Joining Technologies of Commercial Importance

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Lecture – 05
Protection of Weld Metal

Hello, I welcome you all in this 5th presentation on joining technologies for metals and this presentation is based on the protection approaches which are based for a development of the sound joint. In the last lecture, I have talked about a that the different ways by which the joints can be made.

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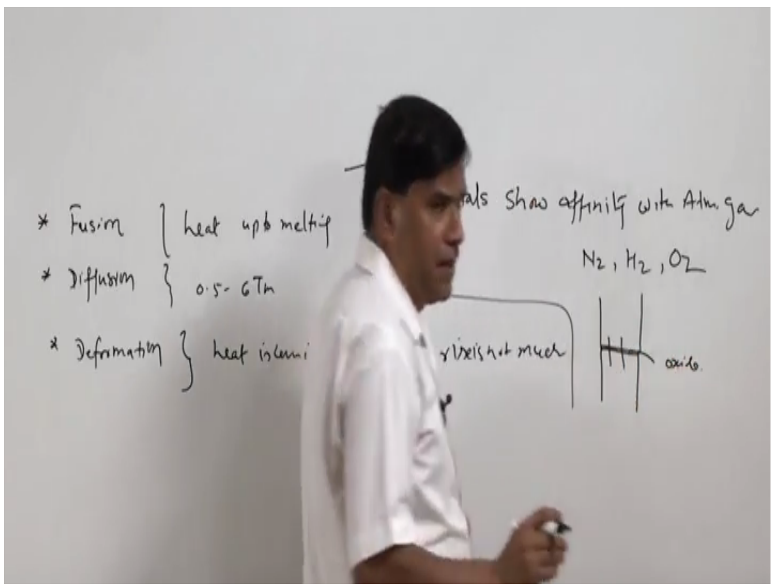

And the fundamental mechanism which are used for the development of the joints includes like a fusion, then diffusion and deformation or the plastic deformation, which way be with or without re-crystallization. So we know that a for fusion we have to heat up to the melting point. Well the diffusion takes place in the range of 0.5 to 0.6 times of the melting point in Calvin. Well the deformation based approaches where either heating is a limited or it is very negligible.

So the heat is a limited and temperature rise mostly is not much, temperature rise is not much, but in some of the cases like a friction is welding and friction welding of the steels the temperature can go as high as 700, 800, or even 1000 degree centigrade. So under those conditions, we may require protection to avoid the interaction of the metal with the atmospheric gases. We know that in all these cases, the metals when they are heated all metals, metal show affinity with the atmospheric gases.

These gases are like nitrogen hydrogen and oxygen, so increased activity and affinity of the metals at high temperature becomes problematic specially when the fusion is achieved for development of the joint or diffusion is a required across the interface of the components to be join because formation of any layer at the interacting surfaces in case of the diffusion if any layer of the oxides are these, nitrites is being formed.

Then it will hinder the diffusion across the interface and will act as a barrier for the development of the joints, so it is not good. We need to protect the joining process by the diffusion when using either a inert gases or the vacuum and in case of the deformation, normally if the temperature rises not much then separate protection of the metal from the atmospheric gases is not required but if the temperature rises to much and the metal is sensitive.

Then of course we need require protection from the atmospheric gases even the deformation based joining approaches. So, now we will focus on the two aspects mainly may lay here like the diffusion and the fusion because the problem of interaction of the atmospheric gases with the solid state process is not that much unless very specialized a metal system are welded like the titanium alloys which may require protection.

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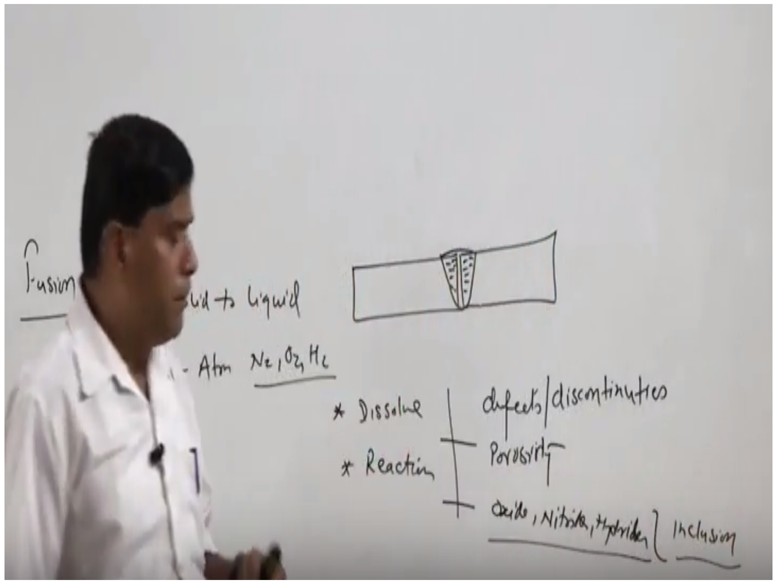

