Welding Processes
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Selection of shielding gases for engineering alloys

So last class we were looking at the shielding gases, so the various characteristics of gases and how these shielding gases are affecting the arc characteristics and we also looked at the primary functions of the shielding gas is to strike an arc, to strike a low voltage arc which is needed for our applications.

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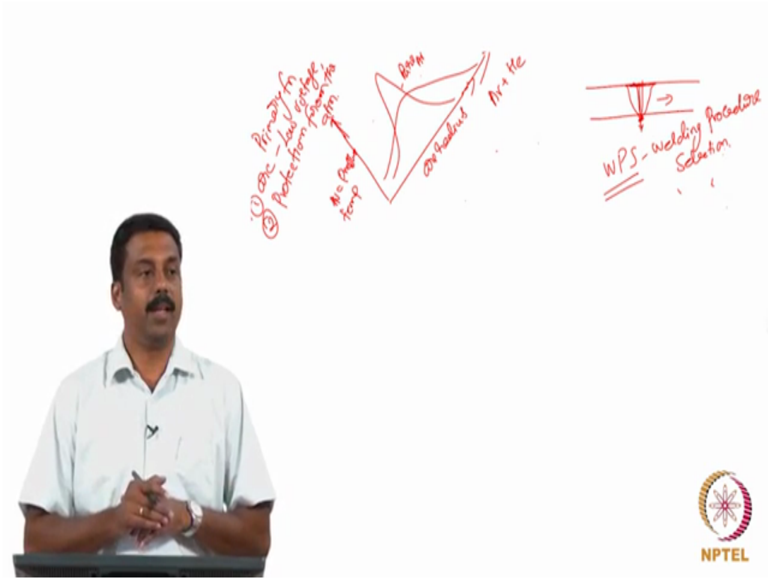

So what is the primary function? Is to have an a sustained low voltage arc throughout the welding processes so and apart from that it also protects the weld pool from the atmosphere. So first is the low voltage and then protection from the on the atmosphere and apart from this there are lot of secondary functions we looked at. So for example the weld bead geometry the depth penetration as well as the width the weld aspect ratio can be seriously affected by the shielding gas and we looked at the relationship between, right.

So for example the arc pressure arc arc temperature, so if it is arc radius so if you use an argon (your) the arc pressure will be extremely high in the centre of the arc, whereas if you use either diatomic gas or gasses with high thermal conductivity, is it not? So high thermal conductivity is defined by how good the convection heat transfer in some of the gases and then what happens the temperature can be effectively transferred by the convection to the outside envelop of the arc, is it not?

Suppose this is pure argon, if you replace this with argon plus say some amount of helium so then the temperature would the arc pressure and the temperature would be something like homogeneous example like this, is it not? So because of the effective heat transfer from the arc core to the arc envelop and this would lead to obviously the penetration characteristics. So the selection of shielding gas you know it is also determined from the physics of arc like how good a gas is in terms of transferring heat from the arc core to arc envelop as well as if you use diatomic gas the similar thing happens, there the heat conduction will be very effective because of the de dissociation, right.

So then the same effect you would also expect when you use the diatomic gas with the mixture of argon. So the selection of shielding gases you need to be really careful and if you want to control the heat input or you want to change the bead geometry so you can accordingly change the composition of the gas from one gas to other gas. Suppose if you also see that some you need to increase the productivity.

So then you can also choose the gas which gives high heat input, so high heat input can be obtained by increasing the arc energy the arc energy can be increased again if you use a gas with high ionization energy then the amount of heat liberated per ionization process is also high, the electrons which are emitted from the ionization process if he has a high ionization energy gas the energy of electron which is emitted is also carry you know high energy because the ionization energy you are giving it is actually released by the electrons energy the electrons carry that.

So obviously when those high energy electrons collide there will be high energy at change leading to high heat generation, so arc energy increases, right so suppose if you want to increase heat input obviously you can also use high energy gas as well and some of the gases we looked at can also be reactive for example carbon di oxide. So carbon di oxide would also dissociate and then it will form carbon mono oxide and oxygen, subsequently you may also end up swiping carbon mono oxide into carbon and oxygen but that is very unlikely, but we may also expect some carbon pick up in the base material. So then you will also change the base material composition.

