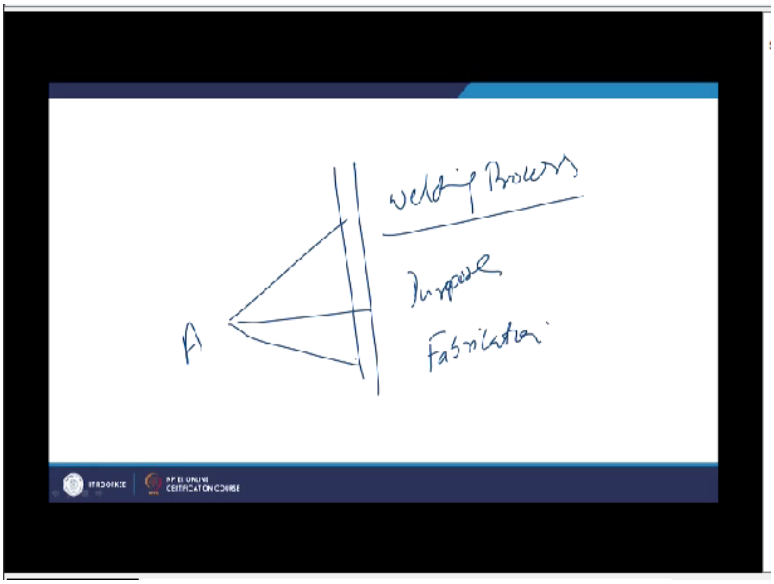

And weldability of metal for a given welding process for a given purpose and for a given set of the fabrication conditions. These are the one set of the boundary conditions which we can say that metal A can with what is a metal A can be welded by a given process for a given purpose under given set of the fabrication conditions. But if you have to if you try to understand this definition in more generic way.

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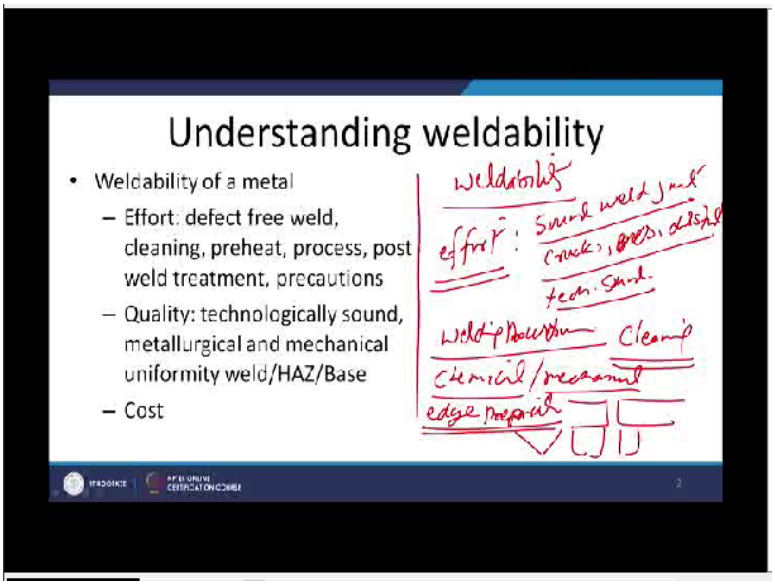

Then for that we need to see that the weldability of the metal if you have to assess then we would like to see how much efforts we have to put in for developing a weld joint which can serve the intended function. So to assess the weldability how much efforts we have to put in, so that a joint can be made which can serve the required function. So in this connection our efforts will be there to use such kind of the welding procedure which will help us in developing the sound weld joint, like it is free from all cracks, pores, distortion extra.

So, the sound weld joint is made and it is not just a free from the defects but also it is technologically sound which means the weld metal properties and the heat affected zone properties are such that the joint will perform for long and it will not lose it is performance during the service. So how to quantify the efforts for that we need to see the various aspects related with the welding procedures is what are the different welding procedural steps which are needed.

So that a joint can be made which is free from the defect and technologically sound, so that it can perform the intended function during the service for a given life which includes right from the cleaning. There are various methods of cleaning like simple mechanical cleaning or mechanical+chemical cleaning which method of the cleaning will be used so that it is free from the inclusions and the defects free from the oil and grease and during the welding it does not impose any problem.