So, here when we talk about that the fusion, because of the change in state from the solid to liquid these gases from atmosphere like nitrogen, oxygen and hydrogen. These are the main problematic gases as far as the fusion welding is concerned and these gases whenever the components to be joined and they brought to the molten state.

So, these gases interact with the molten metal in the 2 ways; one either these were gases will get dissolve because of the high solubility elevated temperature in the molten state or they will react so according to the way by which they interact with the molten metal. They will be resulting in the defects or discontinuities which may lead to the rejection of the weld joints when the discontinuities are beyond the acceptable limits.

So, when the gases dissolve a larger quantity in the molten state and during solidification if they do not get enough time it results in the development of porosity and when the gases interact with the molten metal at high temperature, they will be resulting in oxides, nitrites hydrides. So these things will be if they do not float over the surface if they are not separated then they will be present in the welled as inclusions.

So in both the cases, the presence of porosities or inclusions in the weld will deteriorate the mechanical performance as well as other performance which are expected during the service like corrosion or ability to carry the fatigue loads or the tensile loads. Therefore, it is required that during the fusion welding the weld metal is protected using suitable approaches from the atmospheric gases.

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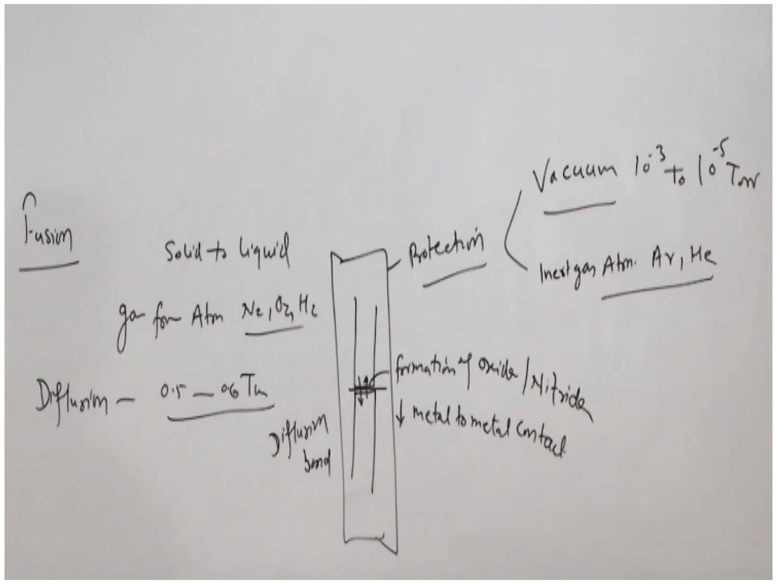

And now another thing is about the diffusion. We know that if the diffusion has to take pace in 0.5 to say 0.6 times of the melting point range, so there is very much possible if it is carried out in the environmental condition or ambient conditions, this kind of heating will result in the formation of oxides and nitrides at the interacting surfaces. So formation of these oxides and the nitrides at the interface will reduce the metal to metal contact.

And this kind of hindrance will result in the hindrance will reduce the diffusion of the atoms across the interface which normally takes place for development of the diffusion bonds and this is the prerequisite that across the interface diffusion has to takes place then only the bond will be developed, so the formation of this kind of oxides and nitrides due to the heating at high temperature is undesirable.

And that is why it is necessary that entire system for the diffusion bonding process must be protected and this protection is normally provided using two approaches, the most common one is the application of vacuum. Vacuum ranging from 10 to the power -3 to 10 to the power -5 Torr is very commonly used for the diffusion bonding process on the other hand if the metal is not that sensitive.