Same goes with the oxygen, so if you use oxygen in a shielding gas the oxygen can also be get dissolved in the base material and the base material the oxygen (())(5:08) can increase and that may lead to non-metallic inclusion formation or if you have highly reactive elements added to the base material. For example aluminium, so aluminium readily reacts with oxygen and then it lead away all the element in the liquid metal into aluminium oxide slag, so that can also happen.

So the secondary function of the shielding gas is very critical as well to determine your choice for the shielding gas, okay. Similarly you may also have material with varying thermal conductivity. So for example comparing the austenitic stainless steel to conventional low carbon steel the austenitic stainless steel have a three times lower thermal conductivity than the conventional steel.

So imagine you use the argon for low carbon steel and you want to suddenly assume that this is same thickness and it is also steel right stainless steel okay so you can also use why do not you use argon simply argon? As you use in the conventional steel low carbon steel, but you may end up getting extremely deep penetration in stainless steel, okay because stainless steel they are very poor conductor of heat, they have very low thermal conductivity compared to steels.

So suppose if you want to achieve a wider penetration or wider bead geometry something like that, so for example so this is your base material bead on plate and you see that now in your conventional low carbon steel your bead geometry is something like that when you are using argon, but if you use the similar parameter same welding parameter with argon when you weld the stainless steel the heat is not transferred effectively.

So you will contain the heat, so you will end up making in a very narrow bead and you will have sagging outpoll because weld pool which is there in the middle would start heating up because it is not transferring heat. So you will end up having a weld pool sagged. So in this case what do you do immediately? You will have to distribute the heat in the arc. Since I am using argon so you can had some high conductivity gasses you can either add helium into argon or in stainless steel austenitic stainless steel can also had hydrogen.

So 5 percent hydrogen added to argon is commonly used for austenitic stainless steels because to effectively distribute the heat so that you can increase the weld bead width, is it clear? So these are all the considerations so the secondary considerations are commonly used while selecting the shielding gas it is not like ions argon bottle can I (())(7:48) so it is not like that I mean the welding procedure selections what you call WPS and it is a very large exercise if you want to generate a welding process parameters and we will had to consider all these aspects in order to generate sound weld bead, okay.

So sometimes you also see an effect of the dissolved gases on the surface tension of the weld pool, surface tension of the weld pool can also change your bead characteristics. So again so these are all secondary functions you need to consider while selecting the shielding gas so that is what we looked at in last class, right. So we will move on to the material specific shielding gases by considering all these aspects and then in this class we will see you know what are the commonly used shielding gases for a given alloys, okay so we will start from steels.

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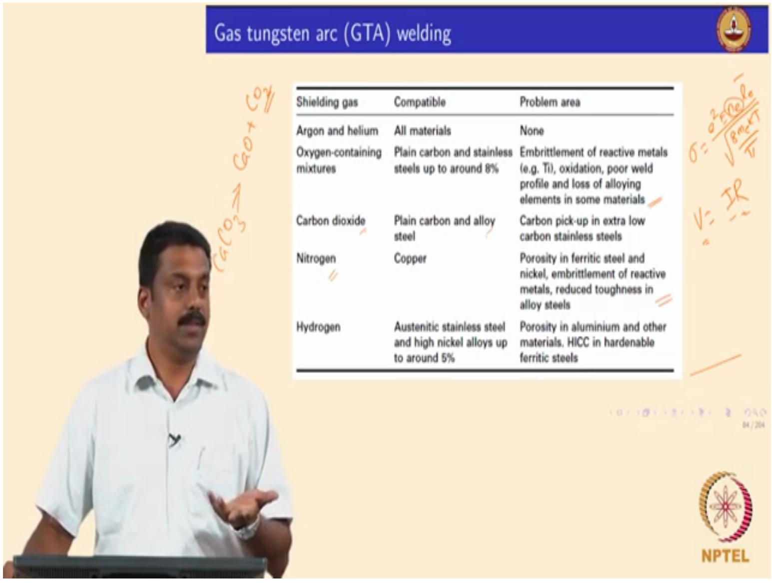

The shielding gases for GTAW is argon, okay and if you are using manual metal arc welding or shielded metal arc welding in most of the case sometimes you use self-shielded electrodes, what do you mean by self-shielded? That means the shielding gasses generated by burning the flux, so these fluxes generally contain Ca Co 3 so when you burn this so it becomes Cao plus Co2 that is how we generate the shielding gas, okay so (())(9:27) this gas is generally used for arcing.

