Joining Technologies of Commercial Importance
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Lecture - 07
Fundamentals of Welding

Hello, I welcome you all in this 7th lecture on the Joining Technologies for Metals and in this particular presentation I will start first with the gas welding and the performance the factors affecting the performance of the gas welded joints and there after I will start the fundamentals of the arc welding processes. And then I will try to take up the basics of the shielded metal arc welding.

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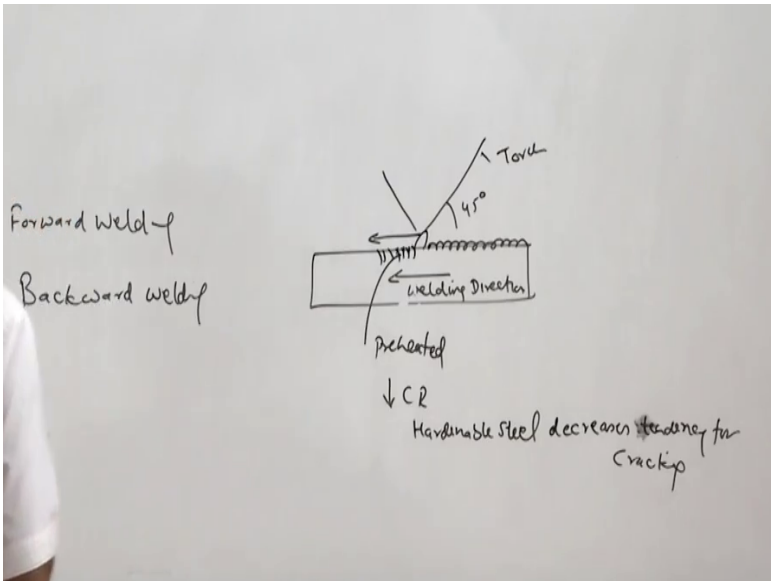

So you know the as far as the gas welding is concerned gas welding is performed using two techniques like forward welding and backward welding, forward and backward welding these two names come from the orientation of the - the welding torch with respect to the welding direction, if this is the welding direction and then torch is pointed at about 45 degree and the tip of the or you can say the torch nozzle off the torch is a point in towards the direction of the welding in this case.

And then the welded portion will be in this direction and this is the direction which is yet to be welded, this is a torch of, and this is the torch position during the welding and here you can see

the filler which is being used is applied, so in this case the since the torch is pointing towards the direction of the metal which is yet to be welded. So the metal which is yet to be welded will be preheated - will be preheated so this kind of preheating actually reduces the cooling rate.

And reduction in cooling rate especially in case of the hardenable steels - hardenable steels reduced cooling rate in case of the hardenable steels results in or decreases - decreases tendency for - decreases tendency for cracking so this is good in that way further apart from this reduction in cracking tendency due to the reduced cooling rate, it also preheats so the melting of the material is fasten and this in turn helps to increase the speed of the welding.

So this is one advantage of this forward welding, well in case of the backward welding what we will see that the - the - the situation is different or rather it is opposite in the sense of the direction of welding.

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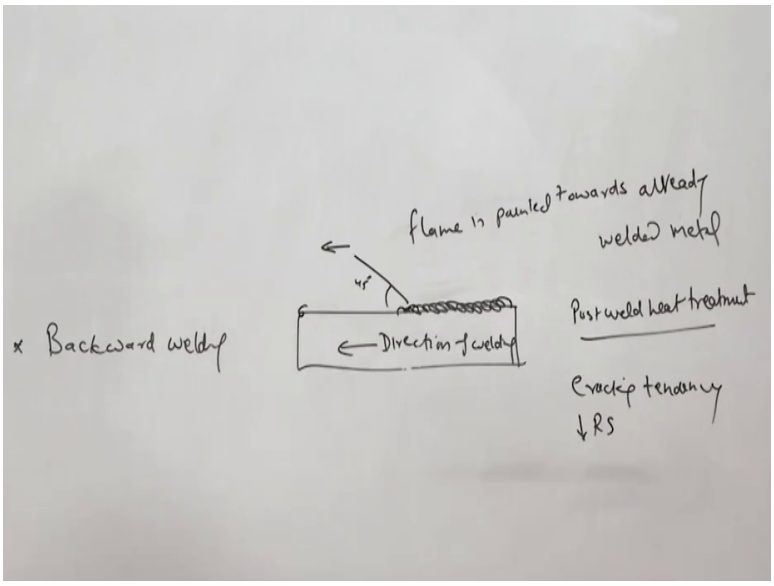

And the direction in which the torch will be pointing say again this is the direction of welding and the filler position, so in this case - in this case the - the torch position if this is the welding direction then this is the welded portion say then torch is inclined at about say 45 degree and it is pointed towards the direction towards the already welded metal and the torch is basically moved in the direction same as that of the direction of the welding.