Similarly use of chemicals for so chemical or mechanical cleaning, we have to remember that more the efforts more the steps are needed for completing a given a step of the welding procedure lower will be the weldability. Because we need to use more resources more time for completing that particular step, so obviously if welding of a given metal needs just mechanical cleaning it will be of the better from the weldability point of view as compared to the metal system which needs both chemical+mechanical cleaning.

Now edge preparation, second step is edge preparation, there many metals which offers, so good weldability that even simple square groove geometries can be used. It does not require any edge preparation but there are many metals in order to achieve the required depth of penetration required fusion through the thickness of the plate. The preparation of the edges in form of the V-groove U-groove or the G-groove geometries is required. So, whenever edge preparation is performed it requires the steps in form of machining.

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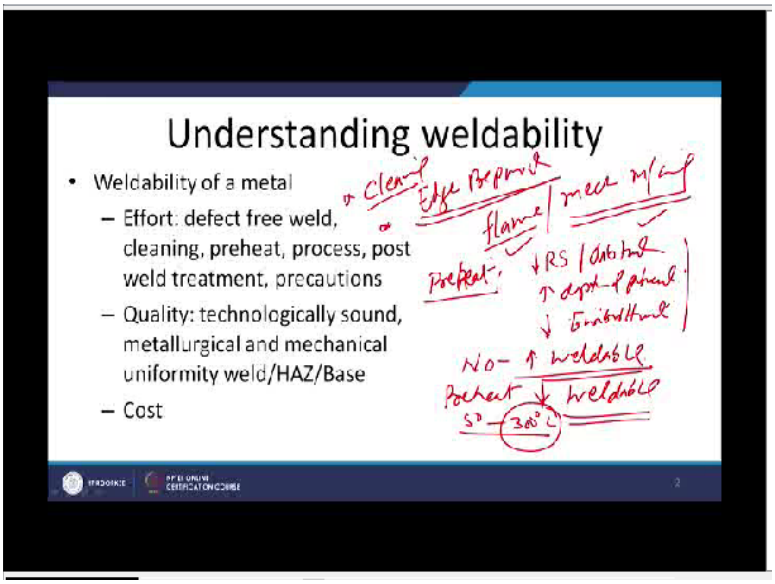

So, for edge preparation we need to perform it may be like the flame cutting or it may be mechanical machining. So, flame cutting is not considered to be good for those metals which are hardenable because it forms a very hard and brittle structure on the cut edge which is a produced by the flame cutting.

Mechanical machining is considered to be good for the edge preparation like flame cutting can be used for the V groove preparation. But if the metal is hardenable it will lower down the weldability, simple mechanical machining is a better from the edge preparation point of view but the process is slow. So, it will take longer time and that will be poor from the productivity point of view.

And something which is taking longer time more efforts for completing one step like edge preparation or cleaning it will lower down the ease of welding or the weldability. So, which type of the edge preparation is needed which method of them edge preparation will be used like flame or the mechanical machine that will also determine the ease of welding. So after the 2 steps like cleaning mechanical or chemical cleaning, edge preparation, flame cutting or the mechanical machining or the given groove geometry.

Like no edge preparation required for a square groove geometry as compared the when significant machining is needed for the V and the U or the J or dual groove geometries. So, the more efforts are lower will be the weldability then after the edge preparation as per the metal system we may require preheat of the different magnitude different temperatures. For example preheating is performed for the different functions for different purposes is like to lower down the residual stresses to lower down the distortion tendency to increase the depth of penetration to reduce the embrittlement due to the hardening tendency of the given metal.

So that the metals which require no preheat from the preheat point of view will be considered to be more weldable as compared to the metal systems future for producing sound weld joint which can perform the required intended function for longer life. If preheat is needed it will be lowering down the weldability. So, weldability will be reduced if we require preheat, now another thing like if limited preheat is to be used.

The preheat may likes if 50 degree centigrade to 300 degree centigrade in case of the steels. So lowers the amount of the preheat needed is there will be the weldability or the better will be the weldability as compared to the cases where higher degree of the preheating temperature is

needed. Because it will be more difficult to work with the preheated plates, preheated metal systems, so the weldability will be poor.

So no preheat is the best possible situation from the weldability point of view and if the preheat is to be used then preheat should be as less as possible for the better weldability higher the pre-requirement lower will be the weldability of the given metal.