So carbon di oxide is also widely used for very low end applications again if you use pure Co2 as a shielding gas and there are lot of problems we looked at it because of the dissociation and the very reactive nature of the gas the arc voltage has increased significantly. So any diatomic gas would lead to increase in arc voltage, why do we increase the arc voltage? Because when you have you need to have sustained generation of ions so that know you will have good electrical conductivity.

So again the relationship between the electrical conductivity with the number of electrons, what is that? Can you recall? Common guys, sigma is equal to e square e then n e and then l e (common I am older than you) 8 e m e KT (())(10:37) so this guy, what is that n e? So the number of density of electrons, so now if you have gas with high ionization energy or diatomic gas, so what will happen then?

The amount of electrons in the arc decreases significantly, suppose if your diatomic gas so if the de dissociation would eat away the already dissociated gas atoms, gas molecules. So then again the process has to be started again to generate more electrons. So in that process your resistivity of arc increases significantly because you lose the electrons, so if resistivity increases obviously voltage would what is the relationship between resistance and voltage?

Student is answering: V equal to IR.

V equal to IR, good. So what happens then if R increases for a given current?

Student is answering: Voltage increases.

Voltage increases obviously, so it is all again coming from the physics so when you use a diatomic gas your resistance of the arc increases then voltage increases for a given field, right. So that is the reason when you are using say for example Co2 your heat input also increases significantly, the arc energy increases significantly because voltage increases, okay it is clear?

So manual metal arc welding if you are doing a very rough work see what is good, reasonably better because we want to have on a very high input so that we can weld more volumes so we can melt and then deposit we can melt more volumes, so carbon dioxide few carbon dioxide can be used and because of all these dissociation phenomena the increasing voltage if voltage increases then the arc stability decreases because the fundamental definition of arc is you need to have a very low voltage on high current.

So then the arc stability decreases significantly when you use a carbon di oxide or any diatomic gas, is it clear? So for the steel in order to if you want to have on a very good quality welds done save bit is use argon, but argon again you will have a deeper penetration and if you want to weld an autogenous mode so you will have to spread the heat. So generally we add 1 or 2 percent or 5 percent carbon di oxide or helium or in austenitic stainless steel hydrogen so that we can spread the heat, otherwise you will have a very narrow bead and which is not good for the mechanical properties of the weld, is it clear?

So in this table I just showed you the commonly used shielding gases, so argon and helium can be used for any material to be safe but then these are expensive gases. So you cannot use it for a road side shop if you want to repair your motor bike, so you would not expect that guy to use helium as a shielding gas but then he will bankrupt. So best bet is to have one SMAW either with carbon dioxide cylinder the black cylinder which you commonly have observed and then just weld you just need a joint.

So in a conventional steels when you are welding it we use argon an argon plus some composition some elements we add, some gasses like carbon di oxide or sometimes oxygen, oxygen is also commonly used not more than 2 or 3 percent to have a non-metallic oxide inclusions to stabilize to promote a Acicular ferrite formation, is it not? Acicular ferrite is known to nucleate or non-metallic inclusions.

So toughness of the weld increases significantly by adding oxygen so that oxygen can form inclusions which in turn can act as a nucleus insights for Acicular ferrite the microstructure. So again the carbon di oxide is commonly used plain carbon and alloy steel and the problems I put already here so oxygen again so oxygen can also effect the oxidation of some elements which are dissolved like for example aluminium and in fact 2 weeks before we were trying to add aluminium in environmental arc welding fluxes we were aiming for 1 percent aluminium in the base material but we could never get not even more than 0.5 percent aluminium because all aluminium is eaten away by oxygen as a slag ultimately you have aluminium oxide slag.

So it is very difficult to have aluminium added from the consumable to base material when you are using in a consumable welding process because aluminium is very difficult to add from the electrode to the base material because aluminium would oxidize readily from aluminium oxide, okay. So you need to have a proper control shielding to have aluminium diluted to the weld metal, okay sometimes we use nitrogen so nitrogen is commonly used for copper, so helium is most advantageous for copper but nitrogen is also equally good convective gas but not as good as hydrogen or helium it is expensive okay both hydrogen and helium so sometimes nitrogen can be used, but nitrogen can never be used for nickel alloys.