So here we will see the weld will be developed gradually one by one in this way and that the flame is pointed or directed towards the - towards the already - already welded metal, so advantage of this is that your flame keeps on heating the weld metal even after the solidification so this kind of heating causes the you can say the post weld heat treatment of the weld metal. So you can say it this reduces the cracking tendency and reduces the residual stresses.

Also these are the two aspects related to the forward and the backward welding. In the backward welding the weld metal the torch is directed towards the already welded metal and here you can say the position of the filler metal is in case of the gas metal sorry gas welding process. In addition to these the forward and backward welding aspects another important thing is about the joint performance.

You know that in gas welding in any case we have to in case of gas welding we have to using the flame the base metal the faying surface of the base metal brought to the molten state.

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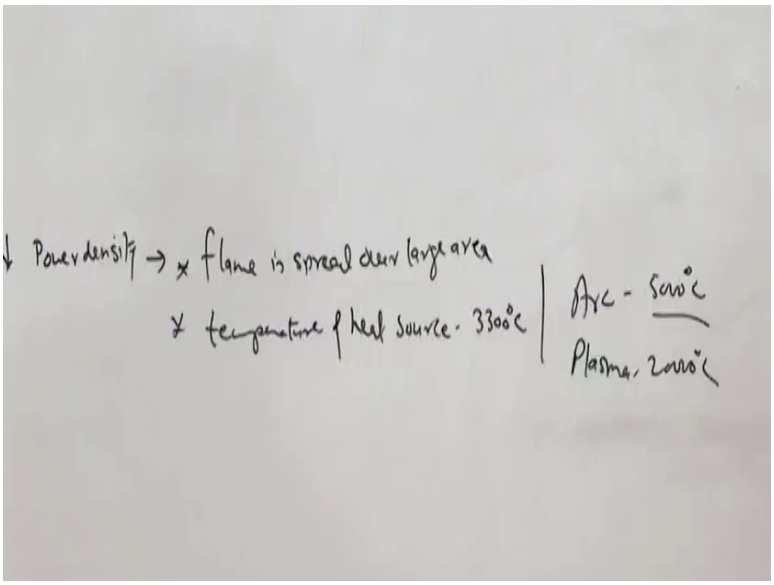

But since this process is of the very low power density and therefore the low power density is because of the 2 factors because, one is the flame is spread over a large area - frame is spread over large area, so heat being delivered is not very concentrated and therefore it takes lot of time before reaching to the molten state and the temperature is also very limited temperature as compared to the arc welding and laser welding plasma.

In case of the flame temperature of the heat source is also limited say maximum it is 3300 degree centigrade, so it is very low as compared to the arc - arc welding minimum say 5000 to 6000 degree centigrade or like in plasma maybe 20000 degree centigrade and further higher in case of the electron and laser beam welding process, so because of this the power density related to the gas welding heat sources is very low and due to the low power density lot of heat is required for achieving the molten state.

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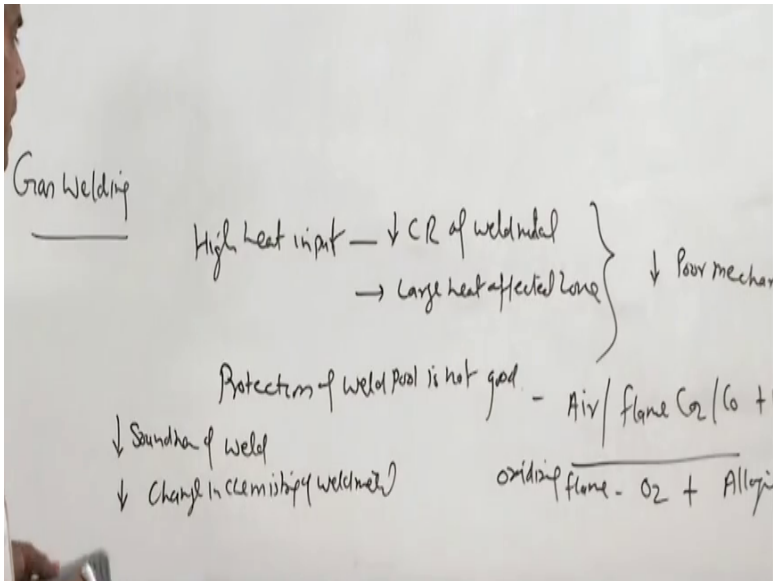

