Welding Engineering
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Module - 2
Physics of Welding Arc
Lecture - 5
Arc Efficiency

So, in this presentation, we will see that how the successful weld joint can be made using the heat of the welding arc. In connection with the physics of the arc welding, we have seen that, how to initiate the arc? What are conditions required for a maintenance of arc? And how to select the polarity and the role of polarity on developing the sound weld joint? So, in continuation of the physics of the arc welding process, today we will see the two important aspects related with the physics of welding arc, and these are the arc blow. The methodology which is used for calculating the arc efficiency to see that how effectively we are utilizing the heat of the welding arc.

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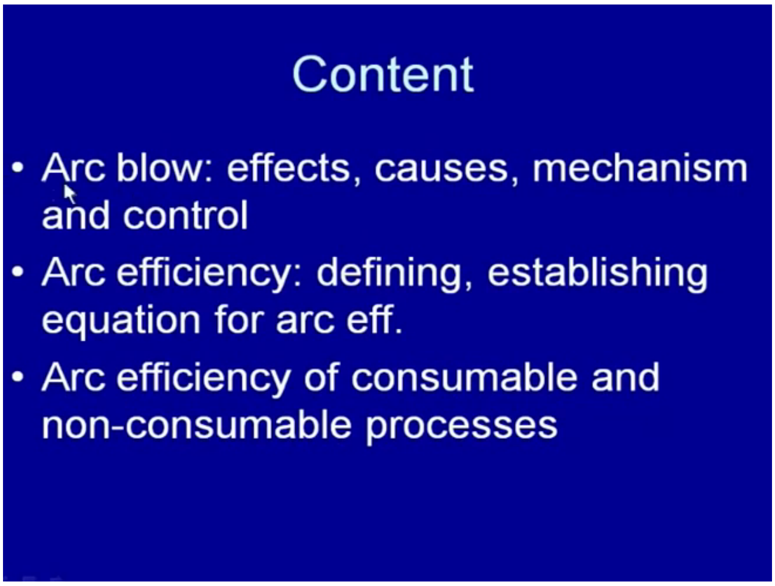

So, as far as content is concerned for the today's presentation, we will be looking into the arc blow in respect of the effects of the arc blow, in development of the sound weld joints. What are the main causes, which lead to the arc blow? What is the mechanism of the arc blow? What are the different ways and methods, which can be used to control the arc blow, so as to get the desired welled joint. The second important aspect is the arc efficiency; how to define it? Methodologies which are which can be used to calculate the arc efficiency, especially in case of the consumable arc welding process and the non consumable arc welding processes. So, these are the main three aspects related with this presentation.

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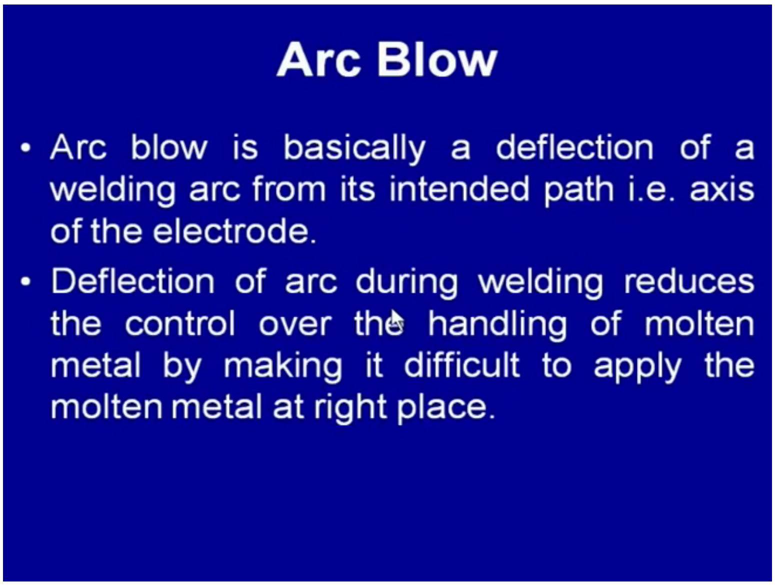

So, we are starting with the arc blow; it is an undesirable undesired phenomena, which is normally encountered during the welding of the, during the welding. So, and especially this phenomena is observed when we are using the D C welding, direct current welding. So, in this arc blow basically, the deflection of arc takes place from its intended path and which leads to the undesirable placement of the molten metal, especially during the consumable arc welding process.

So, arc blow is primarily associated with the deflection of arc from the axis of the electrode and this make the placement of the molten metal into the desired position difficult. Indirectly it increases the spattering by falling of the molten metal or placing of the molten metal in uncontrolled manner here and there. So, if we have to understand the arc blow it is important to see that, how the deflection of arc can take place? And how can we understand the arc blow in better way?

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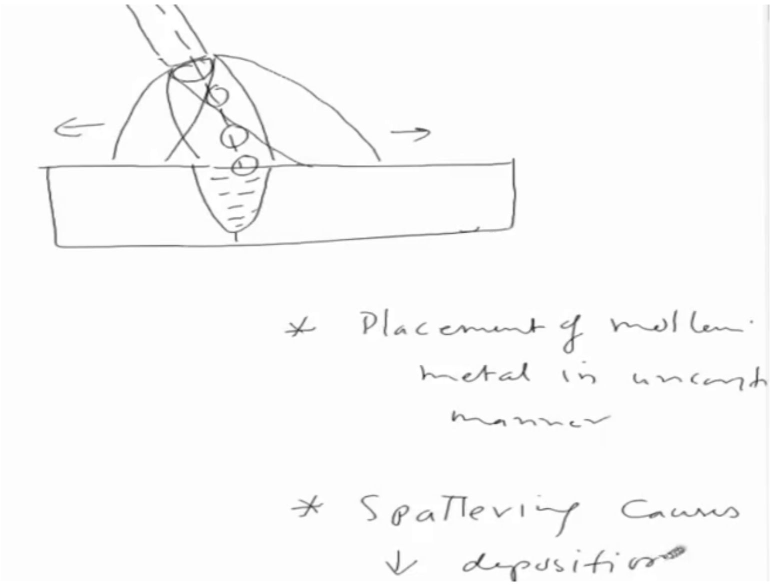

So, to see that if we say that this is the consumable electrode having the arc and this is the base metal. So, after with the heat of the arc molten metal will be melting at the tip of the electrode and it will be moving along the axis of the arc. So, if the arc is moving along the axis of the arc that is the intended path then the molten metal will also be moving along the axis of the arc and will be helping us to place the molten metal in the desired position. But in some of the cases the deflection of the arc either in forward direction or in the backward direction it can take place.

So, this deflection of arc from its intended path either in forward direction or in backward direction can lead to the placement of molten metal in uncontrolled manner. This is one of the major problem and it makes the placement of the molten metal in position difficult. The second aspect uncontrolled placement also leads to spattering of the molten metal and spattering causes the reduction in the deposition efficiency. Because, we are melting the molten metal, but we are not able to deposit it at the right place, which in turn leads to the reduced deposition efficiency of the welding process. Therefore, it is always desirable to avoid the arc blow and not to have it while using the arc welding.