I will go one by one in the slides because of nitrogen used porosities, okay so we will see one by one so I am just giving summarizing this table and hydrogen not pure hydrogen pure hydrogen never used in welding then you will have fun in the lab. So hydrogen some amount is added again to distribute the heat, arc, temperature because these are the very highly convective gas, okay and mainly for austenitic stainless steel to overcome the problem of low conductivity thermal conductivity in order to increase the bead width so we add hydrogen so that we can also add helium both can work well but the principle is the same the convective gasses distribute the heat in the arc so that bead can be increased and if you use a diatomic hydrogen obviously the arc voltage increases leading to heat input increase increasing heat input and we can bead now we can weld it faster because we have wider bead and then high heat input you can weld faster so productivity increases, is it clear?

So whatever you choose a shielding gas, it all comes from the physics what you studied so far the equations are derived for thermal conductivity it is also important. So that gives the basic knowledge about how the arc temperature is generated the relationship between the ionization and the electron flow in the arc. So that would in turn determine by the composition of the shielding gas, okay and the heat transfer I thought you it is also again determined by the nature of the shielding gas the conductive heat transfer determine by the collision as well as the dissociation and de ionization, is it not? And the conductive transfer buoyancy and plasma formation again related to density buoyancy flow. Less density gasses are highly convective, okay so this is all physics so we may see that welding is not a white collar job, you know welding does not have any hard science but it is wrong. So we need to understand all the physical phenomena beyond this process so that we can control the process much better, okay good.

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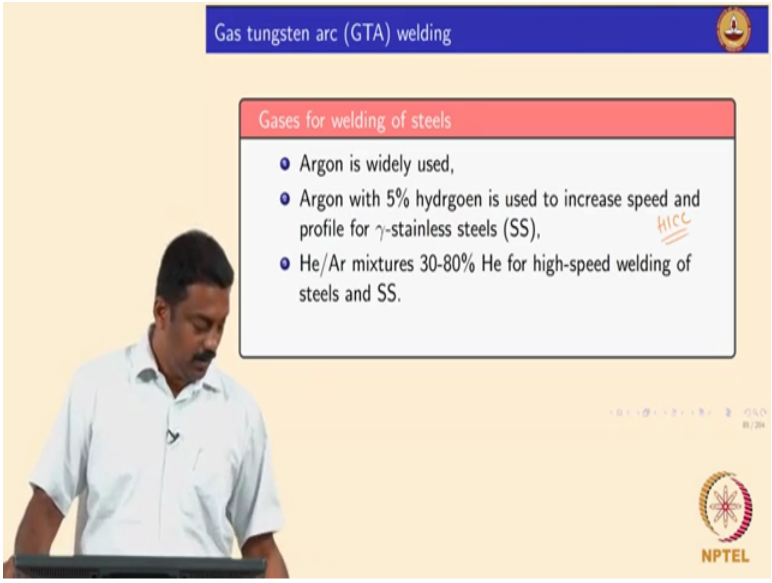

So we will go one by one the first thing is I just put very silent features of what we discussed so far. So we can look at readily refer these slides for welding of steels for example argon is very widely used so we can add with 5 percent hydrogen only to weld austenitic stainless steel, for ferritic or martensitic or conventional low carbon steel you can never use hydrogen then you will end up having just a simple crack developments if you use hydrogen for BCC structure or even BCT tetragonal structure or HCP structures, so we can use hydrogen only for FCC, the reason is due to because of hydrogen induced cold cracking okay hydrogen (()) (19:48).

So we add some amount of helium again to increase the productivity the reason is already explained so the helium is highly convective gas so that now we can spread the arc heat to make a wider bead and because of high ionization energy so obviously heat input also increases, is it clear? Good, so for GTAW for steels argon is commonly used shielding gas for GMAW sometimes we mix it with helium for low carbon steels in increase the heat input as well as to improve the bead geometry and austenitic stainless steels the hydrogen is commonly added upto 5 percent, good.