Then inert gas atmosphere can also be created to avoid this kind of interactions of the surfaces during the diffusion bonding like formation of the oxides and nitrides and for this purpose like argon and helium are the most commonly used the gases to protect the fink surfaces from the atmospheric interactions in case of the diffusion bonding. Now, we will see if the protection is not provided then what it leads to in respect of the specific gases.

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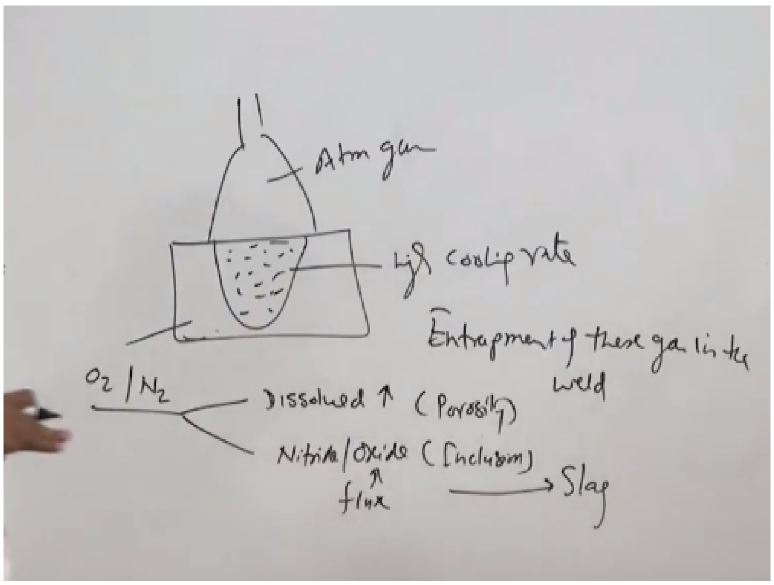

And that is what we will see first that if that atmospheric gases like the wave, if the atmospheric gases are present in the in the fusion zone or in the like say arc environment or whatever heat sources being used. So these atmospheric gases when they get mixed up with the molten metal, high cooling rate of the molten metal sometime causes the entrapment of these gases in the weld. So such kind of entrapment will of course will be appearing in form of big gas pockets and another problem which is encountered is the porosity.

The porosity due to the difference in the solubility of the gases in the liquid and solid state when the gases dissolved with the molten metal or the gases coming from the fusion of the metal in solid state the gases which were already dissolved in the base metal like say in the base metal is already having lot of oxygen and the nitrogen content. So after fusion, these gases will be automatically present in the weld metal also.

These gases must be taken care of otherwise they can react in 2 ways like I have said the dissolution, the dissolved gases will tend to come out if there are not able to come out up to the floating surface up to the surface of the pool, then they will be present as porosity or if they react with the metal then they will foam the oxides and nitrides and which will be there as inclusions. So we need to take care of these oxides and nitrides using suitable fluxes. So fluxes react with the oxides and nitrides to form slag and slag is designed to be the lighter.

And so it floats over the surface of the weld pool and get separated. So, the now we will see how specifically these the gases affect the weld joint whenever these are present in the larger quantity, so before going into that from the welding point of, we will try to see that how the gaseous content or content of the gases in the weld metal is affected by the process being used like a so before going into that we will see what are the approaches available for the protection of the weld.

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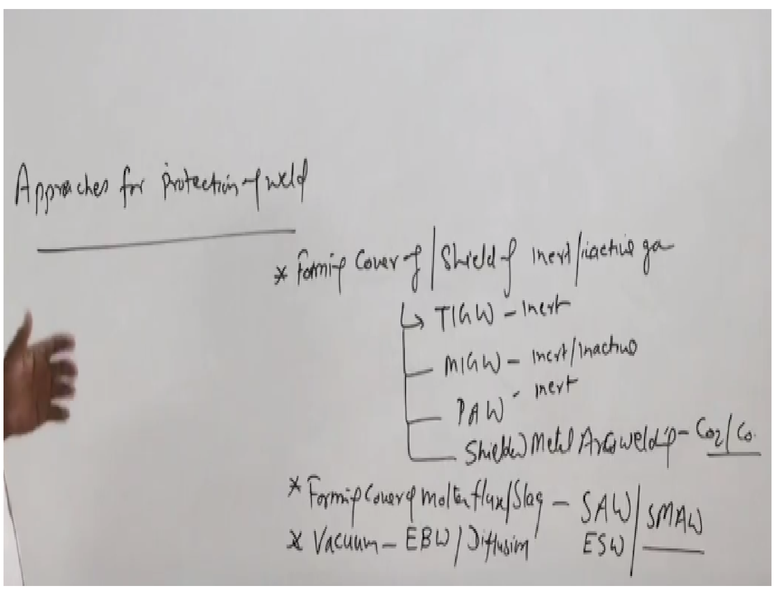