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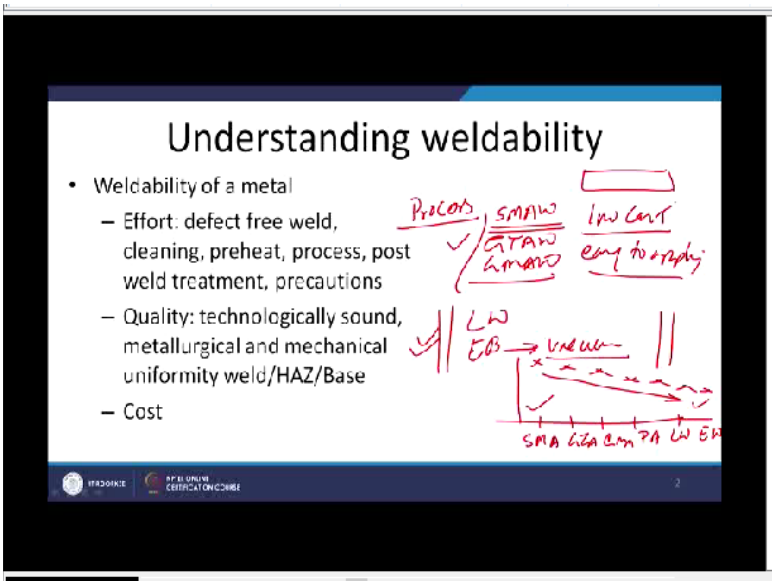

Then we have the process, we know that there is a range of the welding processes which can be used a metal can be welded using a different types of the processes. But like if one which can be welded easily with the SMAW process which is very easy to apply low cost does not require much is skill and expertise. It will offer the low cost and easy to apply, so it will offer the better weldability as compared to the case.

If it require the laser welding r the electron beam welding these are very specialized processes advanced processes. So this requires the vacuum and a lot of work initial investment, so the cost is high the equipment are very high expertise is needed. So, more the efforts in terms of the advance process used for development of the weld joint lower will be the weldability as compared to the case when the simpler processes like SMAW process or the gas tungsten arc welding process or the gas metal arc welding process.

If these can be used then the weldability will be better, so if joining or the welding of metal needs a simpler process which is easily available can be applied easily for development of the weld joint. Then it will be considered as a better weldable or of the good weldability as compared to the other metals which are require the advance processes like the laser welding and the electron beam welding.

So, if you compare if the requirement for the welding process is like this SMA, GTA, GMA then plasma arc laser and electron beam. So, we can say the in order of the decreasing weldability if the metals needing the advanced processes then the weldability will be considered to be reducing. It will be easier to apply low cost very flexible SMAW process of will be considered of the higher weldability as compared to the laser and the electron beam welding.

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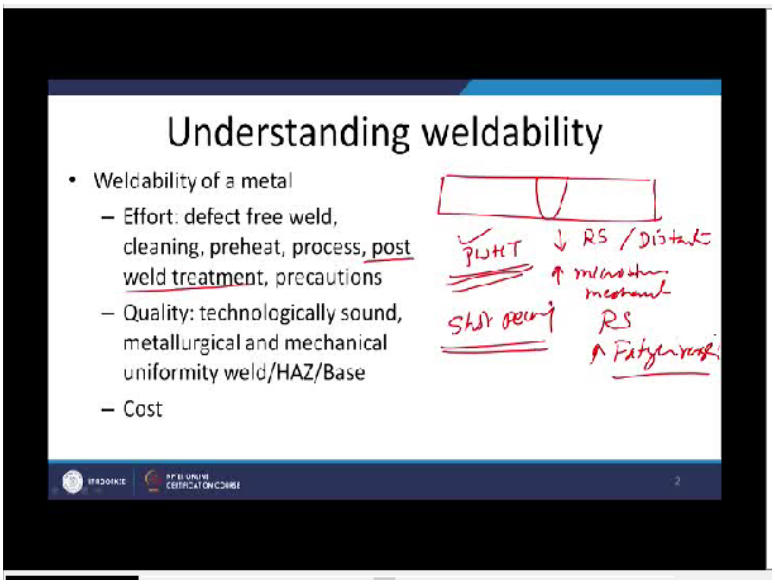

Likewise if we see the post weld treatment requirement, suppose we have made by after proper cleaning after proper edge preparation preheating of the waste metal. We have developed a sound weld joint but in order to impart the required a technological properties it may be required to perform the post weld heat treatment like for lowering down the residual stresses and distortion tendency, for improving the microstructure and mechanical properties.