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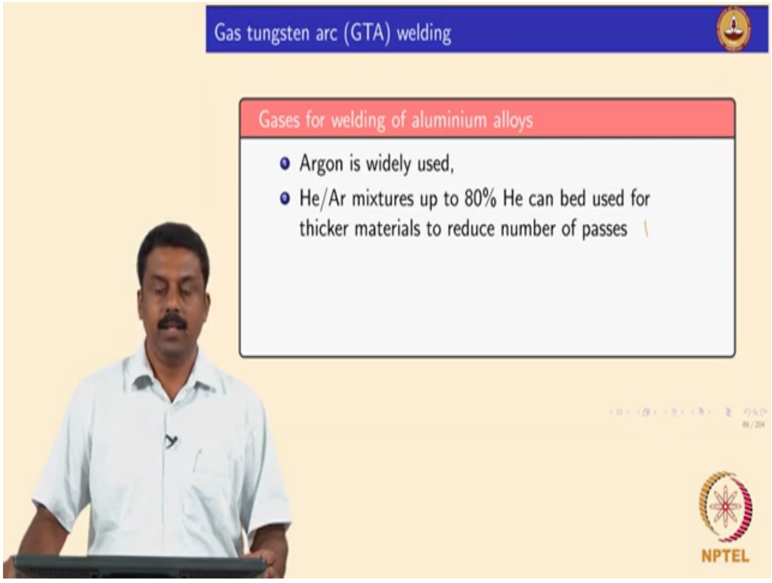

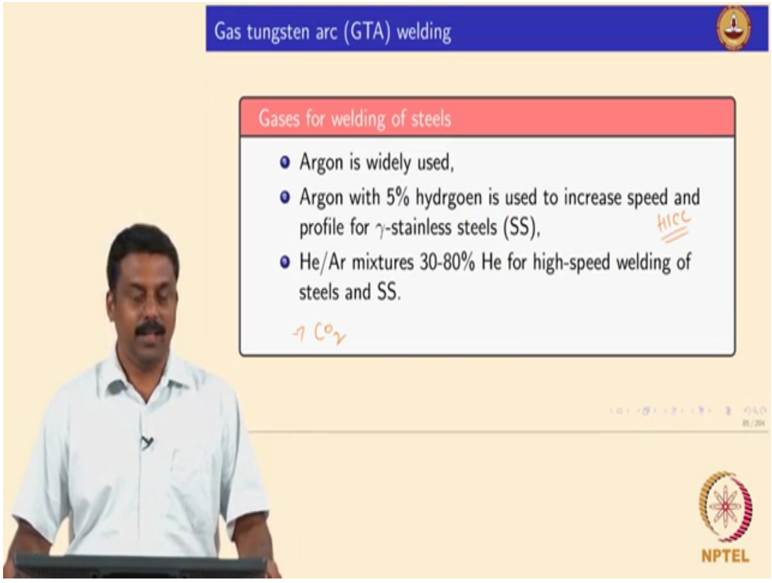

Next is aluminium again so aluminium we can use argon so most of the cases heat be welding with a thin sheets of aluminiums are welded mostly by GTAW gas tungsten arc welding, right and not any other gas. So mostly argon is used for welding of gas tungsten arc welding of aluminium alloys and increase again if you want to use thicker section obviously you can add helium, so helium can be added upto 80 percent in fact to increase the depth of penetration by increasing the heat input to reduce number of passes so obviously.

So in the steels of course apart from argon and helium carbon di oxide is also commonly used so I forgot to mention about it for low cost welding again so carbon di oxide is very cheap and very economical to use for large applications for example you know construction applications when you want to weld kilo meters so carbon di oxide based process also very widely used especially in structural and marine ship building applications you know in a conventional ship we were working on a project to develop a welding process procedures selection WPS to fabricate the world's largest ship.

So the ship dimensions are so huge the actual length of ship is 750 meters almost 3/4th of a kilo meter and width of the ship is 250 meters almost so that is the actual dimensions if you want one place to tip to other tip one hull to other hull at backside you need to walk a kilo meter okay so the length of the weld of the entire welds were done to make that hull it is close to 30000 kilo meters of welds.