Basically three approaches are normally used, one is forming cover of the shield of inert or inactive gases as per the metal. So this kind of approach is used in case of like say the TIG welding, tungsten inert gas welding, and metal inert gas welding like plasma arc welding, like a shielded metal arc welding, so these are the different processes like a TIG variably uses inert gas while forming it can use both inert or inactive gases like carbon dioxide.

Plasma also normally uses inert gases argon and helium and shielded metal are gas uses the flux coating so which produces CO2 to protect the weld from the atmospheric gases. Another is like forming the cover of molten flux or slag. This one is used in case of submerged arc welding where arc is completely cover with the granular flux which is brought to the molten state in course of the welding.

So its interaction of the weld pool from the atmospheric gases prevented and second is electro slag welding. In the electro slag welding also the molten flux and the molten slag completely covers from the molten metal and there by its provide protection to the weld pool and this principal also to some extend is used in case of the like the molten slag covers the weld metal in case of the shielded metal arc welding process also.

Because in shielded metal arc welding, the fluxes react with the impurities to foam slag and slag floats over the surface of the pool. And there by it separates the weld metal from the atmospheric gases, so it uses both foaming the sealed of the inactive gases like COCO2 and covering the molten metal with the molten slag in case of the shielded metal arc welding process so both the approaches are used in case of the shielded metal act welding.

Now, we see the kind of vacuum. Use of the vacuum for protection of the weld pool is also effectively used for protecting the joint. And the weld joint and this is used in case of the electron beam welding and as I have said just now, the diffusion bonding also vacuum is used to avoid interaction of the atmospheric gases with the fang surfaces, so since the approaches are different and the welding condition are found to be different while actually welding.

So the kind of protection which becomes available to the weld metal becomes the different and accordingly the quality of the weld which is made is also found to be different that is what we will see from the generally observed the gaseous content in the weld metal produced using the different welding processes.

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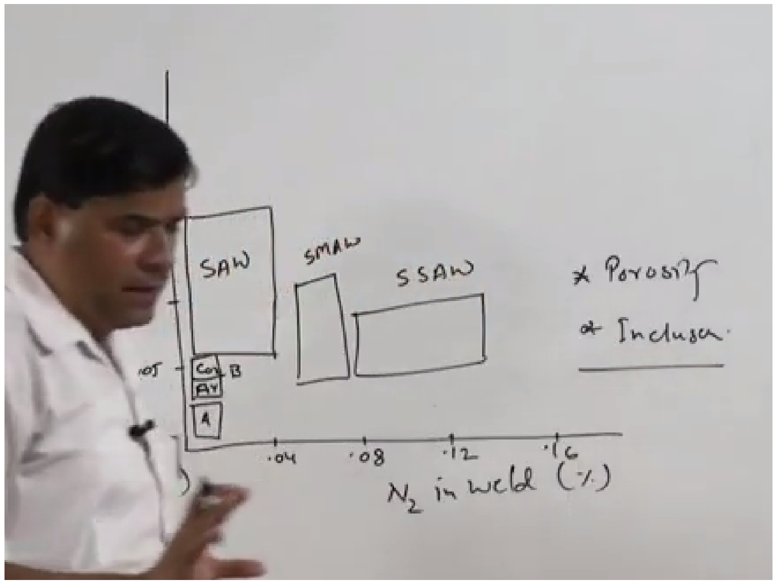

So, this is what we will try to see from this diagram, which will highlight the kind of cleanliness with which the welds are produced by the different welding processes. So, in Y axis we will mention the percentage of the oxygen in weld and in the X axis, we will mention the percentage of nitrogen, in the weld, in terms of percentage. So, here like I say 0.04, 0.08, 0.12, 0.12 like this and here 0.05, 0.1, 0.15 and 0.2.

