Joining Technologies of Commercial Importance

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Lecture - 02
Fundamental mechanisms of Joining

Hello, I welcome you all in this course on the joining technologies for the metals. This is the second presentation on the same. In this presentation, basically I will talk about the fundamental mechanisms of the joining.

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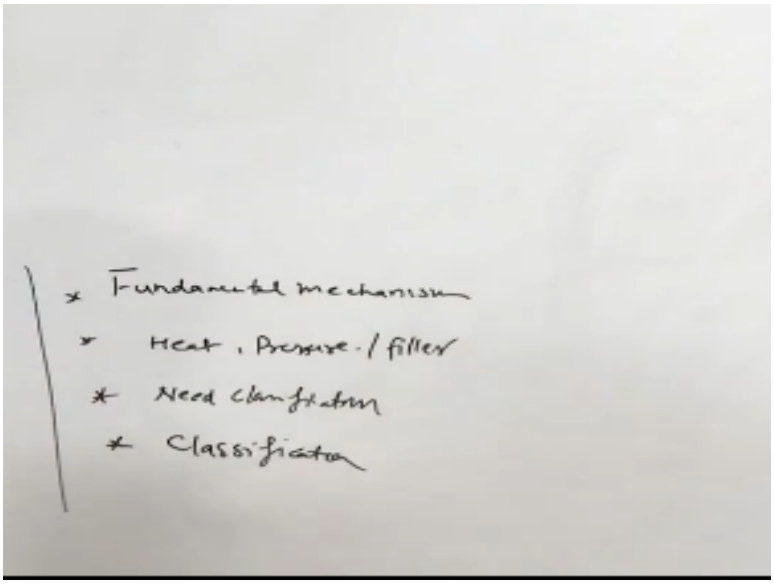

Then we will see that for the joining purpose basically we use heat pressure and filler. So, what is the role of the heat pressure and filler in the joining processes? And then based on this since over a period of time lot of the joining process have been developed so how can we classify? But before going into the bases for the classification we will try to see the need for classification. So, the need to see the classification of the joining processes.

So, these are the four aspects that we will try to see in this presentation. So, this presentation basically involves the fundamental mechanisms and the need of classification

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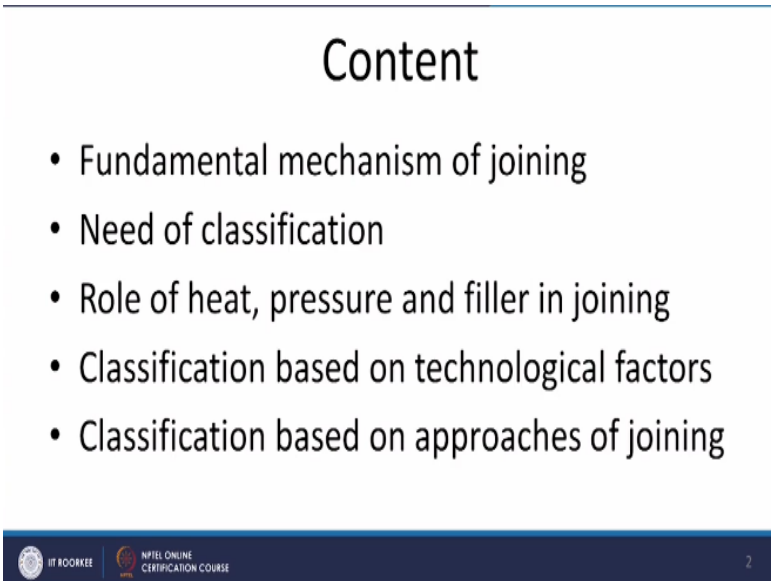

Role of the heat pressure and fillers classification based on the two aspects. One is like say the technological factors which is basically in form of those technical aspects which are used in the joining processes like whether the filler is used or not or whether the pressure is used or not. You are the kind of energy which is being used with the source of the energy for the welding purpose then there is whether arc is there or no arc process and then there is like the pressure and the fusion.