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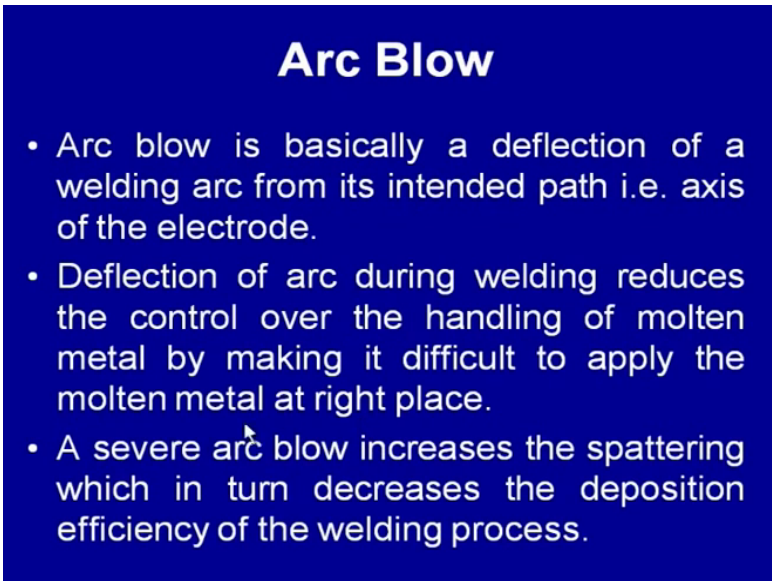

So, to look into the other details related with the arc blow if we see here, a severe arc blow increases the spattering, which in turn decreases the deposition efficiency of the welding process. So, there are two main issues related with the arc blow, one is difficulty in supplying or applying the molten metal at the right place. Or falling of the molten metal here and there leads to the spattering, which in turn will be reducing the deposition efficiency. Increasing the molten metal, which is falling here and there increasing the loses of the molten metal. So, arc blow ((Refer Time: 06:31)) say normally this is the direction which is expected one that along the axis of the electrode arc will be moving.

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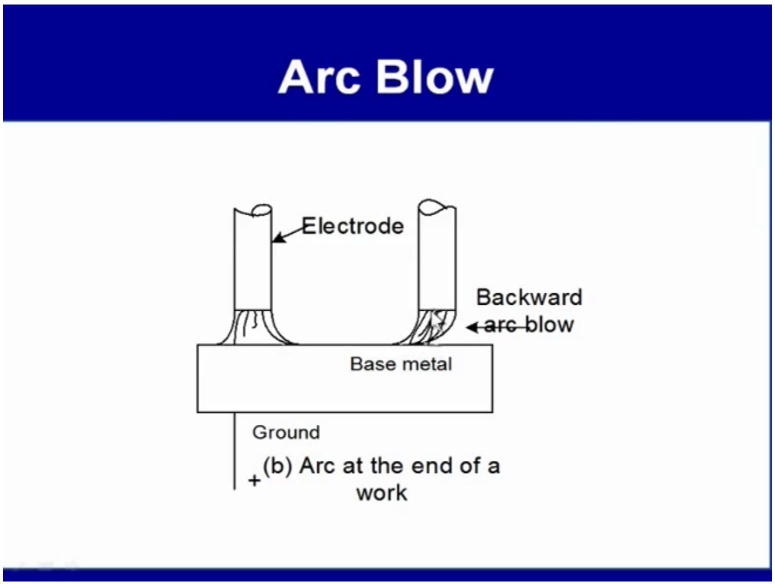

But if due to the various forces experienced in the arc zone, if arc tends to deflect from its intended path that is along the axis of the electrode, then we say that the arc blow is taking place. So, arc blow is primarily the deflection of arc from its intended path leading to the placement of the molten metal at the wrong place and which in turn decreasing the, which in turn decreases the deposition efficiency and makes the placement of the molten metal difficult at the desired place. So, depending upon the direction of the deflection of arc with respect to the welding direction arc blow can be defined as a forward or backward arc blow.

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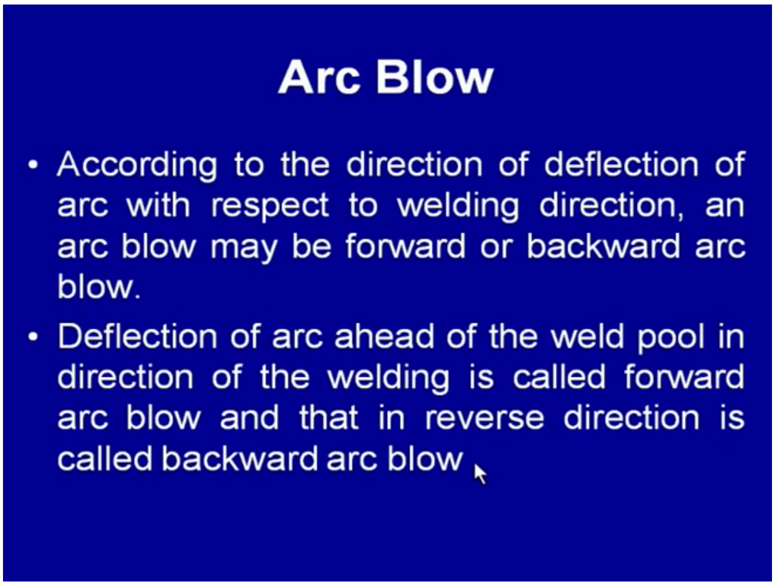

So, due to the electromagnetic forces or the various forces being experienced in the arc region, if the arc is trying to deflect ahead of the welding direction, then it is termed as forward arc blow. If the arc deflects in the direction opposite to that of the welding direction then it is termed as backward arc blow. So, the deflection of the arc ahead of the weld pool in the direction of the welding is called forward arc blow and that in reverse direction is called backward arc blow.

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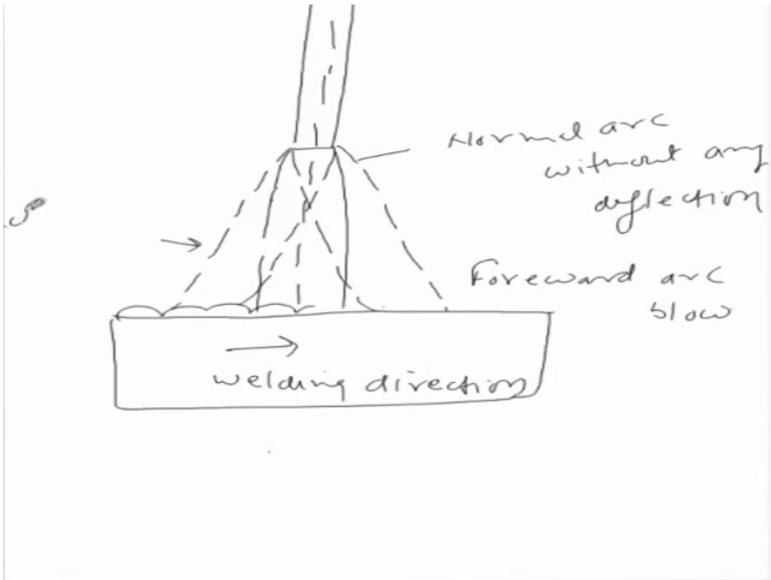

So, to look into this in clear manner, if we see this is the electrode, this is a base metal and the weld is being made in this manner. So, the direction of the welding is this. So, presence of the arc along the axis of electrode is a normal position. So, this is the normal arc without any deflection. Well if the deflection of arc takes place in the direction of the welding ahead of the weld pool then this termed as... So, this is a welding direction and the deflection of the welding arc ahead of the welding direction, ahead of the weld pool in the welding direction is termed as forward arc blow. When the arc tends to deflect in direction opposite to that of the welding direction then it is termed as backward arc blow.

In both the cases whether it is backward or forward, the both these types of the arc blows makes placement of the molten metal in the right position difficult and increases the spatter. So, it is always desired to avoid arc blow. So, various approaches are used for avoiding the arc blow, we will see that what are the important causes, which lead to the arc blow and what is the mechanism of the arc blow. Thereafter we will look into the methods which are used for controlling the arc blow. So, the deflection of arc ahead of the weld pool in the direction of the welding is called forward arc blow and that in reverse direction is called the backward arc blow.