So if you have to perform the post weld heat treatment this will be the another step which will be needed. So, those weld joints which do not require any post weld heat treatment will certainly be

considered of the better weldability as compared to the metal systems which requires the post weld heat treatment. Likewise in order to reduce the residual stress and distortion tendency post weld treatments in terms of the sort peening may help in lowering down the residual stresses and distortion tendency and improving the fatigue resistance.

So, for improved performance of the weld joint if you have to perform the steps like post weld heat treatment, shot peening or any other treatment which is required for developing the joint which can perform the required function.

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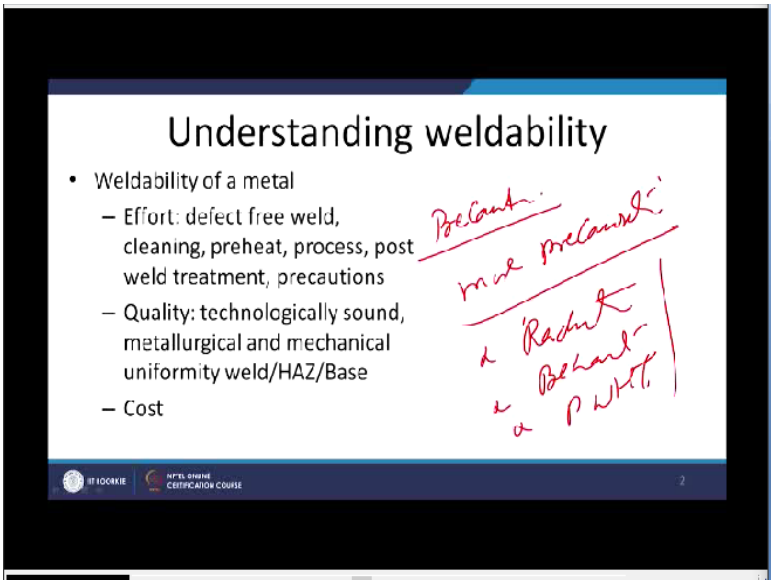

Then we need then that will be reducing the ease of welding, the another point is the precaution, like for developing the weld joint of the given metal if we require more precautions in terms of the radiations or in terms of the preheat or the post weld heat treatment for developing the joint which is having the required mechanical and metallurgical properties. So, that it can perform the required function during this service then certainly it will be reducing the ease of the welding.

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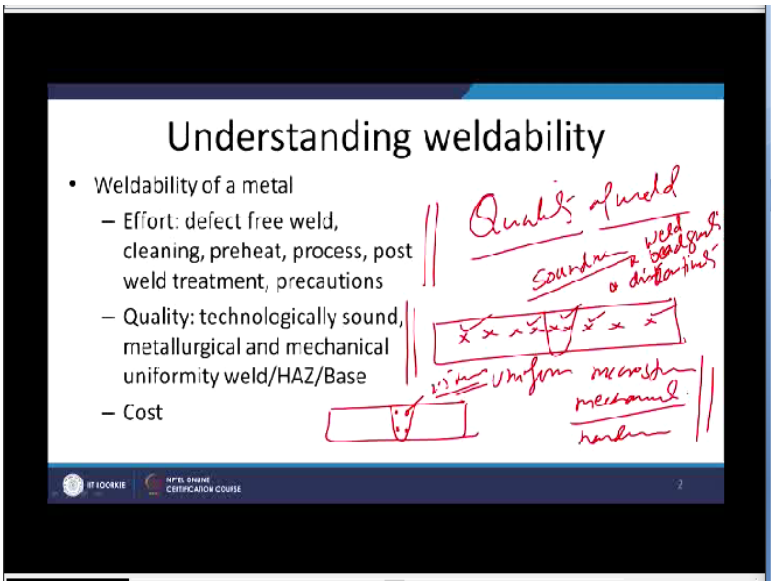

Now so the efforts required for welding of a given metal will be an important aspect in determining the weldability which we can see in respect of the edge preparation, cleaning, preheat process, post weld heat treatment and the precautions required. We have also to see for assessing the weldability of metal like what kind of the quality of the weld joint is being is produced. Quality is very generic word, so to assess the quality of the weld.