So, these are basically the technical factors that whether the pressure is being used or the melting is achieved? Whether arc is being used in the joining process for developing heat or not? The kind of energy which is being used or whether filler is used or not. So, the classification based on these are the technological factors then we will see that the approach being used for the joining purpose.

Approach means that how the joint is made so how that joint is made basically involves whether it is cast weld process or it is the fusion based process or it is a solid state based process or the resistance heating is involved. So these are the four ways by which the joint is made. Here in the cast weld processes molten metal is fed between the faying surfaces to be joined. So this is the entire coverage of the presentation.

So, we will see first the mechanisms which are used for the developing joints. Basically there are

three mechanisms which are used for developing the joints one is like say the deformation.

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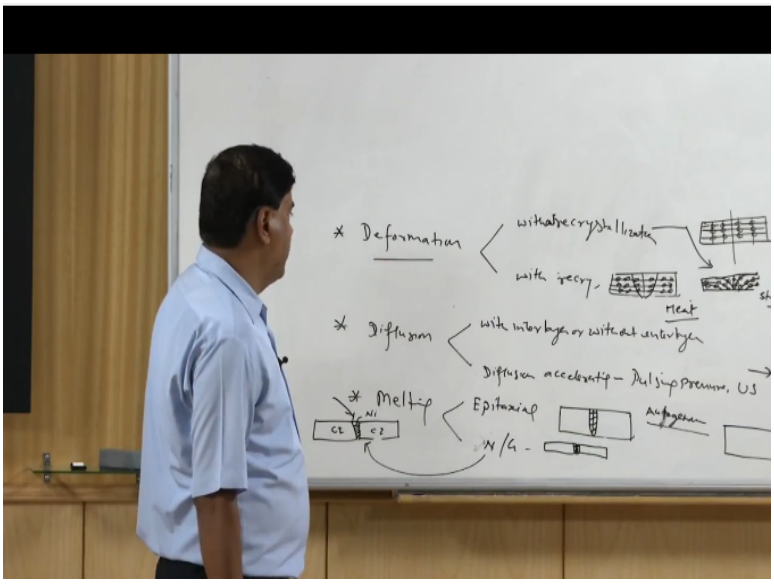

The deformation where the interfacial or the bulk deformation is used so this deformation may be with recrystallization or without recrystallization with or without recrystallization. So, if the second one is like the diffusion so the diffusion at the faying surfaces which may be done with interlayers or without interlayers and here sometimes the diffusion accelerator or accelerating approaches are used like pulsing pressure or ultrasonic vibrations are applied.

Third one is like the melting or the fusion of the faying surfaces involving direct growth through the Epitaxial mechanism or the second one is like the nucleation and the growth mechanism is involved. So, each of these I will elaborate one by one. Like say the two components having the regular arrangements of the atom like this and this is the interface. So this arrangement on the atom here existing in this way, the sides.

And when the joint is being made we will this arrangement of atoms is disturbed in this manner where the continuity is achieved but the arrangement of the atoms near the interface is disturbed so like here they are like this but here as soon as we approach towards the interface the arrangement of the atoms or orientation of the atoms the lattice gets disturbed. So, here it will have that strained lattices with the distorted or the disturbed arrangement of the atom.

So, this is the approach where without recrystallization. So, no recrystallization this is the case when the atoms or the regular arrangement of the atoms is distorted when the metallic continuity is achieved and if the recrystallization is involved you will see that the joint is continuous and arrangement of the atom is still maintained even after the welding because of the fresh grains are formed and there is not lattice strained.

So, this happens when lot of heat is generated in course of the welding and here the heat generated is limited. So, these are the deformation based joining process where heat generation is limited. You will see that strained lattice and disturbed arrangement of the atoms and otherwise when the recrystallization takes place in deformation with the recrystallization when sufficient heat is generated the normal arrangement of the atoms is achieved.