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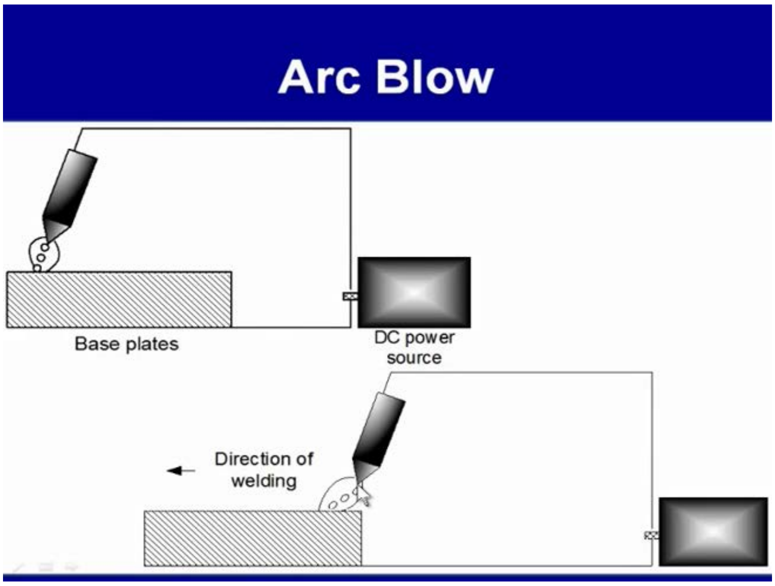

Here if you can see this is the normal direction when there is no arc blow, it tends to the molten metal drops after melting, move is around the axis of the electrode and they are placed where we want to deposit it. But due to the deflection of the arc in the direction of the welding, ahead of the weld pool makes it difficult to deposit in the place where it is desire. In that case, in that case the axis of the movement of the molten metal drops coming from the electrode will be ahead of the weld pool and this will be making the deposition of the molten metal difficult. Now, if you have want to look in the various causes lead to the arc blow, arc blow is mainly caused by the interaction of the electromagnetic fields in and around the arc zone.

So, when the various electromagnetic fields acting or present in the arc region interact with each other this kind of the arc blow is experienced. But not all type of the arc welding process experience this type of the deflection of arc, but it is mainly encountered when the DC current is used. Here the DC current maintains its direction and magnitude during the welding. So, whatever electromagnetic fields are set up during the welding, if they interact during the welding, then that chances for the deflection of arc from its intended path increases. So, these incidences of interaction between the electromagnetic fields mainly occur in the areas where these fields are localized.

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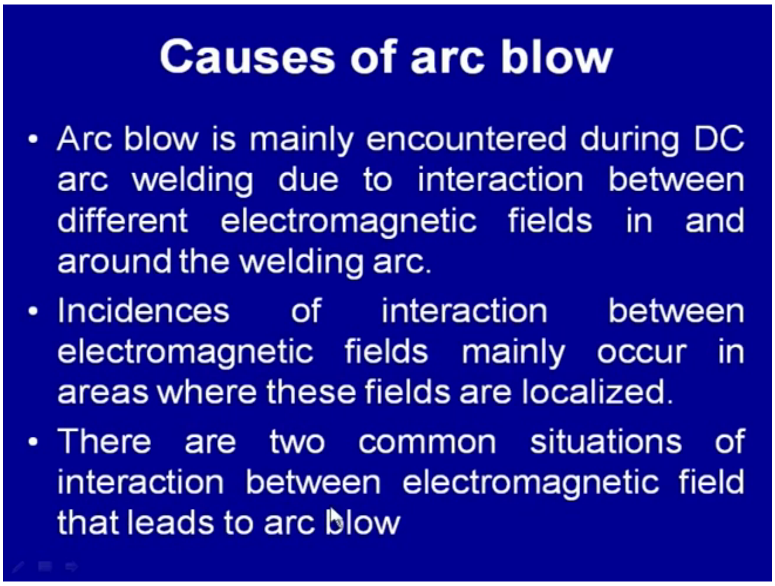

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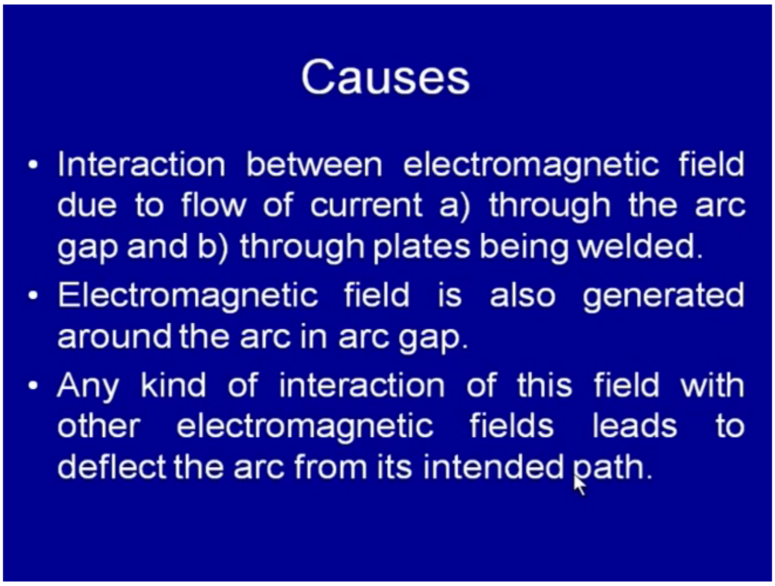

If the electromagnetic fields are uniformly distributed around the arc, then chances for this kind of interactions are reduced. But if their localization of electromagnetic fields due to one or another reason takes place, then this kind of interactions increase and which in turn increases the chances for arc blow. It is commonly observed that that two situations are commonly observed as far as a interaction of the electromagnetic fields that leads to the arc blow. These two common situations, where interaction between the electromagnetic fields leading to the arc blow are observed. In case when the interaction or between electromagnetic fields, being developed due to the flow of current through the arc and that is flow of current taking place through the welding plate being welded.

So, these interactions frequently cause the arc blow, if the significant localization of the electromagnetic have taken place. We know that electromagnetic field is generated around the arc due to the flow of current through the arc gap. When the electromagnetic field established around the arc due to the flow of current, interacts with electromagnetic fields generated all around the arc in the base plate. Or in the direction, where current is flowing, then it tends to deflect the arc from its intended path.

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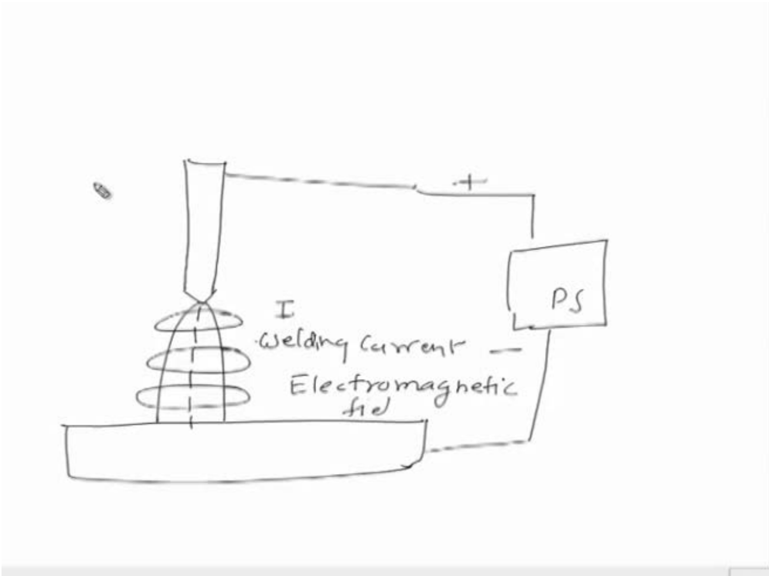

So, if we see in this schematic diagram that in the normal when there is no arc blow, then how the electromagnetic fields are established. Say this is the welding ark and this is the base metal connected to the power supply, say positive terminal to the power supply P S and the negative terminal to the base metal. When there is arc there is a flow of welding current, welding current I and because of this flow of current there is always electromagnetic field normal to the direction of flow of current. So, electromagnetic field is established perpendicular to the direction of the flow of current.