We would like to see what kind of the uniformity in mechanical and metallurgical properties exist in when a weld joint is developed for required performance during the service it is important that across the world joint from one side of the base metal to the another side. It is by and large having the uniform micro structure and mechanical properties in which normally we measure using the hardness.

So the microstructure from the base metal to the heat affected zone to the weld metal and again heat affected zone to the base metal. If everywhere the microstructure and mechanical property is same then will consider the quality of the joint is good, another way to assess the quality of the joint is the soundness. Whether it is having the required weld bead geometry or it is free from the discontinuities, whenever you make any weld joint the weld joints invariably contains the discontinuities.

These maybe find this may be acceptable, so if we make a weld joint there will always be discontinuities in form of pores or inclusions which may be extremely fine like 2 to 5 micrometer. But these are discontinuities may be acceptable, so those welding process which either developed the weld joints which are free from such kind of the discontinuities or discontinuities are negligible are there very fine in size to have any adverse effect on the performance of the weld joint.

Then those weld joints will be considered to be of the better quality as compared to the otherwise weld joints where there are issues related with the weld bead geometry and the large discontinuities in the weld joints are present.

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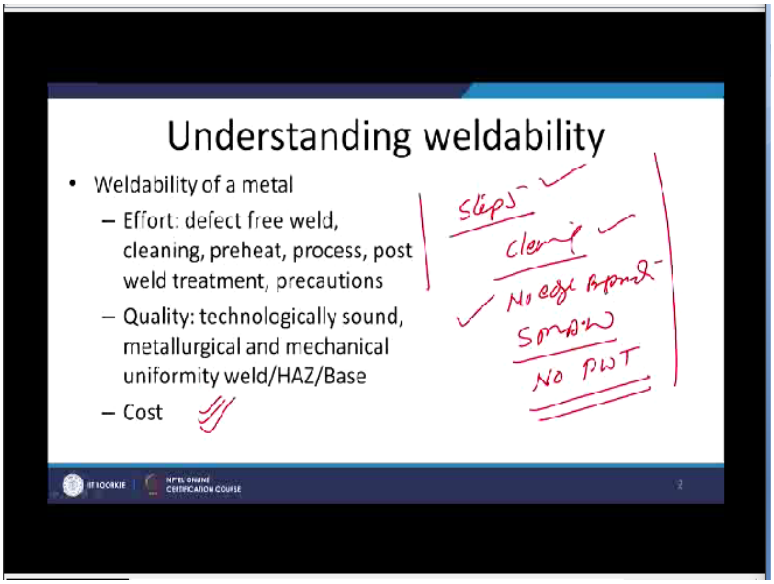

So, efforts to a great extent will be assessed determining the quality of the weld joints as well as the cost which is involved. Cost is very important in making decision about whether a metal should be welded by a given process using given set of the conditions or not. Because more the steps **re** are involved in development of the weld joints greater will be the cost, simple mechanical cleaning, no edge preparation, simple SMAW process, shielded metal arc welding process is used.

No post weld treatment required probably this will be leading to the minimum possible cost of the weld joint. But all the metals do not offer such kind of the luxury, we may require the

mechanical+chemical cleaning, we may require very precise as preparation using like J or the U group geometries. We may require laser welding or the gas tungsten arc welding processes we may require a number of post weld heat treatments.

So, that the required set of them technological properties required in joints can be achieved, so that it can be perform the required function during the service. So, the greater the number of steps required for developing a joint with the required set of the properties which can perform the intended function greater will be the cost and which in turn will be reducing the weldability of the metals.

So lower is the cost of welding of a given metal with the required set of properties which can perform higher will be the weldability. Now we will be talking about the different aspects related with the metals which will be affecting the weldability.