And therefore high heat input during the gas welding reduces the cooling rate of the weld metal this is 1, and it results in very large heat affected zone - very large heat affected zone, so these 2 factors actually contribute towards the somewhat poor mechanical properties. Apart from this one more aspect that adversely affects the mechanical properties of the gas welded joint is that the protection - protection of the weld pool is not good is not as good as in case of say shielded metal arc welding or gas metal arc welding or GTAW processes so is not very good.

And because your - the air or the atmospheric gases and flame having the CO2 or CO in case of the incomplete combustion all the gases will be interacting with the molten metal and especially in case of the oxidizing flame high concentration of the oxygen is present, so these this oxygen actually reacts with the alloying element present - alloying elements of metal or weld metal and which in turn leads to their loss from the weld metal.

So the loss of the weld alloying elements from the weld metal presents of all these gases lower the soundness actually they lower the soundness of the weld metal as well as they reduced the rather change the chemistry - change in chemistry of the - of the weld metal which are basically appears in form of the loss of the alloying element. So reduced soundness in terms of the - in terms of the increased depressions of the inclusions or sometimes even porosity.

And the change in chemistry of the weld metal, reduced cooling rate, larger heat affected zone as a whole they result in somewhat poor mechanical properties of the welded joint made by the gas welding as compare to the arc welding processes. And that is why the gas welding processes or gas welding is normally used for the null and critical applications where the - where the other welding processes are either not available or it is difficult to apply them.

And that is why it is generally preferred to use the arc welding processes over the gas welding.

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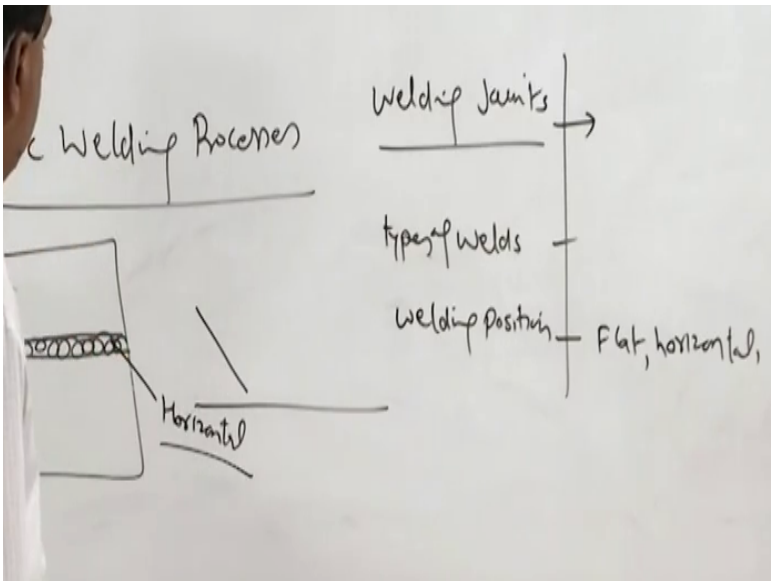

So, whether it is a gas welding or arc welding certain things are very common in case of the weld for developing the weld joints. so first of all I will talk about that the things which are very common and is used they are used in all the cases that is about that welding joints the types of the weld joints which are made then, types of the weld's which are made and then the you can say the welding positions - welding positions.

So first of all I will talk about this irrespective of the welding process being used, so the weld joints they are four or five types of the weld joins are there similarly, four five types of the types of the weld weeds and weld positions, so weld positions like flat position which is normally down hand welding position where the plate is in flat position and the welding is applied welding is carried out using arc or the gas in this down hand position.