So, you see that there is a joint but the arrangement of the atoms have not been disturbed much. In case of the diffusion the components to be joined in very clean polished condition are brought together and they are kept under pressure usually in the vacuum. It may be in active or inert environment also. So when there is direct metallic intimacy due to the concentration gradient of the elements across the interface the diffusion starts across the interface.

So, the diffusion is facilitated basically by the temperature over a sufficient period of time. So, when the sufficient time and temperature is given the bond at the interphases formed. So, to facilitate the diffusion across the interface sometimes to overcome the problems related with the surface roughness interlayers are used, interlayers of the soft metals are used. So, under pressure they get deformed and fill the cavities.

And the regularity presented the surface in order to facilitate the diffusion across the interface. And sometimes the pulsating pressures are also used so that the peaks and valleys get collapsed under the pulsing and pressure conditions and bring the metallic intimacy in the firm contact with each other. And similarly the use of the ultrasonic vibrations also helps in facilitating the diffusion across the interface. So, that the diffusion bond can be developed at a much faster rate.

The melting of the fusion based approach where the components to be joined are brought with

the molten state. So, these are the two members so in case of autogenous weld just the edges of the components to be joined are brought to the molten state and the metallic continuity is obtained. This kind of joints are called autogenous weld where just the melting of the faying surfaces are achieved and after the solidification we get the sound weld joint.

And when the greater thicknesses are to be joined then the groove is usually made and this groove is filled using the filler. Filler may be of the same composition as that of the base metal or of the different metal. So, if it of the same if the filler used same as the base metal then again epitaxial solidification takes place but if the filler metal is different from the base metal then the nucleation and the growth mechanism of the solidification is involved.

So, these are the approaches which are used for developing the joints. For example, for this case like in the laser welding or tungsten inert gas welding processes where thin sheets of say 3 mm, 4 mm are brought to the faying surfaces are brought to the molten state and then after solidification we get the joints. So, just melting of the faying surface is achieved. No filler metal is used in in these situations but for specific requirements.

Sometimes what we do that the components to be joined are welded using the filler of the different composition like say in case of the cast iron it is common to use the nickel as a filler metal. So, here it is a completely different this has like say cast iron has BCC structure and the Nickel has the FCC structure so because of significantly different use of the filler metal first the nucleation and then growth mechanism is involved in course of the development of the welded joints.

So, whenever the fusion is the joining mechanism you will see that either the epitaxial or the nucleation and growth mechanism are involved for the completion of the solidification. So, these are the fundamental mechanisms. So, if we see here these three mechanism will be using either the heat or pressure or both. So, the different processes of the joining will be using either of these three, one of these three mechanisms for developing the joints.

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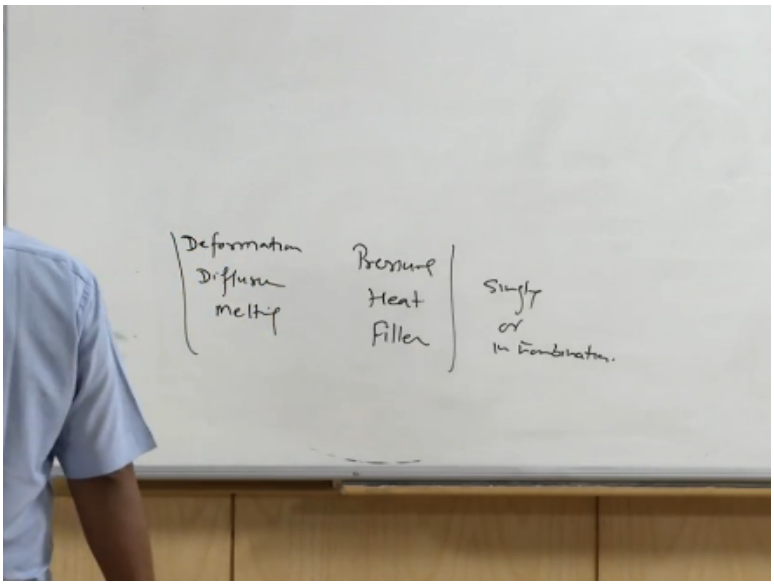

Since the deformation, diffusion and melting these are the three things which are there they will use pressure, heat and filler either singly or in combination. So, using these three fundamental aspects the different range, very wide range of the processes have been developed over a period of time. So, over a period of time we will see that very large range of the solid state joining process, very large range of the solid liquid state process and the liquid state process have been developed.