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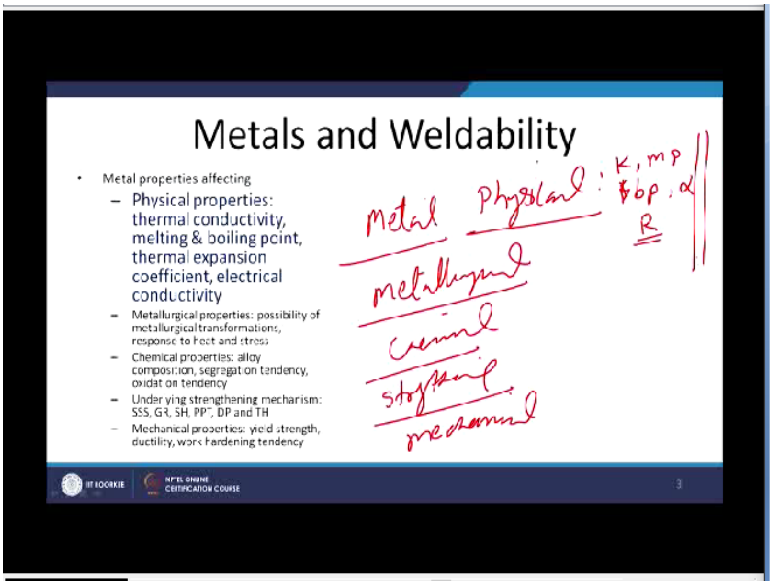

So, there are various properties associated with the metals that affect the weldability, these are like say the physical properties, then metallurgical properties, chemical properties, strengthening mechanism and mechanical properties, one by one I will be explaining all these points. So among the physical properties the points which are important like thermal conductivity melting point, boiling point, thermal expansion coefficient and electrical conductivity like resistance.

So these are the physical properties which will be playing big role in determining the ease of welding of the metal.

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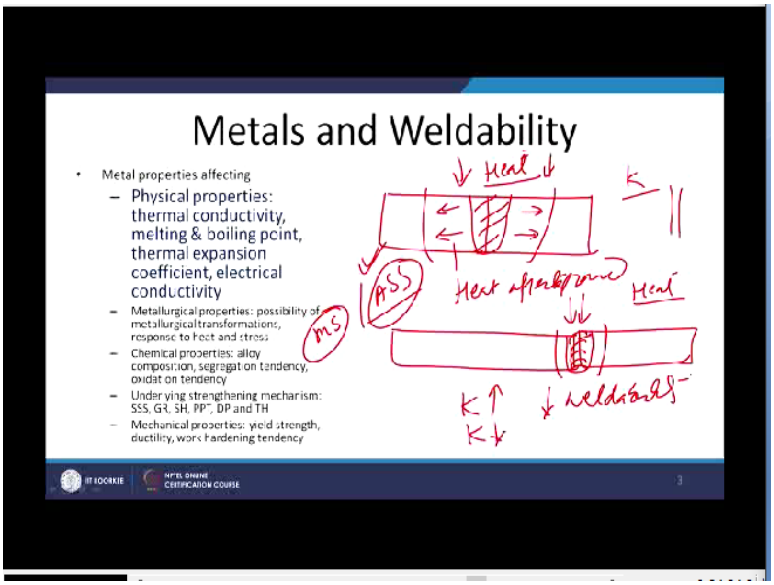

Like in the fusion welding process when we apply heat near the faying surfaces in order to facilitate the fusion of the faying surfaces. So, that metallurgical continuity can be achieved, so the application of the heat to facilitate the fusion when this heat is applied a part of the heat is used for melting the faying surfaces. But a part of the heat due to the thermal conductivity of the metal is transported to the underlying base metal which in turn leads to the development of the heat affected zone.

So greater is the thermal conductivity of the metal, greater with the amount of heat required to facilitate the fusion and great this will be leading to the greater heat affected zone. So, it will be considered to be undesirable from the melting point of view. So those metals which have the lower thermal conductivity, they are able to transfer the heat to the underlying base metal in very limited quantity.

And that is why most of the heat which is applied is used for facilitating the fusion, this will be reducing the weld zone size, this will reducing the amount of heat to be applied. And at the same time this will also be reducing the size of the heat affected zone which will be formed. So, in general higher is the thermal conductivity, lower will be the weldability because require more

amount of the heat which produces the larger heat affected zone as compared to the case when the low thermal conductivity metals are used.

So low thermal conductivity metals like simple mild steel or the austenitic stainless steel. So, if you compare the mild steel with the austenitic stainless steel probably from the thermal conductivity point of view ASS will be offering a much better weldability as compared to the mild steel because ASS has the lower thermal conductivity due to the higher concentration of the alloying elements, then the melting point.