And then overhead, then horizontal welding horizontal position in case of the horizontal the plane of the welding is actually vertical but the joint is made in horizontally on the vertical plane, so that say this is the groove, so the weld will be deposited in vertical plane in horizontal direction so this is the horizontal position, it is difficult to control the molten metal in case of the horizontal welding.

Because the weld metal is applied in vertical plane, direction is horizontal but it is applied in the vertical plane so that is why the control is somewhat difficult while the flat welding the weld it is the plates to be welded are kept in a horizontal flat position and then weld metal is applied from the top so it is called dine - down hand welding position or the flat welding position then - then vertical position is also similar to that of the horizontal but the deposition is in vertical direction.

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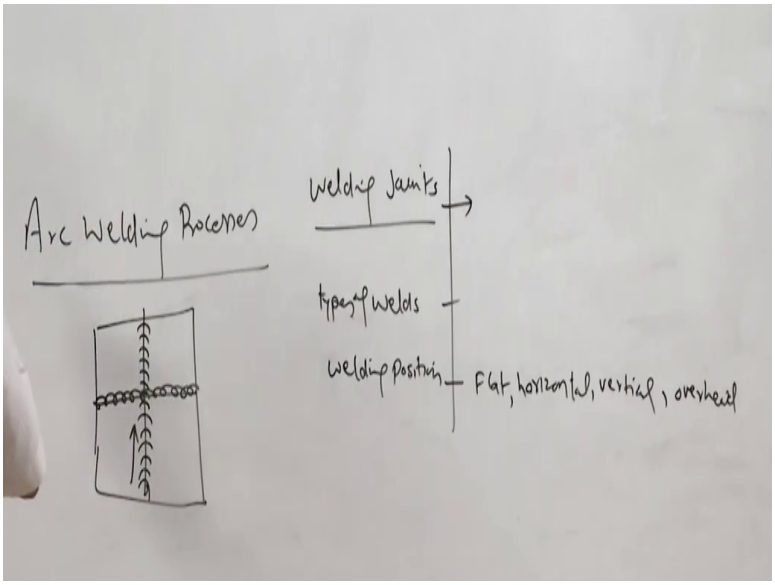

So in this case like say this is the vertical plane and the weld metal deposition is also vertical, so it can be moving down or it the position can be in up fill manner like moving up, so both types of the movements are used for depositing the weld metal, its - it is difficult to deposit the weld metal in both vertical as well as a horizontal position and further more difficult position is the overhead.

Overhead welding where metal is applied from the lower side it is just like the deposition is to be is done in the metal is applied from the lower side and it is transferred from the lower side to the upper side for applying the weld metal in, you can say overhead position say this is the corner and if the metal is to be deposited than electrode is kept like this and material is deposited in this position this is further difficult and very close control over the welding parameters is required for the proper placement of the weld metal in case of the overhead welding.

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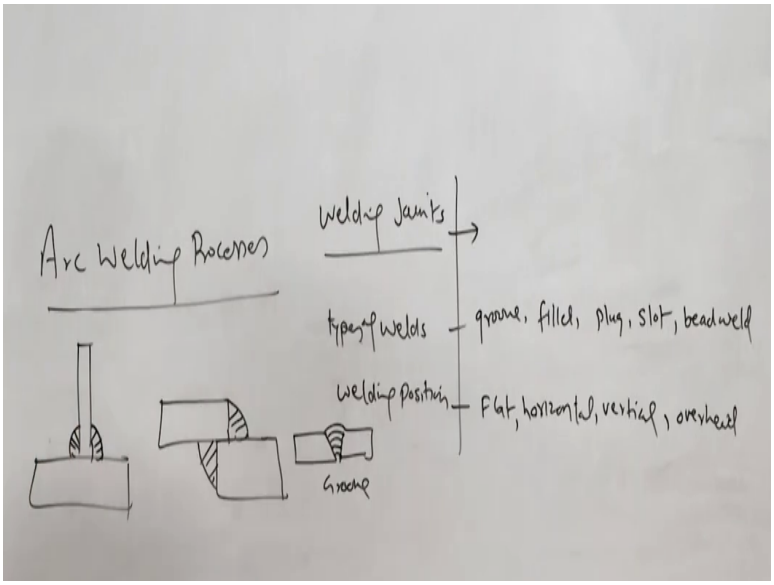

Then types of the weld like one is the groove weld, then fillet weld, then we have like plug weld, slot - slot weld and bead weld - bead weld. So the groove welds are simple where either the square joint the - the groove is made at the faying surfaces or then the weld joint weld metal is filled in this is called groove weld.