So, here we will see, very narrow bend of oxygen and nitrogen, the weld produced using the process like say A, A is TIG welding, TIG invariably uses the inert gases and it produces the cleanest weld and thereafter we will have the MIG welding, MIG or GMAW it can use CO2 or argon like say if argon is used, this lower bend and if the CO2 is used, higher bend. So, this second one, the joint made using the process B when using is say the GMAW gas metal arc welding using CO2 or argon.

So CO2 result somewhat higher percentage of the oxygen in the weld as compared to the argon and cleanliness point of view, the cleanest weld is being produced by the GTAW and then GMAW and then we will see the submerged arc welding. Submerged arc welding process offers much higher bend of the, much larger concentration of the oxygen in the weld and then thereafter we have shielded metal arc welding process like this.

This is what we can see from this diagram also like shielded metal arc welding, submerged arc welding, this is for the submerged arc welding and this is for the shielded metal arc welding process. Shielded metal arc welding process offers the greater percentage of the oxygen as well as the nitrogen, here we can see the cleanest weld is being produced with the help of the GTAW.

Thereafter, GMAW, using argon or the CO2 and then submerged arc welding and thereafter more concentration, more oxygen in the weld and nitrogen, more nitrogen in the weld produced using the shielded metal arc welding.

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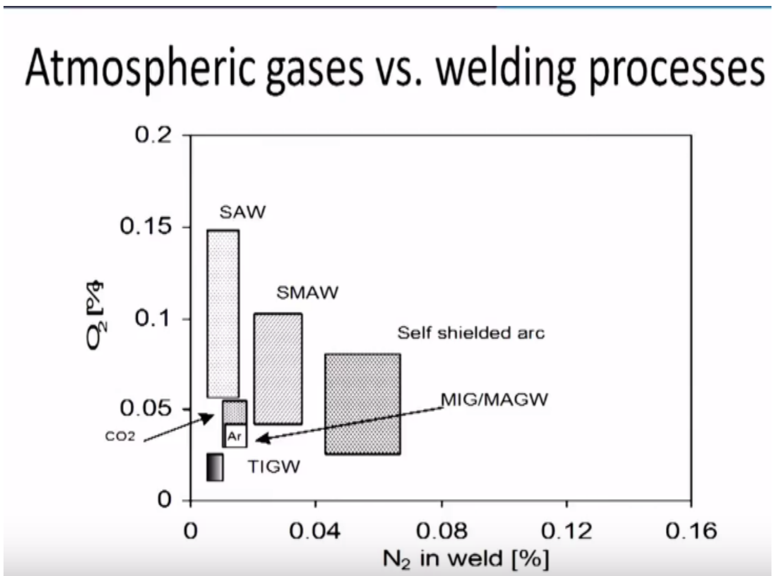

And thereafter self-shielded arc welding process like flux code arc welding which offers much higher concentration of the oxygen as well as nitrogen. So, this is what we can correct here little bit. So you can see this is for the SMAW and here we have self shielded arc welding like flux code arc welding, they offer much higher concentration of the nitrogen in the weld, so since the protection approach is being used in the different welding processes are different.

And that is why the kind of cleanliness or the kind of the nitrogen and the oxygen content in the weld metal is also found to be different. And accordingly, we can expect the percentage of the porosity or inclusions in the weld, it is very clear that greater is the percentage of the oxygen and nitrogen in the weld, greater will be the porosity and other inclusions. To see the effects of the specific gases like oxygen and nitrogen on the weld we will see the 2 diagrams.