So, in order to understand clearly for better communication, it is required that they are classified appropriately. So, as we know that the entire range of the joining process we can put in three categories involving the chemical or the adhesive joining involves the chemical interaction with the surfaces like the soldering brazing and the adhesives are used.

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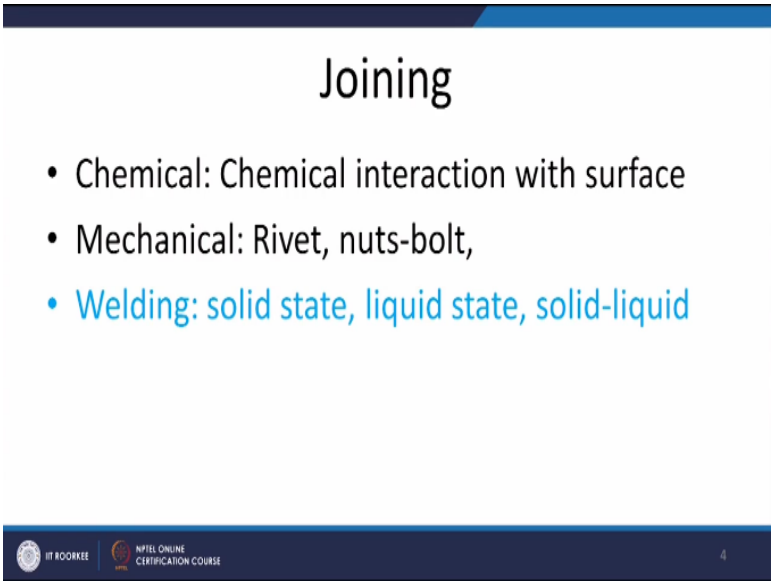

The mechanical joining where the use of the rivets, nuts and bolts or the press fit arrangements are used or the welding involving the solid state, liquid state, and the solid liquid state. In solid state the process like friction stir welding or the friction welding process or the forge welding processes, liquid state process where the fusion of the faying surfaces are achieved for melting purpose and the solid liquid processes where the base metal remains in the solid state

And the filler metal in form of the solder or the brazing material is brought to the molten state to develop the joint. Since, the range of process in each of the category is very wide so we need to see really how the different processes can be grouped. So the grouping is to be done for the specific purpose we have seen that the joints using these three fundamental approaches can be developed with or without use of heat or with or without use of pressure or filler.

And since these are the three fundamental things or features which may be involved in one or other joining processes. So, since the existence of the very wide range of joining process is there so we need to see really how the grouping of the different processes can be done that is what is called the classification. So, as far as the need of the classification is concerned we need to see that how the different processes can be grouped at one place based on their fundamental similarity or the dissimilarity.

So, the one reason you need to classify is that we want to see that how the grouping of the

different joining process is possible based on the fundamental similarities or the dissimilarities. We can organize the different joining process also effectively if they are classified properly. So, organization means solid state joining process or the resistance welding process or the fusion welding process or arch welding process.

There can be so many ways to group or classify the joining process. And then easy to communicate like this category of the metal will be subjected to solid state joining or this category of the metal will be subjected to the or this similar combination will be subjected to the like the solid liquid based process because of the metallurgical incompatibility. So depending upon the requirements we can use the different kind of processes in the different categories.

So, important thing is like our communication to use a particular kind of joining process becomes effective that is what is there?