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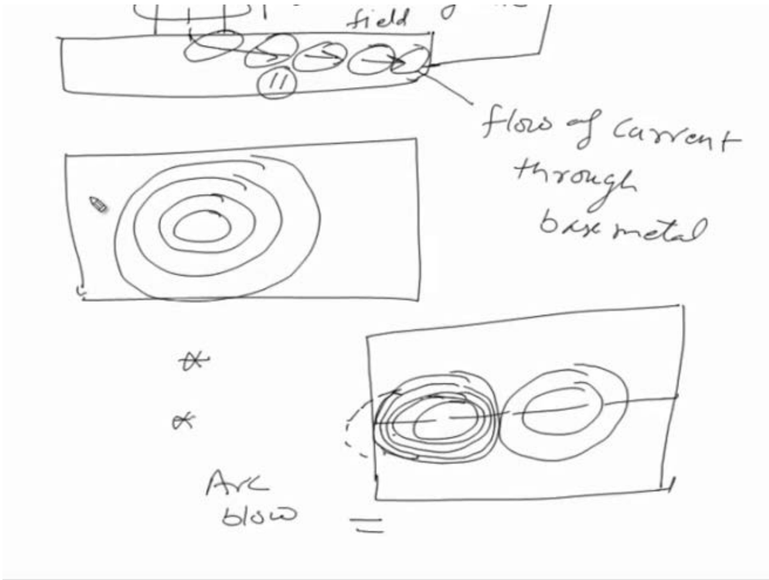

This electromagnetic field, in normal case is found to be uniform if we see it in the top view, then around the weld pool. We will see that this field is equally spaced and uniformly distributed around the welding arc, this is the normal situation. What when this current will be flowing, will be flowing say this is the ground connection, so current will be flowing through this way. So, when it is flowing through the base metal again the field is established all around this zone also.

So, this field is because of the flow of current through base metal and it will have its own electromagnetic field. So, basically we have the two electromagnetic fields; one due to the flow of current through the welding arc one electromagnetic field that is this and the second electromagnetic field that is this due to the flow of current through the base metal. When these two electromagnetic fields interact with each other the there will be the chances of the deflection of arc from its intended path.

So, these two electromagnetic fields should not interact with each other if you want to avoid the arc blow, this is the one situation. Another situation that leads to the interaction of the electromagnetic field is that when we start welding near the edges of the plates. So, when we weld near the edges of the plates say this is the line along which welding is being done, this is the position of arc. When the arc is away from the edges of the plates electromagnetic field is distributed uniformly, but when as we approach closer to the edges of the plates the clustering of the electromagnetic fields start near the edges of the plates.

This kind of clustering leads to the increased interaction between the electromagnetic fields around the arc and electromagnetic field being generated, being localized near the edges of the plates. Because, these electromagnetic lines of the forces cannot move through the air and that is why they are localized largely near the edges of the plates. So, this localization further causes the interaction of the electromagnetic fields generated around the arc and that is localized near the edges of the plates.

So, these two interactions also cause arc blow. So, efforts are made to avoid the interaction between the electromagnetic fields, which are generated either around the arc due to the flow of current or in the base metal again due to the flow of current from the arc zone to the ground connection. Similarly, the interaction between the electromagnetic fields around the arc and that is localized near the edges of the plates is also to be avoided. So, these are the two main factors that contribute towards the interaction of the electromagnetic fields between electromagnetic fields being generated during the arc welding. So, we will look into the details of the causes that lead to the arc blow.

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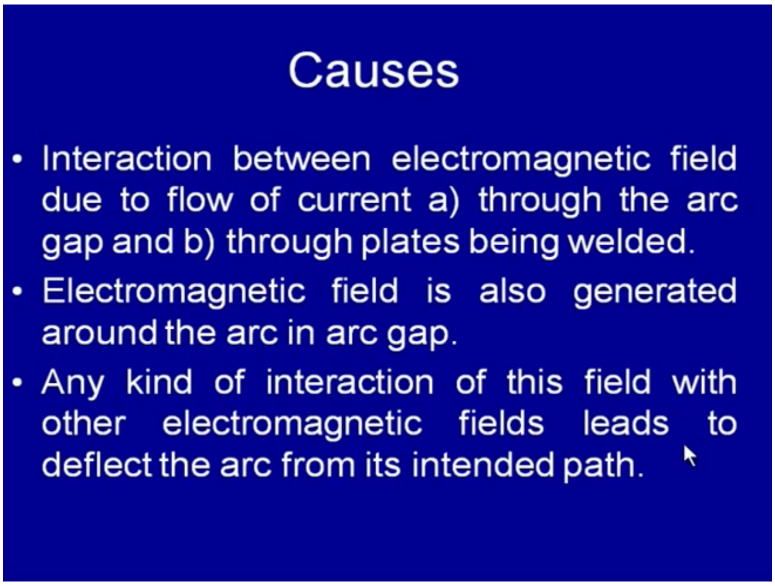

As I said the interaction between the electromagnetic fields due to the flow of current, through the arc this develops one type of electromagnetic field. The flow of current through the plates develops the another electromagnetic fields, when these two fields interact with each other arc blow tendency increases. So, any kind of interaction of this fields with other electromagnetic fields leads to the deflection of arc from its intended path and which is termed as arc blow. So, the interaction between the electromagnetic fields due to the current flow through the arc gap, and the localized concentration of the lines of electromagnetic forces while welding near the edges of the plates.

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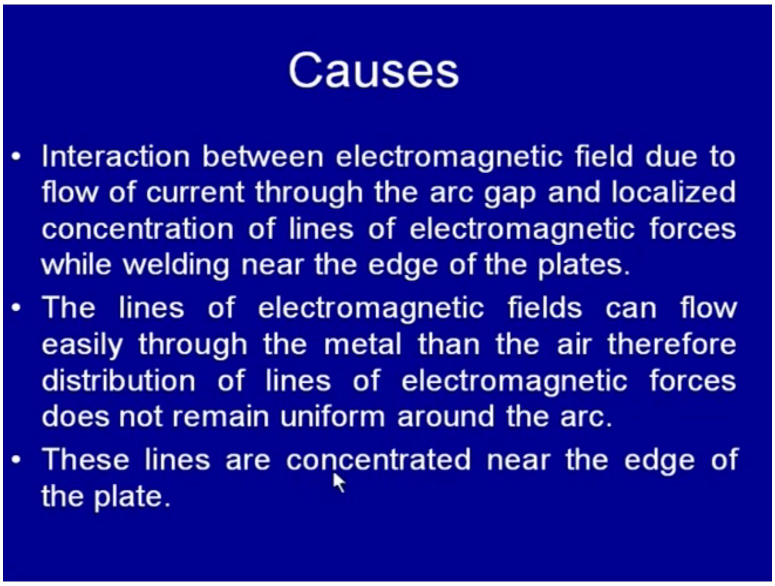

So, this is the another kind of interaction, which takes place as i have just described that the interaction between the electromagnetic fields due to the flow of current through the arc gap. The localization of the lines of electromagnetic forces near the edges of the plates, because these cannot move through the air and that is why they will not be equally spaced. So, this is the lines of the electromagnetic force fields can flow easily through the metal then the air.

Therefore, distribution of the lines of the electromagnetic forces does not remain uniform around the arc and these lines get localized or concentrated near the edges of the plates. So, the electromagnetic field generated, we know that when there is a flow of current electromagnetic field is generated around the arc. Magnitude of this field is directly governed by the magnitude of this field is governed by magnitude of the current and the location we are looking into the field strength.