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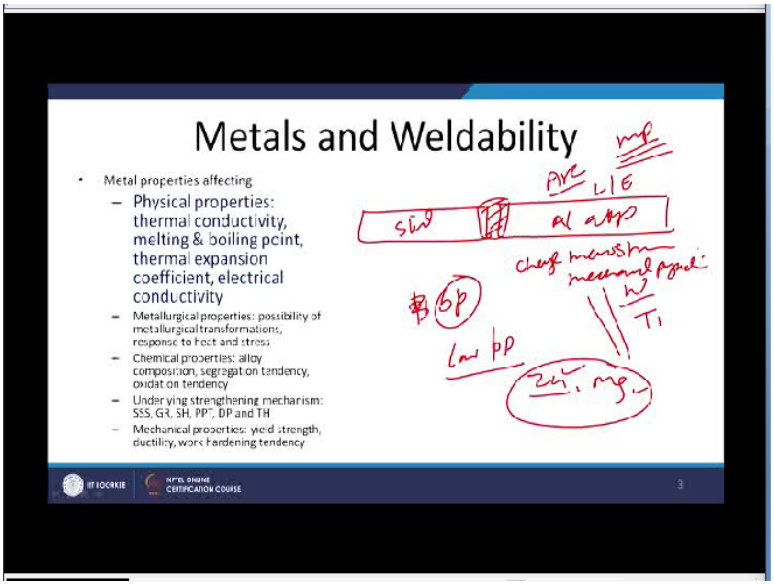

Certainly in case of the fusion based welding process we have to fuse the faying surfaces of the base metal. So, if the melting point of the metal to be welded is high then it will be difficult to melt like metals like tungsten, titanium or these which are having the higher melting point they will require more heat and the energy density associated with the many welding process may not be sufficient to bring the faying surfaces to the molten state.

So, the weldability will be poor we may require more advanced processes to ensure the fusion of the faying surfaces those high temperature metals. But it does not mean that those metals have the low melting point will always be showing very good weldability. Because there are other points which will be determining the ease of welding, so a reasonable level of the melting points certainly will be offering the good weldability.

So melting point determines the ease of the fusion and so low melting point metals in general offers the good weldability as compared to that of the high melting point metals, boiling point is the another important physical property that affects the ease of welding, say those metals having the low boiling point metals like zinc, magnesium during the welding like say using arc welding or using laser or using the electron beam.

The high temperature generated during the welding leads to the evaporation of such kind of the metals which are present in the like say steel or in the aluminium alloys. So, the metals which are being a welded using either arc or the any other heat source if it is having if those metals are having the low boiling point metals as alloying element during the welding these will evaporate. And the evaporation will be leading to the loss of those alloying elements from the weld metal.

Loss of alloying elements of the from the weld metal will be leading to the change in the microstructure, change in the mechanical properties which we might have not anticipated. So if the boiling point is high then chances for the evaporation will be very limited during the welding and the will not be losing those elements during the welding. So the properties and the structures will remain intact even after the fusion welding.

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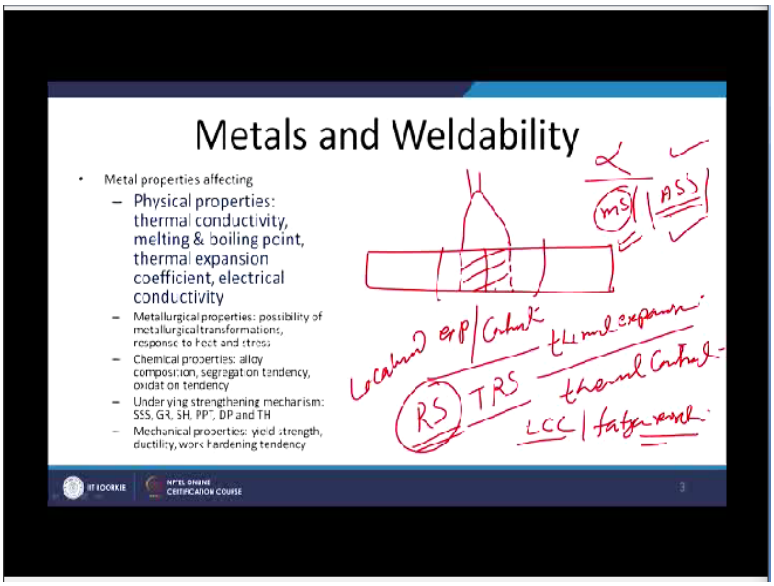

Next is the thermal expansion coefficient, we know that during the welding basically the heat is applied in very localized manner. This is the line of this weld line and heat is applied to the suitable heat source, so this is the only zone which is being heated which is being brought to the molten state and there will be a zone next to the molten state which will be heated to the high temperature.