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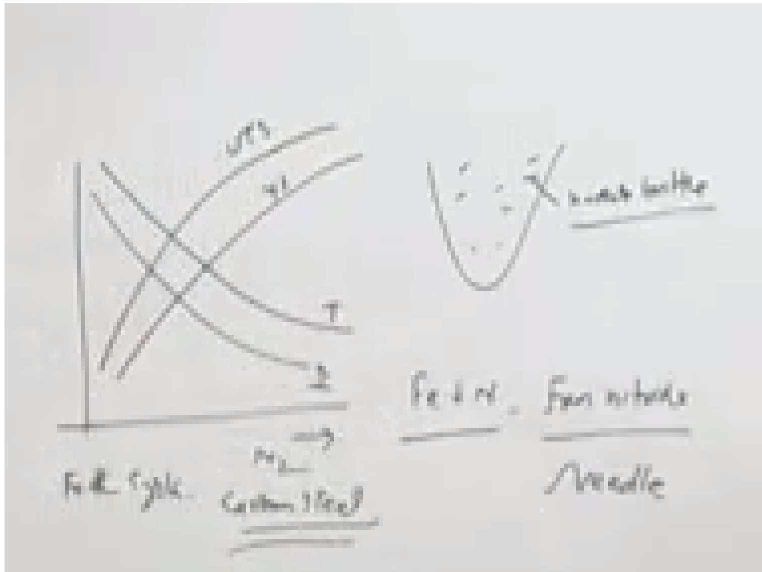

One for oxygen and another for nitrogen, here increasing concentration of the nitrogen in the weld in general increases the strength and ultimate strength like say UTS and yield strength but it happens at the cost of the ductility and toughness, so the ductility and toughness in general decrease with the increase in the nitrogen concentration in the weld while yield strength and ultimate strength increase.

This is true for the iron, carbon, systems, especially in case of the carbon steels and this variation is achieved to the interaction between the iron and nitrogen, leading to the formation of the iron nitride and this iron nitride appears in form of the needles, so needles of like say in the weld will see very fine needles of iron nitride, these needles are very hard and brittle, so the presence of hard and brittle needles in the matrix of the iron provides very good strength.

But the sharp edged needles also facilitate the easy nucleation and growth of cracks and that is why the ductility and toughness in general reduced with the increase in the nitrogen content. So this is the effect of, presence of the nitrogen up to a limit is good from the strength point of view but it compromises with the ductility and toughness of the weld joint.

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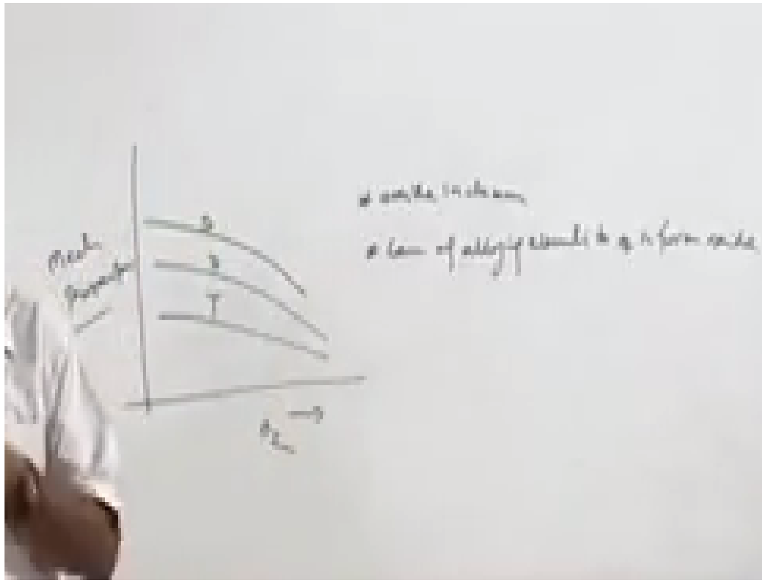

On the other hand, if we see the effect of oxygen, and the mechanical properties on the Y axis and increasing oxygen content in general decreases the strength ductility and toughness and so strength, ductility and toughness also decrease with the addition of the nitrogen content. And this is attributed to the formation of the oxide inclusions. 1 and 2 laws of alloying element to the oxygen in form of oxides.

And this is what also can be seen from the effect of the elemental efficiency, effect of the oxygen on the elemental efficiency, so if the alloying elements are lost or the oxide inclusions are present or the more oxygen is leading to the loss of the harden ability due to the loss of alloying elements then they will degrade the properties of the steel. Inclusions effectively reduces the load at cross sectional area in the weld joint.