So the plates were the hull plates were the hull plates were made with S690 (())(22:51) steels of thickness of 20 mm and each weld has 6 passes of 30000 kilo meters of welds 30000 kilo meters of welds, imagine amount of gas we must have used, okay you took as more than 7 years to build the ship so we were developing the welding procedures and if use helium we would consume the entire helium and during this process, okay.

So the best (())(23:19) is to use carbon di oxide, so otherwise if you use argon the entire project will be bankrupted, so we will be using tons and tons of argon. So this kind of voluminous applications CO2 is the saviour, but then there are some problems as explained the high arc voltage, heat input, reactive gas but then we will have to play around with the parameters so that now we can optimize the process for pure carbon di oxide, okay so it is also commonly used it is not advisable but we can work with that, right good.

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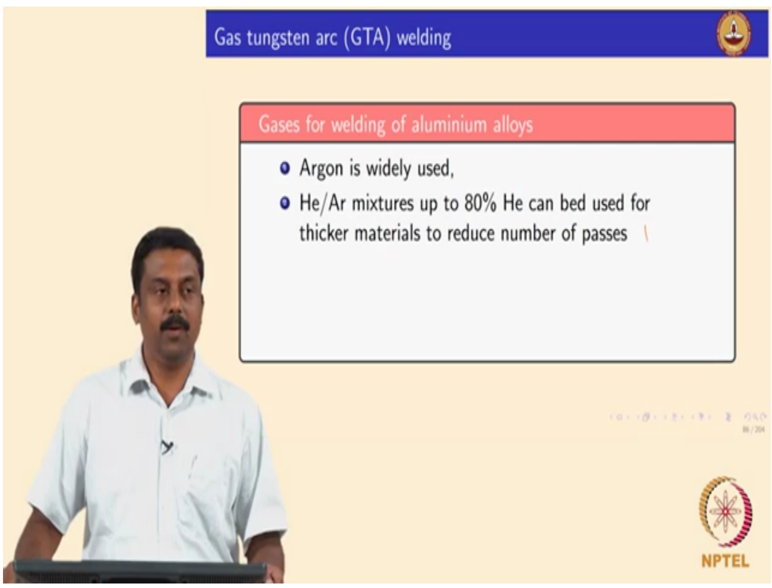

So for aluminium as I said argon is widely used, welding of aluminium is always tricky in terms of weld ability aluminium alloys are always probabilistic child problem child you can say because of cracking and various issues because of the thermal conductivity and distortion issues. So controlling the arc characteristics is the safe by atleast to weld aluminium alloys, so most of the cases when you are welding aluminium we use simple argon and we do not want to complicate the already complicated situation by using (())(24:35) mixtures okay so argon is widely used and helium mixtures up to 80 percent sometimes can be used to increase the penetration to weld the thicker sections, good.

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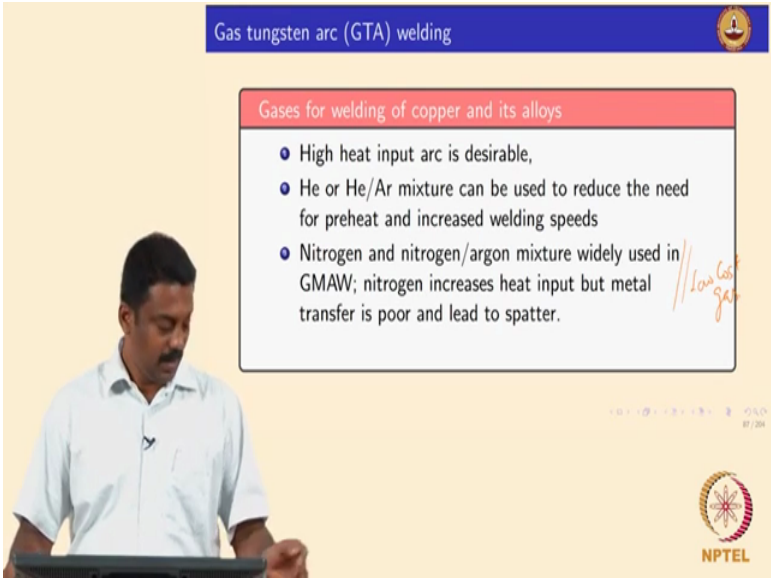

So welding copper and copper alloys so obviously copper is highly conductive material, is it not? So if you want to contain the heat so you need to do it in a high heat input, so otherwise heat will be dissipated you will not be welding the material effectively because heat is dissipated much quickly so you will have to increase the heat input of the arc so that you can make some penetration some melting.