So the metal in vicinity of the weld zone which will be heated to the high temperature will be experiencing the thermal expansion during the welding. And once the heat source has passed due to the loss of heat reduction in temperature it will be subjected to the thermal contraction. So localized basically the problem is the localized expansion and contraction leads to the development of the residual stresses.

And in general in the weld joint as and the heat affected zone we get the tensile residual stresses which tends to distort the weld joint or the plates being welded if the rigidity is limited special in case of the thin sheets, the residual stresses leads to the distortion and also especially that tensile residual stresses reduces the load carrying capacity and the fatigue resistance. So all those metals which offer the higher thermal expansion coefficient during the welding.

They will be showing the greater residual stresses, greater distortion tendency reduced fatigue resistance as compared to the metals which offer the lower thermal expansion. Because the magnitude of the thermal expansion and contraction due to the weld thermal cycle experience during the welding that will be limited in case of the low thermal expansion metal systems as compared to that of the high thermal expansion coefficient metal systems.

For example mild steel if we compare mild steel and austenitic stainless steel ASS offers the higher thermal expansion coefficient as compared to the mild steel. So there are more issues related with the residual stress in distortion as compared to the mild steel in case of the welding of these 2 metal systems by the fusion welding process. The next point under the physical properties category is the electrical properties. Among the electrical properties basically it is the electrical conductivity or the resistance.

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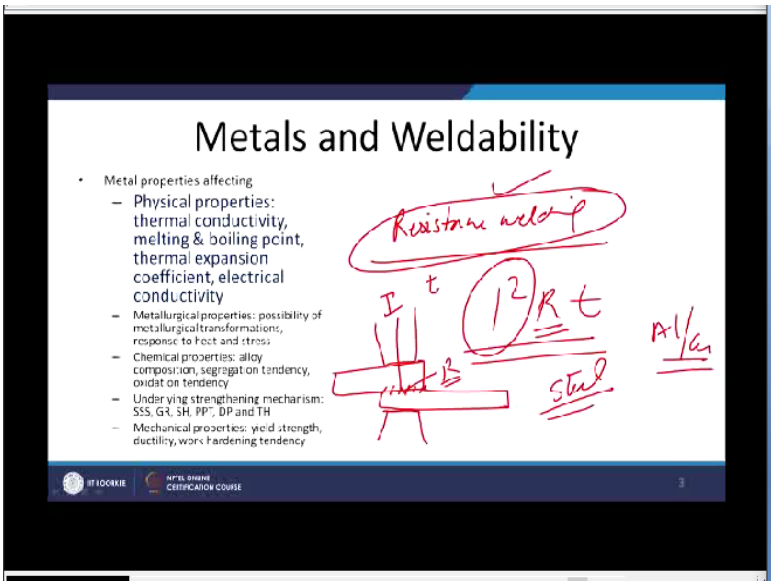

So this electrical conductivity is important from the resistance welding point of view, where primarily i square are preheating principle is used for development of the heat like in spot welding, seam welding, projection welding. The high contact resistance at the interface of the components to be joined is used for developing the heat through the application of the current i for a certain time.

So the contact resistance are at the interface determines the magnitude of the heat being generated. So, if the electrical conductivity is high the contact resistance will be less and it will generating the limited heat. So the high electrical conductivity of metals will require more current for generating the sufficient heat, so that the joint can be developed as compared to the metals which are having the lower electrical conductivity.

So it is always good from the electrical means resistance melting point of view that the metal is having the higher electrical resistance or the lower electrical conductivity. For example the welding of the steel through the resistance welding process will be easier as compared to that of the aluminium and the copper welding. Because both these metals offer the higher electrical conductivity, lower electrical resistance, so we require very high current for generating the sufficient of heat, so that the joint can be developed.

So now here I will summarize this presentation, in this presentation I have tried to talk about the way by which we can assess the weldability using the factors like efforts which are required for developing the weld joint, the quality of the weld which is made and the kind of the cost associated factors and also I have talked about the how the physical properties of the metal can affect the ease of welding, thank you for your attention.