And that is why in general all the properties of the steals mainly decrease, while in some of the cases, increasing presence of the oxygen in the weld metal promotes the acicular ferrite which in turn promotes the toughness of weld joints. So, in some of the cases only acicular ferrite is promoted with the presence of the oxygen and that it turns and improves the toughness. So we will see this is the effect of, this diagrams shows the effect of the nitrogen on the mechanical properties what I have described using board

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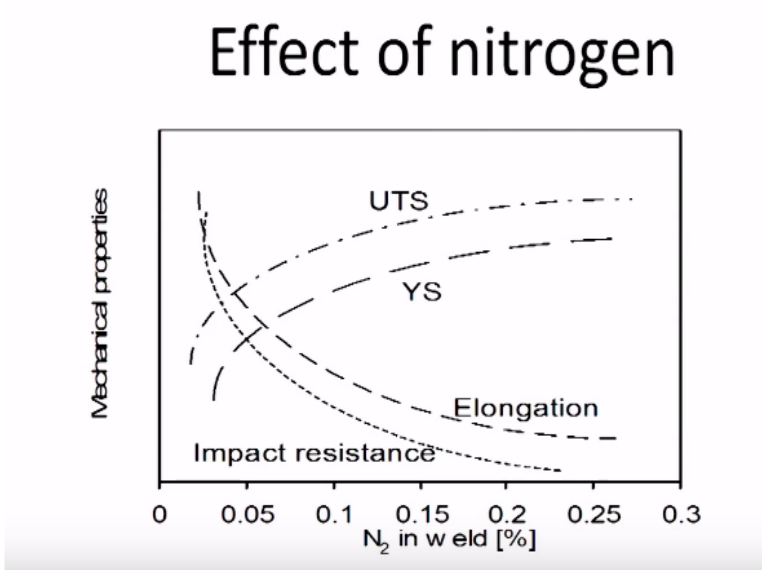
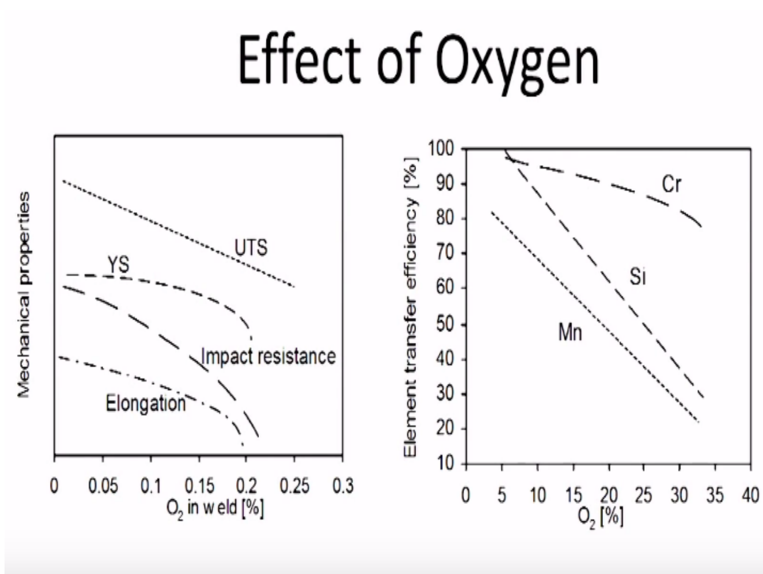


And this shows the effect of the oxygen on the mechanical properties of the weld joint especially of the iron means the carbon steels where loss of the ultimate strength and yield strength impact resistance and elongation everything takes place. So, now you see, that how the element transfer efficiency decreases with the presence of oxygen.



We will see that increasing concentration of the oxygen decreases the manganese and silicon content the chromium content in the weld metal. If the things present in the filler are not being transferred to the weld pool, then it will lead to their loss, so elements are getting lost in course in process of the transfer and this efficiency decreases. For example, if the filler had 2% of the like say particular system like silicon, then for a particular concentration of the oxygen.

We will see that for 25% concentration or 25% of the oxygen it will lead to the 50% element transfer efficiency, means actually the weld will have just 1% of the silicon, so out of the given amount, how much is actually being transferred, that determines the element transfer efficiency and that is adversely effected with the presence of oxygen and that is why it is important to protect the weld.

So this is what I had explained that when the gases are present in the arch environment, they interact with the molten metal and in the molten state, the gases dissolve in the larger quantity as compared to that in the solid state.