So obviously if the arc heat input has to be increased the best way is to use high ionization gas so the helium or helium argon mixture helium 80 percent and 20 percent argon is widely used so that you will have a high input gas so if helium is really expensive and we can also use nitrogen, nitrogen is also it is not that dangerous that ineffective as carbon di oxide, so nitrogen once it is dissociated it becomes highly convective, okay.

So in that case the ionization image of the atomic nitrogen also higher than the carbon mono oxide that means that you can generate high heat input arc and the heat also can be distributed somewhat effectively using nitrogen. So for low cost low and welding of copper alloys pure nitrogen is fairly used. So it can be diatomic nitrogen and then we can play around with the welding parameters to achieve reasonable penetration.

But then nitrogen again because of bead association, dissociation the stability arc stability decreases same as carbon di oxide, voltage increases by using diatomic nitrogen so it may lead to a lot of problems but we will have to overcome that if you want to have a low cost gas, is it clear so far? Steels, aluminiums, copper? So this is not only the arc characteristics we will also consider the base material characteristics when you are choosing a shielding gas, is it clear?

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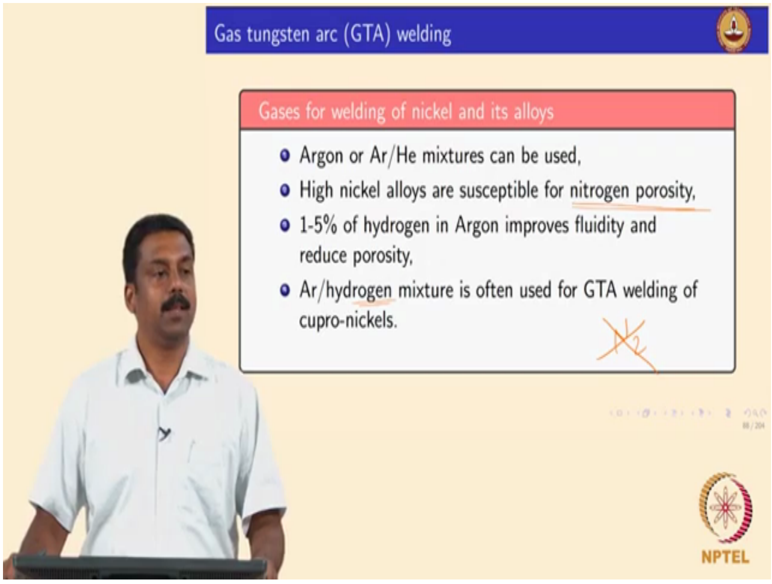

Again welding of nickel and nickel alloys so the commonly used mixture is argon and argon helium so we can never use nitrogen for nickel, okay because of the issue of nitrogen porosity so nickel alloys are known for the gas porosity by nitrogen and if we do not use proper shielding you may also end up getting nitrogen porosity because nitrogen can get diffused into nickel from atmosphere, okay.

So nitrogen porosities are very common problem and other common problem is nickel vaporization when you are welding nickel so nickel vaporization can also be very severe because the difference between the welding point and vaporization point of nickel is quite low compared to other materials, so nickel would vaporize very instantly. So then that will also affect your shielding because metal vapours are denser than so what the shielding gas generally used. So you will end up having nickel vapours exposed to atmosphere forming nickel oxides then that can be trapped.

So best way is to use argon because argon is very dense in order to avoid this problem, so never use nitrogen because nitrogen would diffuse to nickel leading to nitrogen porosity, okay. So we can add hydrogen, hydrogen improves the fluidity means the ease of flow so that now you can spread the bead effectively if the fluid increases and then we can also reduce the porosity because hydrogen is already reactive.

So the most commonly used shielding gas for welding nickel alloys argon are (are) plus argon (argon plus nitrogen) hydrogen sorry, is it clear? So these are all material specific shielding gas selection so first we saw the shielding gas selection in a gas composition perspective and then using that knowledge from the metallurgy of these base materials so we can choose which gas is you know very commonly can be used for welding these alloys, is it clear?