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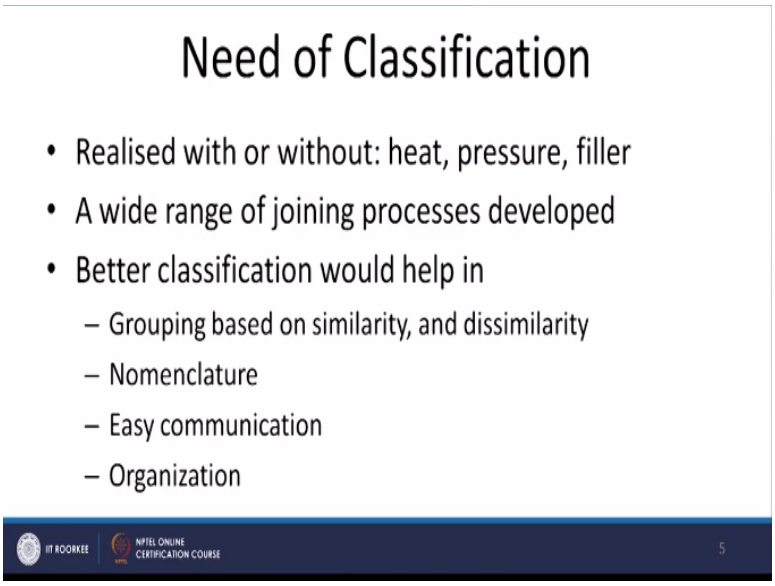

Easy communication and then easy nomenclature. Nomenclature, means under what conditions the joining process is being done that can be used as a bases to classify. Like solid state joining process or liquid state or solid liquid state or the process is based on the arc like that. If some hybrid joining process or the newer joining process also has been developed. Naming would be easier based on the fundamental aspects related with the joining process.

So, the classification also helps in effective and the proper nomenclature. These are the 3 or 4 purposes because of which four reasons because of which classification actually help in realizing these points. So, now we will see that since the use of the heat filler and the pressure is very crucial in joining irrespective of the kind of process which is used wherever these three things are involved. What is basically the purpose?

In general, wherever the joining process is involved, whatever joining process is it will be used in either pressure or heat or the filler or in singly or in combination. So, the specific purposes of the using heat,

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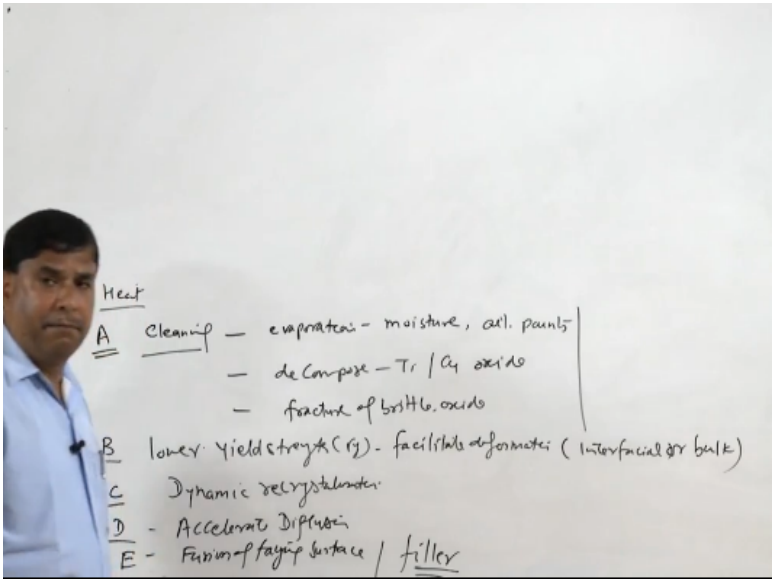

You will see that there are 3 or 4 purposes first is that whenever heat is applied it helps to clean. So the cleaning of the faying surfaces of the base metal or of the substrate. So, basically it evaporates or evaporation of all organic impurities may be in form of oil, pain or moisture. So, all these things get evaporated moisture, oil, paints etcetera. All these things get evaporated. At the same time some of the things get decomposed like some of the oxides of the titanium and copper oxides they get decomposed.