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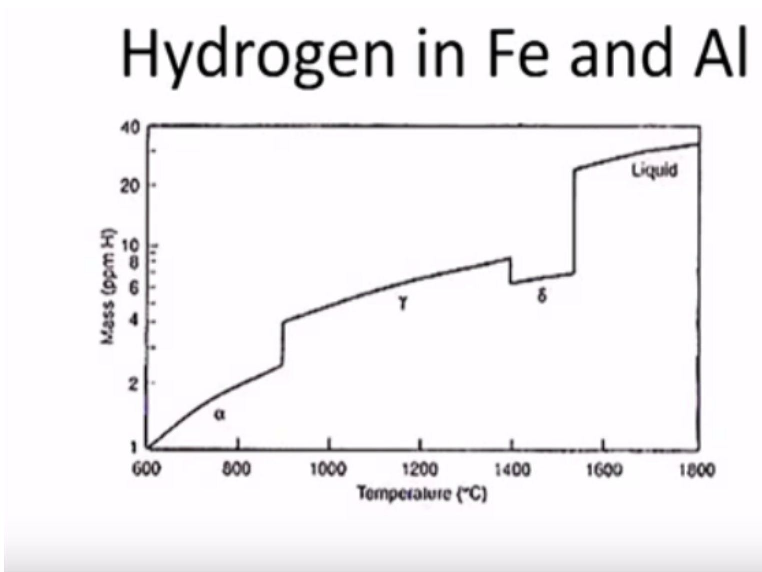

Like say this is the example of the dissolution of the hydrogen in iron, increasing temperature changes the crystal structure like initially it is alpha then it changes to the gamma and then delta. Alpha has the BCC crystal structure, gamma has the FCC and delta has again BCC crystal structure, so because of the changing crystal structures, increased space available for occupying the hydrogen atoms, there is an increase in solubility.

And there is a sudden increase in the solubility of the hydrogen when the transformation from the solid to the liquid state takes place and the same thing happens in case of the aluminum also.

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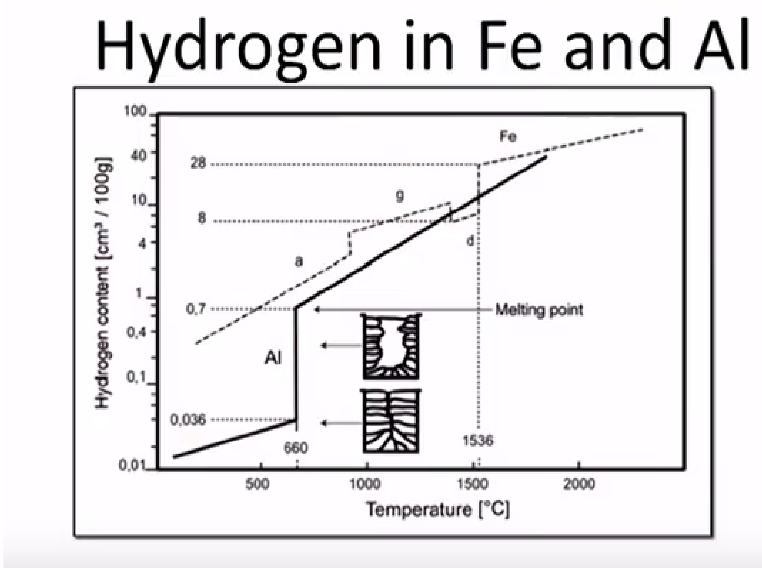

As soon as, the temperature increases above 60-degree centigrade, there is sudden jump in the solubility of the hydrogen in aluminum and thereafter it (()) (30:24) so large difference in the solubility of the hydrogen in liquid and solid state leads to the development of the porosity in the weld joints that is why it is important that if the gases need to be eliminated from the arc environment or we need to take care of them by using suitable approaches.

So, now I will conclude this presentation, in this presentation, I have talked about that why it is important to protect the fink surfaces and the weld metal from the atmospheric gases, how do they effect and what are the various approaches available for protection of the weld pool. Thank you for your kind attention and in the next presentation I will start the basics of the fusion welding processes and also the fundamental principles of the gas welding process. Thank you for your attention.