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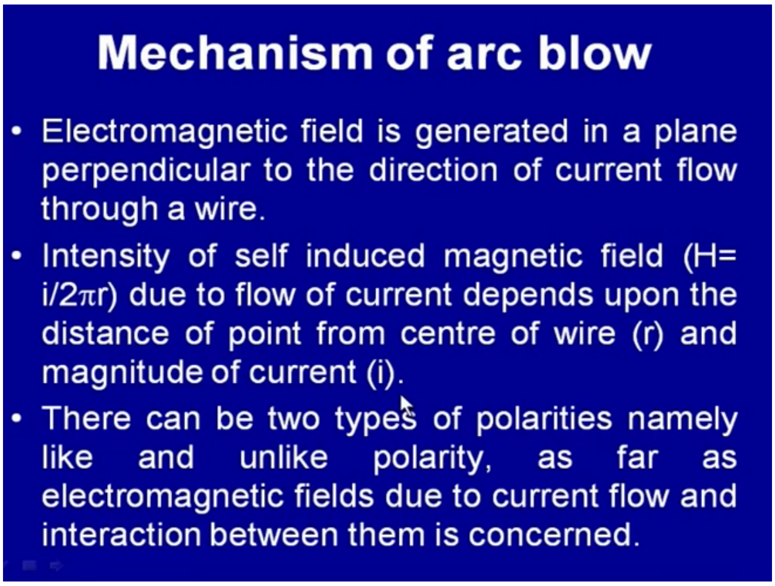

So, this intensity of the self induced electromagnetic field is given by i by 2 r that is due to the flow of current, which depend upon the distance of the point from the centre of the wire. So, r is the distance of the point of interest from the centre of wire and i is the magnitude of the current. There can be two types of the polarities; when we are looking into the electromagnetic fields interactions, one is the like polarity, another is unlike polarity. As far as the electromagnetic fields interactions are concerned due to the flow of current and the their effect is governed by whether we have like polarity of unlike polarities.

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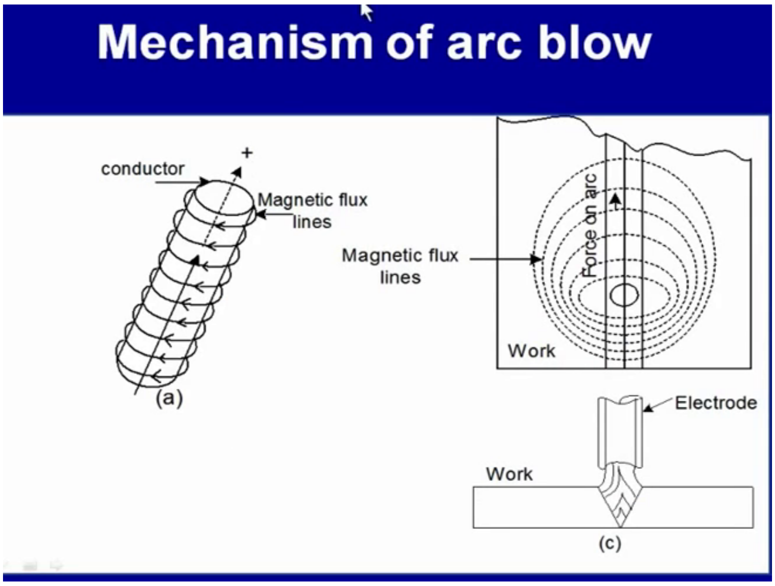

These schematic diagram shows that if there is a current and it there is wire through which flow of current is taking place. Then the perpendicular to the direction of the flow, normal to the direction of the flow the electromagnetic lines are electromagnetic force ((Refer Time: 22:03)) are generated and magnitude of these forces can be identified through that equation i by 2 pi r. So, these when the welding arc is away from the weld centre or away from the edges of the plates these lines of the electromagnetic forces are uniformly distributed. But as soon as the welding arc reaches to the edges of the plates to be welded the, there localization starts and this kind of localization causes the deflection of arc blow away from the edges.

So, frequently this leads to the backward arc blow if the welding direction is taking place towards the edges of the plates, then the arc blow will be taking place in the direction away from the edges of the plates. So, this will be the backward arc blow due to the localization of the electromagnetic fields near the edges of the plates. Otherwise, in normal course arc will be in the line of the axis of the electrode without the deflection of arc. As we have seen that the electromagnetic fields are generated all around the wire normal to the direction of the arc blow, when the flow of current in the two wires is same then it is termed as the like polarity. When the flow of current between the two wires which are close to each other is opposite then we termed as unlike polarity.

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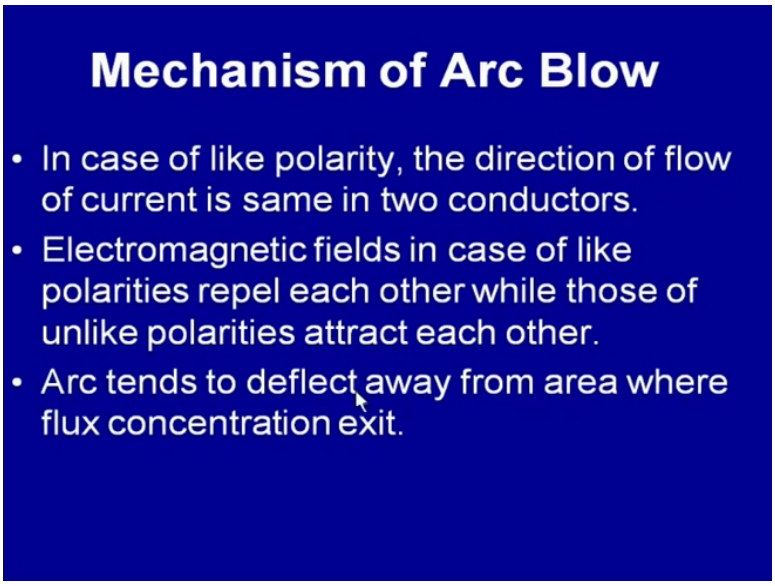

So, electromagnetic fields in case of the like polarity repel each other while in case of the unlike polarities they attract each other. So, in normal welding case normally this the like polarity is observed where welding current first flows through the arc there after it flows through the base metal. When these two electromagnetic fields come close to each other they tend to repel and that is why arc tends to deflect from the intended direction that is the axis of the electrode. So, in case of the like polarities they repel each other while in case of unlike polarities they attract each other. So, arc tends to deflect away from the area where this kind of localization or concentration of the fluxes is taking place.

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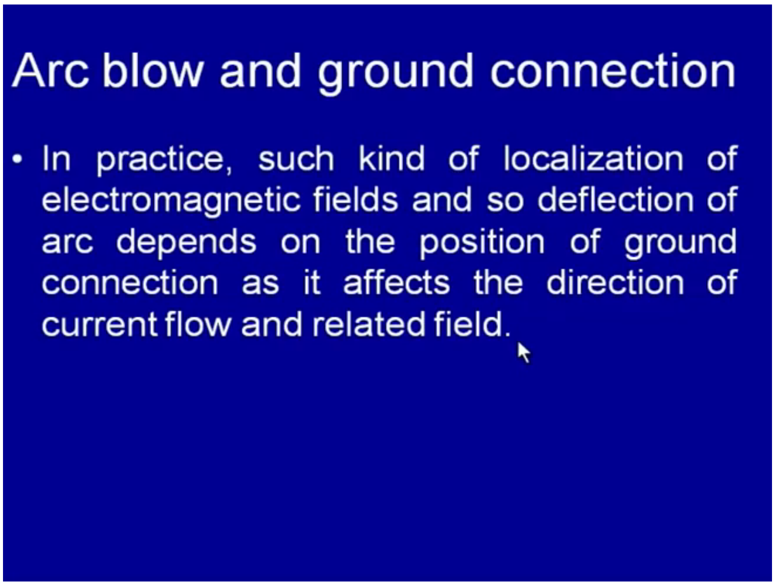

Another important aspect, which will be effecting to the arc blow and tendency of the arc blow is the ground connection, the direction where current flows after ((Refer Time: 24:48)) or after the arc zone. So, that direction significantly affects the tendency of the arc blow or it also helps to control the arc blow. So, in fact is such kind of localization of electromagnetic fields and so the deflection of arc depends upon the position of the ground connection as it affects the current flow and the related field. So, to understand the ground connection we have to look into again the, another schematic diagram.