And so they are removed from the, they get destabilized and they can be easily removed from the surface decomposition and sometimes the fracture of the brittle oxides also takes place due to the differential thermal expansion behavior. Oxides do not expand that much as compared to that of

metal so the differential expansion behavior leads to the fracture of the brittle oxides. So, that is how the heating helps in the cleaning of the metal once.

So, this is one the big factor the second one is the application of the heat helps to lower the yield strength of the metal. So reduction in yield strength sigma y of the metal, it helps to facilitate the deformation. This deformation in some of the processes is used interfacial and some of the process it is bulk. So interfacial deformation like the ultrasonic welding process and the bulk deformation, like friction welding in friction stir welding process.

So, the interfacial or the bulk deformation so sometimes the heat is intentionally generated and applied so that the yield strength of the metal can be reduced in order to faciliate the deformation so that the metallic continuity is achieved. This deformation can be at the two levels one is interfacial or at the bulk level. Third is to see that the dynamic recrystallization whenever heat generated is enough so due to the deformation when the lattice is disturbed.

At the same time, you will see that the fresh grains are formed in the deformed material with the help of the heat being applied. So the dynamic recrystallization is also achieved. Now, the forth important purpose you know that the diffusion rate increases with the increase in temperature in order to achieve the – develop the diffusion bounds in reasonably good time, the high temperature, temperature high enough like say 0.5 to 0.6 times of the melting point in Kelvin is normally achieved by the heating.

So, basically the purpose of heating sometimes is to accelerate the diffusion specially in the diffusion bounding process. Accelerating the diffusion so that the diffusion bond across the interface can be achieved easily. The last one, one more purpose of applying the heat is like for achieving the fusion of the faying surfaces. So that the metallic continuity can be achieved. So here these are the five purposes of applying heat and the most commonly (()) (22:58) fusion welding processes will be using the heat for melting of the faying surfaces.

At the same time this is also used for the melting of the filler metal. So, the process is like brazing and the soldering will be using the heat for the melting of the filler and marginal heating

of the base metal. But in those cases the base metal remains in the solid state. Now, we will see the purpose of the pressure for which it is applied. The pressure in the joining process is used for the different purpose then that for the heat is used.

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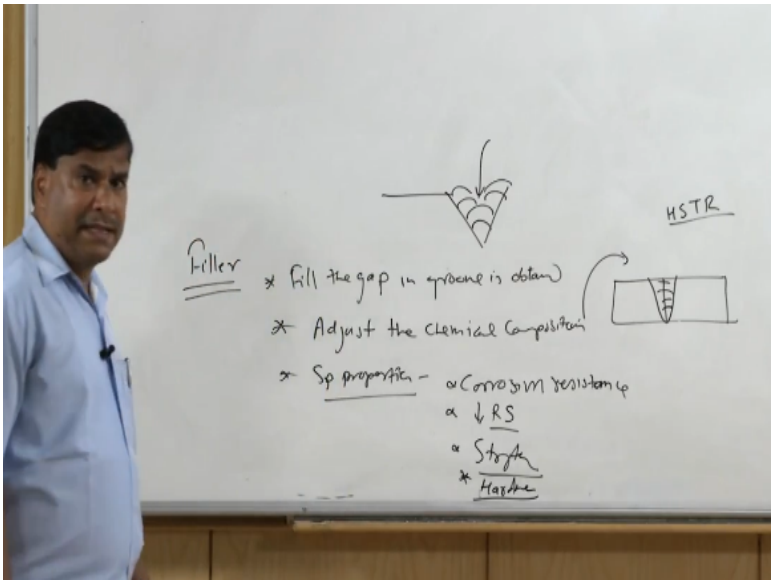

So, the application of the pressure helps in like the purposes for which pressure is applied. One is it is just like disrupting the absorbed gas layer. We know that all the real components are made of the number of like this is a bulk. This is the deformed, then oxide layer and then absorbed gas layer. So, the thickness of these layers may be in very nano level or in micron level. This is a deformed layer.