In case of the fillet whether like say these are the plates to be welded like this, then the fillet weld is made in this manner either single fillet or double fillet or it can be used in case of the Tee

joints where in one and the plates are kept in Tee positions and then fillet weld is made like this, so this is the fillet joint.

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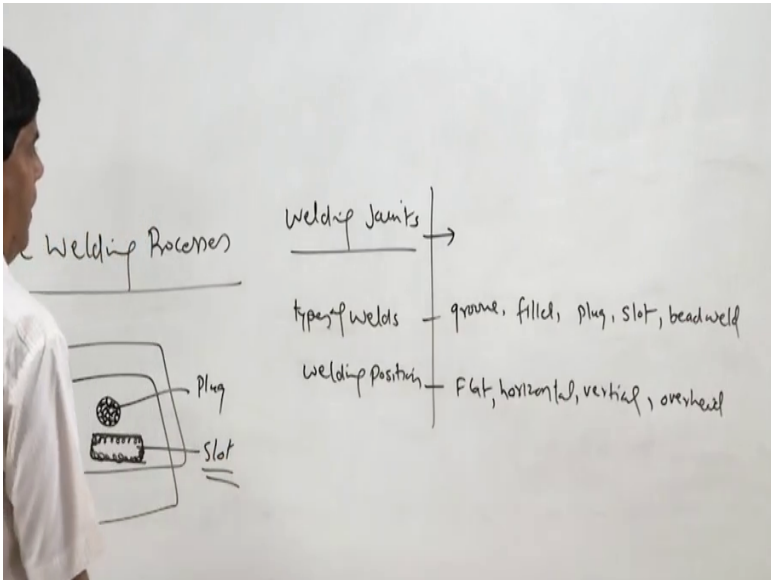

In case of the plug and slot, the plates are kept in like say the two plates one in the in top view if we see and this is the another plate and the two are to be joined then what we do we make as a hole in the upper plate and then the weld metal is deposited like this when the fusion of the lower plate is also achieved. So basically hole is made on the - on the upper plate.

And then weld is made at the - at the corner of with the like the joint is obtained by the fusion of the lower plate as well as the edges of the circular upper plate in case of the plug and then you can say this plug is filled in with the weld metal this is called plug weld. And for slot weld the joint is the approach is same the plates are placed in the overlapping position and then slot is made in the upper plate.

And then the weld is made all around the edges of the slot which has been made for producing the joint, so this is what is called slot weld, and one is bead weld.

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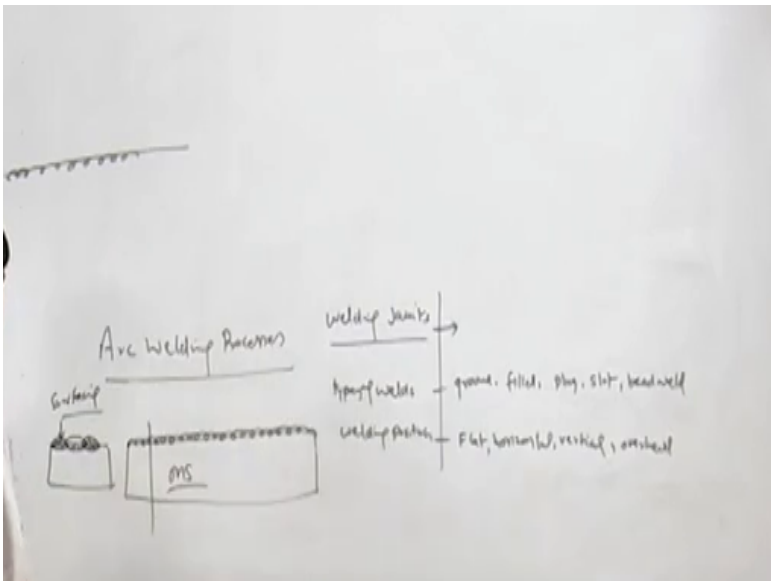

Bead weld is commonly used for the surfacing applications which are used primarily for covering the surfaces of the somewhat low quality materials say mild steel is to be used in corrosive environment or for the abrasive conditions then the surface of the weld - surface of the plate is covered with the bead, so and if we - if we cut the section what we will get like the bead is deposited in this manner.