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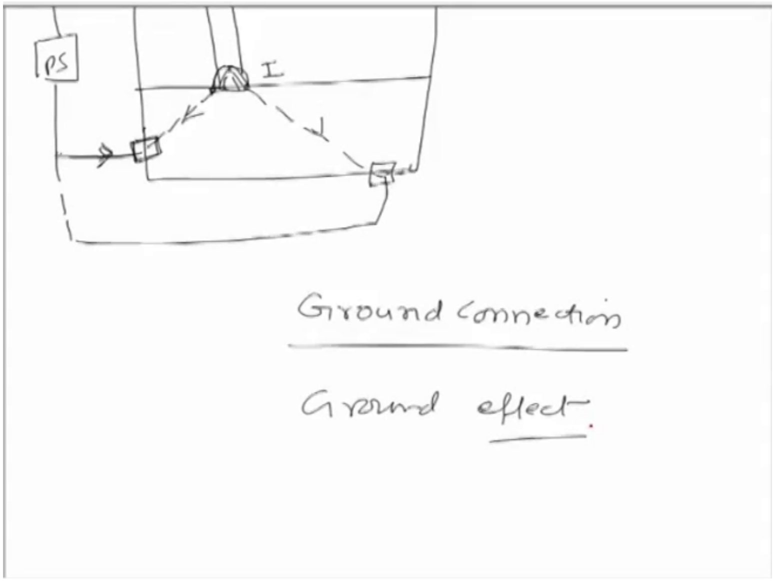

So, to see this... So, if we consider this is the top view of the base plates which are being welded this is the line along which these the weld joints are to be made. So, and here this is the electrode and here we have welding arc. So, the terminal the electrodes can be connected to the power supply say P S 1 terminal to the base metal and another terminal of the power supply to the electrode. So, current will be flowing through the electrode the through the welding arc. Then after passing through the welding arc in which direction it will flow that will depend upon where the connection of the which portion of the base metal is connected with the another terminal of the power source. So, the current may flow in this direction if the ground connect has been made at this point.

So, the current may flow in this direction, if the ground connection instead of here if it has been made at this point. Depending upon the location where the connection of the another terminal of the power source with the base metal has been made the flow of current can take place in the different directions. This will decide where there is a two whether the electromagnetic fields will be interacting with each other or not or if they are interacting with each other it is favourable or not.

So, that interaction many times is done in very controlled way, so that the extent of the arc blow can be reduced. So, this first this connection of the power source terminal to the base metal is termed as the ground connection and its ability to change the direction of flow of current after passing through the arc. Whatever electromagnetic field is generated due to the flow of current after passing through the arc up to the ground connection it will be affecting the arc blow tendency.

So, tendency of the arc blow to whether to increase or to decrease due to the electromagnetic field being generated by the flow of current through the base metal, due to the ground connection is termed as ground effect. So, the ground effect can increase the arc blow or it can decrease the arc blow. We will see in detail that how the direction of the current flow of current can be regulated, can be changed in favour, so that the extent of arc blow can be reduced.

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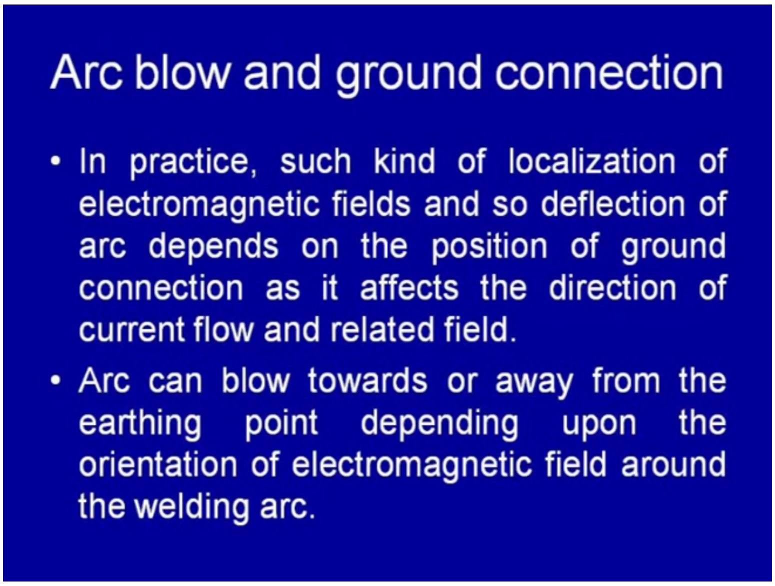

So, arc blow and the ground connection the two are very closely associated with each other. So, in practice such kind of the localization of the electromagnetic fields and so the deflection of the arc depends upon the position of the ground connection, as it effects the direction of the current flow and the related electromagnetic field. The arc can blow towards or away from the earthing point that is the ground connection depending up on the orientation of the electromagnetic fields around the arc.

This is the point suggesting that the arc blow can be increased or can be decreased by the ground connection,. Depending upon the way by which the interaction between the electromagnetic fields being developed around the arc and that due to the flow of current through the base metal is taking place.

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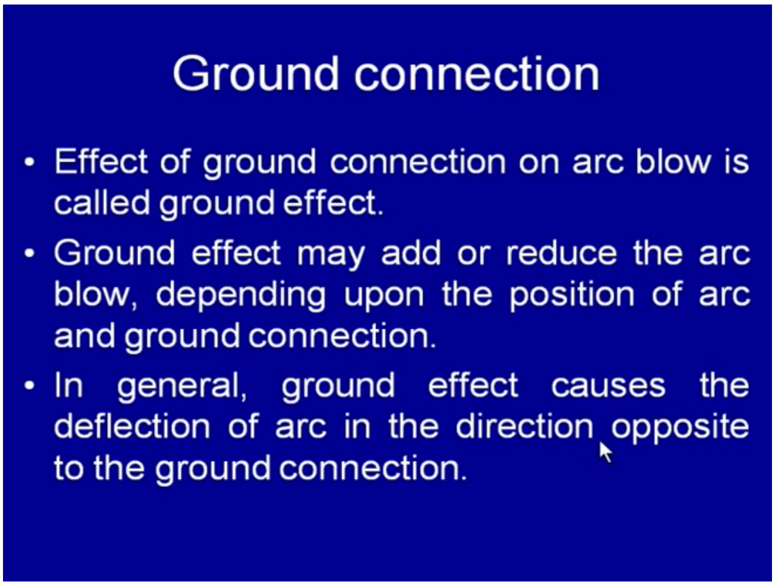

So, effect of the ground connection on the arc blow is called ground effect and the ground effect may add or reduce the arc blow depending upon the position of the arc and the ground connection. So, that is why the ground connection is made in such a way that the interaction between the electromagnetic fields either is reduced or it is made in our favour, so that the extent of the arc blow can be reduced. In general ground effect causes the deflection of arc the direction opposite to the ground connection. So, this aspect is exploited successfully in order to control the deflection of arc blow. So, that the extent of the arc blow can be reduced.