This is the base and it is also the surface very top of very few nano meters is very small having the gases absorbed from the atmosphere. So, with the application of the absorbed gas layer is disrupted or broken down with the application of the pressure. Then fracturing of the oxide layer that is also achieved when the pressure is applied. So the metallic intimacy between the faying surfaces is achieved.

And one more purpose is to achieve the deformation as per requirement. This deformation can be interfacial or it may be bulk. Interfacial deformation as I have said is achieved in case of the ultrasonic welding process and the explosion welding process and the bulk deformation is in friction welding and ultrasonic welding, forge welding etcetera. So, these are the three purposes

which are achieved with the help of applying pressure irrespective of the conditions in which joining process it is used.

So one or more purposes can be achieved through the use the pressure in those joining process where pressure is used as a major variable. And then use of filler, use of filler is very important specially in case of groove welding. This is used to fill the gap; this is one thing. So, in all consumable welding processes the filler actually plays one big role of the filling of the gap. This is one thing that the filling the gap in groove welding is obtained or is achieved.

The second one is it is intentionally sometimes used of the different compositions to adjust the chemical composition of the weld metal. Sometimes, or the base metal becomes very sensitive or cracking like say the base metal have high solidification temperature range. So because of the high solidification temperature it shows the tendency for the center line cracks.

So, that tendency for central line crack is reduced by adjusting the chemical composition of the weld metal in such a way that solidification temperature range is reduced. So, sometimes the filler metal of different chemical composition is used in order to adjust the composition of weld metal so that solidification cracking tendency can be reduced.

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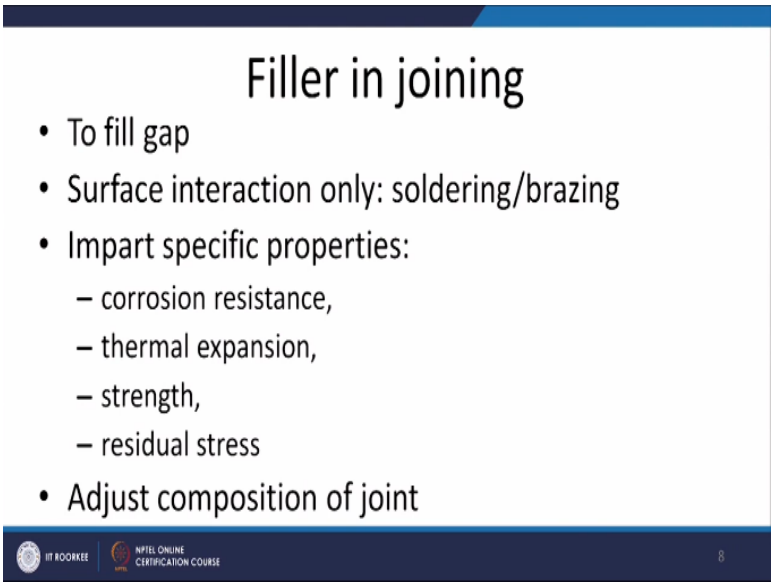

Then it is also used for achieving the specific properties in the weld like the filler can be of the

different composition then the base for having very good corrosion resistance or sometimes the filler metal is selected intentionally of the low strength so the residual stress, lower strength and high ductility so that the residual stress magnitude can be reduced.

So improving the corrosion resistance, reducing the residual stresses and having the desired combination of the strength sometimes the filler metal is selected in such a way that they are much higher strength or much harder of much higher hardness. For say, air resistance application where it is possible that the weld can erode so the high hardness the filler metal is added. This will help in reducing the air resistance of the filler metal.

So, in this lecture we have seen that the different joining process can be categorized based on the fundamental mechanisms. There are three fundamental mechanisms one is like diffusion another is the deformation with or without recrystallization. And third is fusion and this is achieved through the proper application of the heat, pressure or filler either singly or in combination with the other and each of these three factors play very important role whenever they are used in the joining processes.

So, in the next presentation I will talk about the different technological factors which can be used for classification of the joining process. Thank you for your attention.