So the fusion of the best metal is achieved and bead is there at the top, so num - so number of times we make the overlapping bead so that entire surface is covered with the requisite quality of the weld metal, so basically purpose of this is to do the surfacing of the - of the - the plate which is to be used in much more aggressive environment and this surfacing is done normally using the good quality material which can offer the required hardness, wear resistance and the corrosion resistance.

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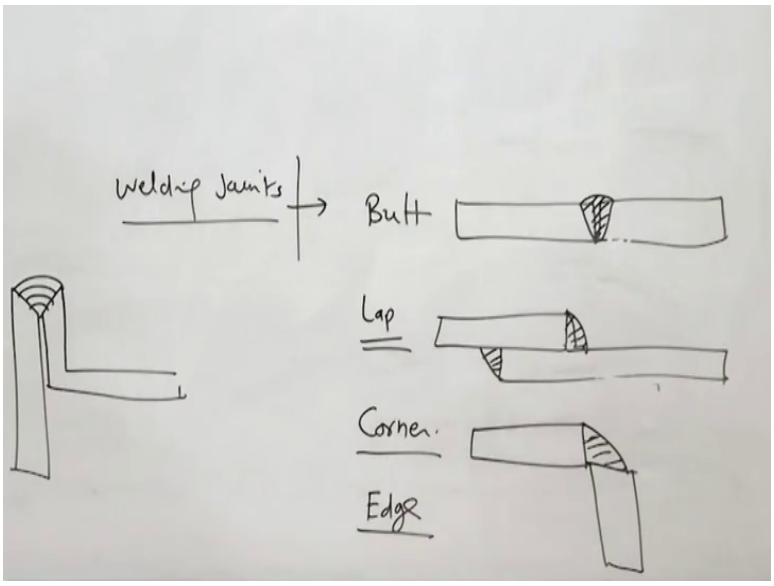

Now coming to the types of the welded joints types of the weld joints are like butt joint when the plates to be welded or kept in butting position means they are in and two ends are matched with each other, it may be square or it may be a V or W, double V, single J, double J like that and different types of geometries are there, so the plates to be welded or kept in butting or and two end touching positions and then joint is made.

Lap joint is one, where one plate is kept over there another plate for developing the joint and the normally the fillet welds, fillet weld is made single or the double fillet weld is made so this is the lap joint. Then corner joint is also commonly used where in that the plates kept roughly perpendicular to the each other like this and this is another component to be joined and then the fillet is made like this at the corner.

So number of the grooves or groove geometries are available for making the joints but here in this case it is simple that the plates to be joined one plate like this another plate is kept at 90 degree and then fillet is made at the corner to increase the throat thickness and the weld area especially groove geometries are available for the edge joint and the you can say the corner joint. Now the last one is butt, lap, corner, edge joint.

Edge joint is made at the edges of the plates to be welded like this is one component and this is the another component, so another component is like this then what is done are like they are

placed side by side and while bead is made at the edges of the 2 components to be joined, in this case sometimes to increase the strength of the - the geometries are slightly modified and like this also the groove is vary intentionally and then weld is made for making the edge joint.

So this is what we can see here groove weld, fillet - types of the weld, groove weld, fillet weld, bead weld, plug weld and slot weld, and types of the joint like butt joint, lap joint, tee joint corner joint and edge joint.