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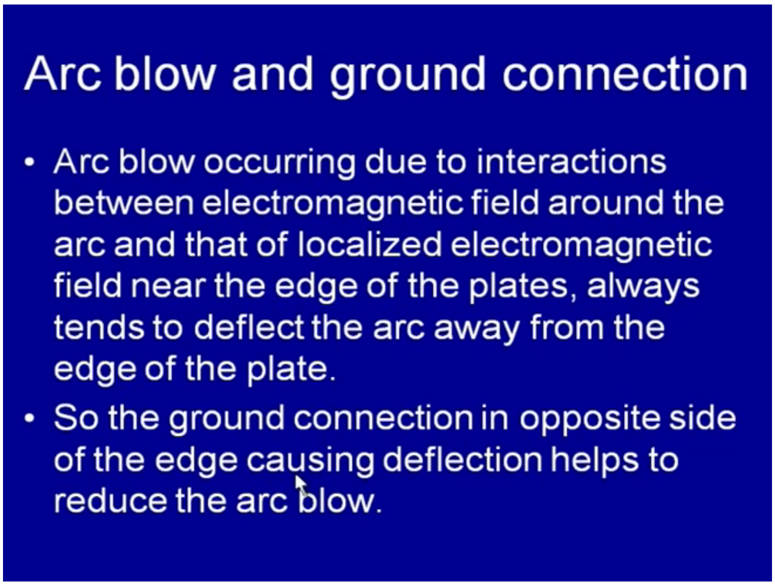

Arc blow occurring due to the interaction between the electromagnetic fields around the arc and that of the localized electromagnetic field near the edges of the plates always tends to deflect the arc away from the edges of the plates. So, when we are welding near the edges of the plates invariably backward arc blow is encountered and that happens due to the interaction be the electromagnetic fields around the arc. That which is localized which has been localized due near the edges of the plates. So, the ground connection in the opposite side of the edge causing the deflection helps to reduce the arc blow.

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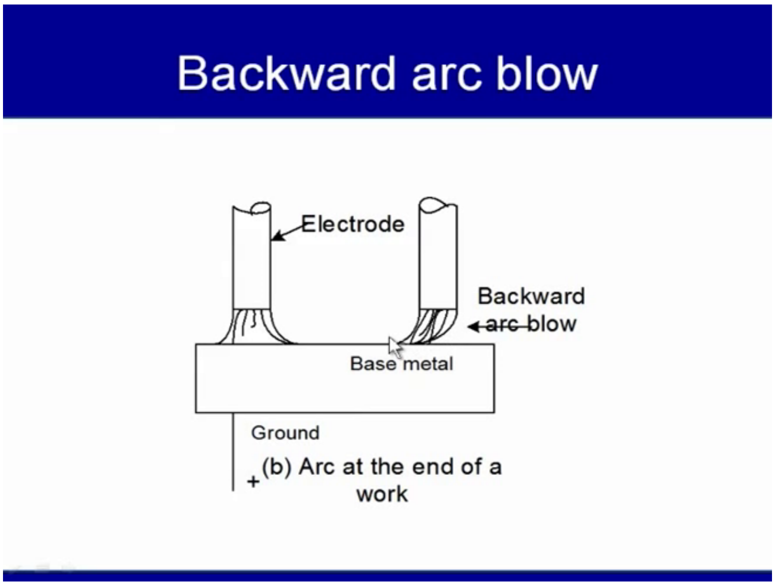

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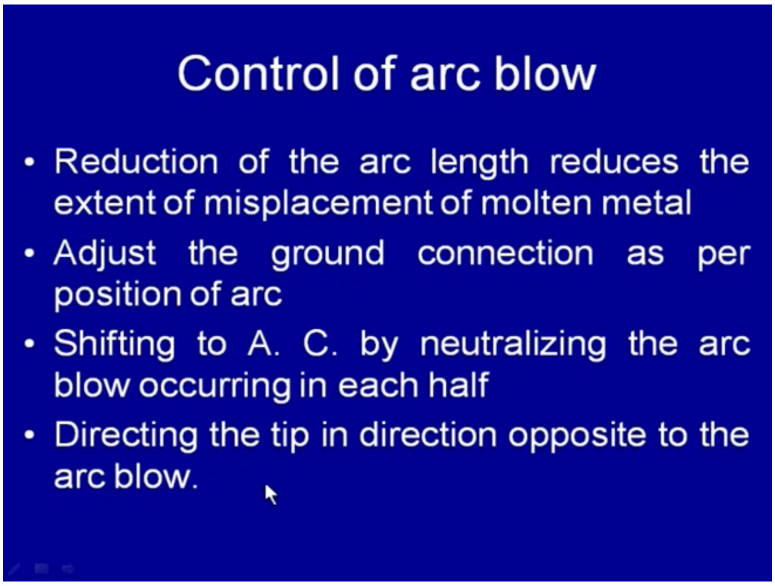

So, this is what happens that if here localization is taking place in this zone during the welding and the arc tends to deflect away from the edges of the plates. To control the various approaches are used for controlling the welding arc blow and reduce its adverse effects.

So, the first aspect is reduction in arc blow length arc length. So, if the arc length is reduced the extent by, then the extent by which molten metal will be falling here and there that will be reduced. So, the extent of the misplacement of the molten metal will be reduced. So, one simplest approach is to reduce the arc length, so that the misplacement of the molten metal during the arc welding can be reduced and so, that its adverse effect can be reduced.

The second is just the ground connection as per the position of arc. As we have just discussed that, if the ground connection is to be adjusted in such a way that the interaction between the electromagnetic fields around the arc. The field generated in the base metal due to the flow of current takes place in such way that the magnitude of the arc blow can be reduced, so that the undesirable effects of the arc blow can be reduced. So, the ground connection adjustment is another important way to control the arc blow. The shifting of the shifting to the A C is another good approach if it is possible, because the arc blow is invariably observed while using the DC, especially under near the edges of the plates or improper arc position is used.

So, here shifting to the A C will neutralize the effect of the arc blow because it will be deflecting in each half cycle to one side to another and thereby neutralizing the any kind of deflection even if it is taking place. So, shifting from D C to the A C is another possible way if it is possible. Because, many times the D C is intentionally used in order to take the advantage of the cleaning action using the positive polarity or the negative polarity and reduce the adverse effect of the heat generation or to rag to have the controlled heat generation in anode side or the cathode side.

So, if it is possible then we can shift from the D C to AC. So, that the deflection of the arc blow after each half cycle can be neutralized and the adverse effects related the arc blow can be reduced. The another method is by directing the tip of the electrode in the direction opposite to that of arc blow, so that its effect can be reduced to some extent. So, this is this was all about the arc blow we have seen that, what are the effects of the arc blow? What are the causes of the arc blow? What is a mechanism of the arc blow? What are the approaches? Which can be used for controlling the arc blow?

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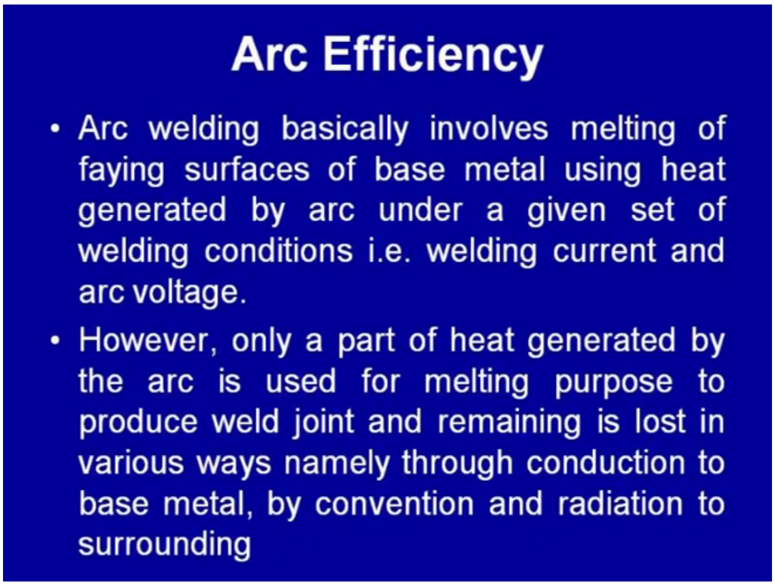

Now, we will see that, what is the arc efficiency? What is its role? How it can be determined in case of the consumable and the non consumable arc welding process? Like any other efficiency we try to see that, what we have supplied? How much portion of the inputs have been effectively used to calculate the arc efficiency also? We know that welding arc is developed primarily to generate heat, so that the melting of the faying surfaces can be used for development of the weld joint. So, out of the total heat generated what portion of the heat has been effectively used for developing the weld joint is used to calculate the arc efficiency.