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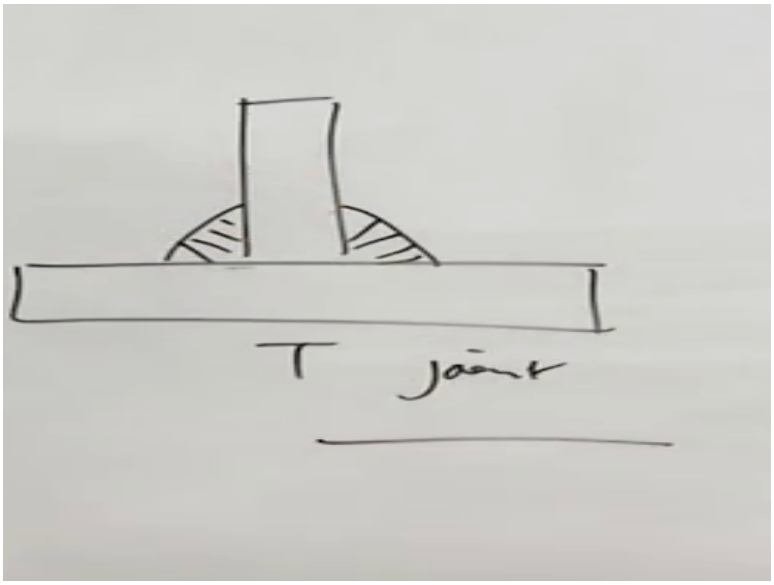

Tee joint is the simple one where the one plate is kept in horizontal position and another member to be join is - is brought somewhere in between at 90 degree and then fillet weld is made to make the tee joints, so this is you can say the tee joint so that is how they are 5 types of the weld joints butt, lap, corner, edge and the tee joint and the welding positions four the flat welding have explained already, horizontal welding, vertical welding and the overhead welding.

Now we will come to the arc welding, principle of the arc welding and how the arc welding processes work for fusion of the faying surfaces of the base metal to be joined.

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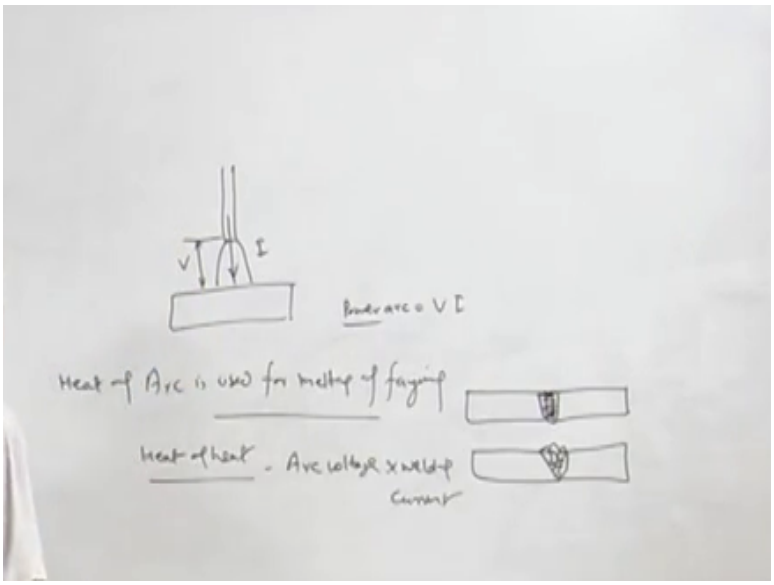

So you know in all arc welding processes the heat of arc is used for melting of faying surfaces this is what is the basic thing, whether it is the square butt or the V in or any other kind of the - the weld or the geometry - or the joint is to be made the fusion of the base metal is achieved if the fusion of the faying surfaces of the base metal is achieved. So if it is autogenous where no filler is added just edges are brought to the molten state to have the metallic continuity weld.

If the filler is used in like the groove is made then this groove is to be filled in, so first the fusion of the base metal is achieved and then groove is filled one by one using the single pass or the multi pass welding approach. So but for this purpose heat is used heat generated by the welding arc is used and that heat of the arc is - heat of the arc is obtained from the - the kind of the product of arc voltage being used for producing the welding arc multiplied by welding current.

So if there is welding arc like say this is the electrode this is the welding arc and the arc voltage between the two tip and the work piece so V and the flow of current taking place is I then the power of arc is given by V I. Since arc is moving continuously during the welding so heat is delivered - heat being delivered is distributed as per the - distributed as per the speed of the welding arc.

And that is why this is that heat generated per unit time and then we will see the net heat being supplied which is obtained from the H net and for that V I by S, S is the welding speed is

obtained which gives us this heat in joule per mm is the normal way by which the heat net heat being delivered during the welding is calculated. So here V is selected as per the process and as per the process means which will make the arc stable the different welding processes require different voltages to make the arc stable.

For example, SMAW processes work with the higher voltages like 50 to 70 volt while the gas metal arc welding maybe using say 20 to 40 volt and the gas tungsten arc welding and the plasma arc welding they work fairly low voltage like 10 to 20 volts. So depending upon the welding process to have this stable arc different voltages are used there are number of factors which will affect the precise choice of the voltage to be used during the process.

Once the voltage as per the circumstances of the process electrode, electrode coating suitable voltage is selected say for GTAW is 15 volt or it is 60 V, then further the heat amount of the heat being delivered is obtained primarily by changing the welding current. So current is mainly used as main parameter to regulate the amount of heat to be delivered during the welding and therefore current is basically adjusted as per the recommendation of the electrode and electrodes being used.

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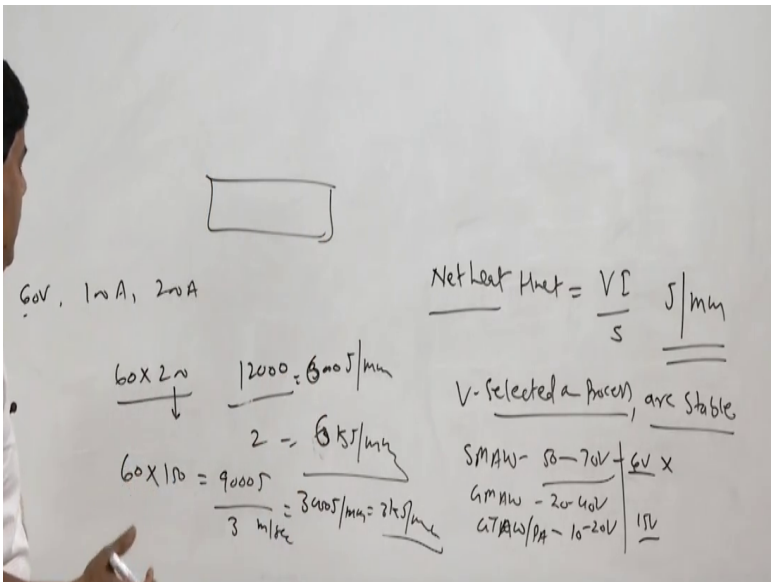

And the requirements the welding current is set for the different conditions say SMAW member work with say 60 volt using current 100 ampere 200 ampere as per the diameter of the electrode

and the heat which is to be delivered for thin plate or for the thick plate applications, so in that case 60 volt multiplied by 200 ampere this will give us the heat being generated in the jewels and then the welding speed in mm per second is applied to obtain the heat in for joule which will be delivered.

So it is common since this quantity comes out to be more like 6000 and if - if the 2 meter - 2 mm per second is being used - 2 mm per second is being used then will be 3000 joules per mm, so normally it is common to express like 3 kilo joule per mm heat input, so if we require lesser heat input then what will primarily be doing will be reducing the current because the arc voltage is normally fixed as per the recommendation of the - as per the requirement for to have this stable arc.

So if for the lower heat input we may use 150 ampere current so which will again adjust the heat being delivered and if we increase the speed from the 2 mm per second to say 3 mm per second then here mm per second what will do it will reduce like 56, here is the correction 6 into 12 so this will go to the 12000 and this will be 6000 joule per mm and this will be 6 kilo joule per mm. While in this case, it will 9000.

So, here it will be left with the 3000 joule per mm that will be 3 kilo joule per mm so depending upon the requirement of the thickness of the plate to be welded we may work with a different kind of the - the welding currents and different kind of the voltages as per the process. So with these basics of the arc welding, now I will conclude this presentation, in this presentation basically I have talked about the factors that affect the performance of the gas welded joints.

And also have talked about that the factors that matter for the heat generation in arc welding and how the heat net heat input in arc welding can be calculated and can be changed as per the requirement it maybe thick welding or thin welding. Or there are different processes and each processes will work over a range of over very wide range of the current so as per the suitability and applications.

And the criticality of the weld joints, different processes are selected and that and accordingly we select the welding parameters to be used for the welding. In the next presentation I will talk about the fundamentals of the shielded metal arc welding process and how do they affect the soundness of the weld joint thank you for your attention.