We know that arc welding basically involves the melting of the faying surface of the base metal using the heat generated by arc and under the given set of the welding conditions that is your welding current and the arc voltage. So, heat generation in during the welding is being governed by the welding current and the arc voltage. So, whatever heat is generated we have to see that, how much portion of the heat has been effectively used for melting the faying surfaces. So, that portion of the heat is primarily used to calculate the arc efficiency. We know that only a part of the heat generated by the arc is used for melting the faying surfaces of that base metal.

So, that the weld joint can be made and the remaining portion of the heat is lost from the arc zone, either to the base metal by the conduction or by convention and radiations to the surrounding. The cool air of the atmospheric that means atmosphere and by the radiation heat loses from the arc zone also takes place. So, only a portion of the heat generated by the arc is used for melting of the faying surfaces, so that the weld joint can be made. Effectively the, this portion of the heat which is being used for melting of the faying surfaces is used for determining the arc efficiency. That is why the arc efficiency of the different processes is found to be different.

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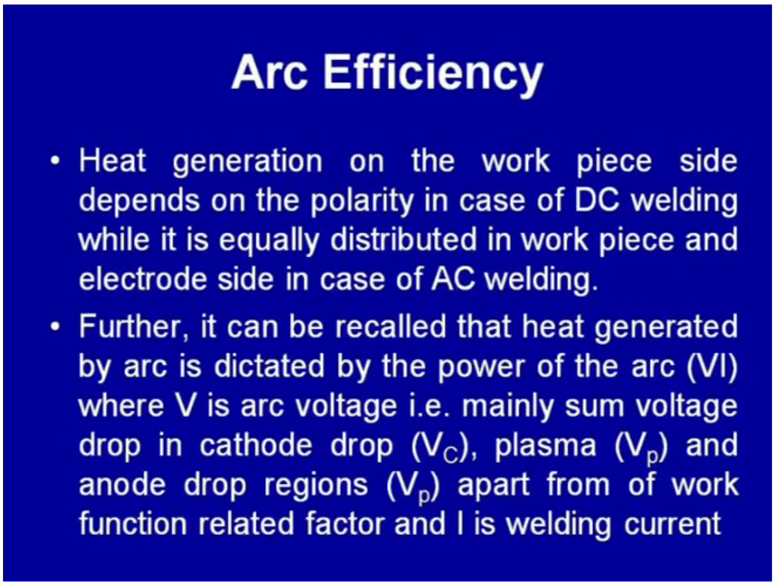

We know that heat generation in case of the D C welding depends upon the polarity two-third of the heat is generated on the anode side and one-third of the heat is generated on the cathode side. Well in case of the A C welding the heat is generated almost in equal amount in both electrode, as well as work we side both anode or anode or the cathode side. So, we have the better control over the heat generation in case of the DC welding. So, even the DC welding is being used then the efficiency calculation approach is different as compared to case when AC welding is used it. If we can recall the heat generated by the arc is dictated by the power of arc that is the product of the arc voltage and the welding current.

So, the arc voltage further is composed of the three voltage drops, that is the voltage drop which is taking place in the cathode drop zone, plasma zone and the anode drop zone.

Apart from the work function related factors and the welding current. So, mainly these are the three voltage drops and some small amount of the work function related factors, also effect the heat generated and the welding current being used for developing the welding arc. Product of the welding current and the voltage drop in a particular region governs the heat generated near that zone, whether it is anode drop zone, cathode drop zone or the plasma region.

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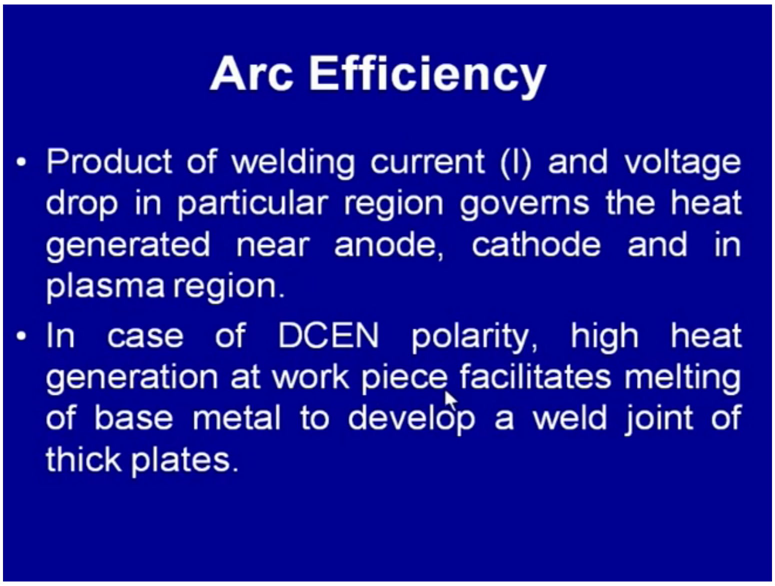

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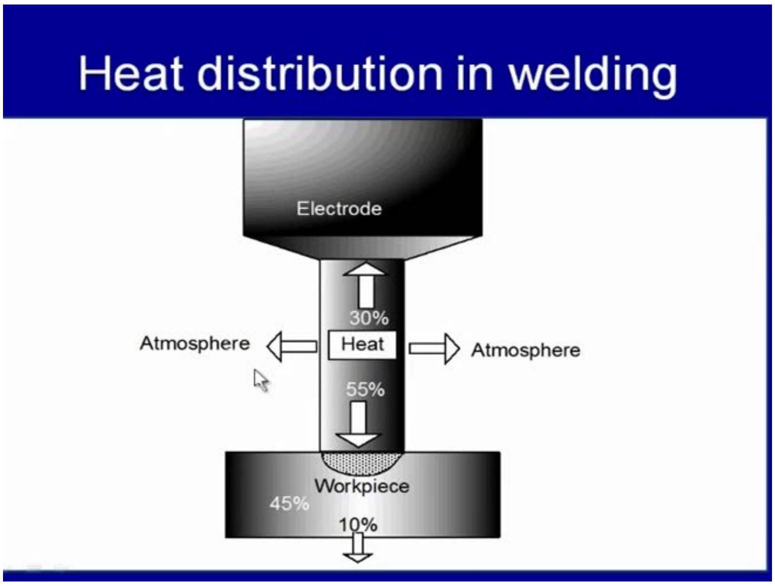

So, in case of the DCEN polarity, high heat is generated in the work piece side, DCEN means electrode is made negative. So, it acts as a cathode and more heat is generated from the anode side, so more heat is generated on the base metal side or the work piece side, which facilitates very rapid melting of the base metal for development of the weld joints.

That is why normally the DCEN polarity offers the higher arc efficiency, then the DCEP where the less is generated in the base metal side more in the electrode side. So, if we consider the case of the DC welding with the electrode negative that is the DCEN polarity is used in this kind of polarity. The two-third amount of the welding arc heat is generated on the anode side and about one-third of the heat is generated in the cathode side.

So, if we as a rough idea if we try to look into about 55 percent of the heat is going towards the base metal, out of that about 45 percent of heat is used for melting of the base metal. The remaining heat is lost to the base metal by the conduction, which mainly increases the temperature of the base metal, but not effectively used for melting of the base metal. This heat frequently causes the development of the heat affected zone. Well about 30 percent of the heat goes to the electrode and the remaining heat is lost to the atmosphere by the convection and the radiation modes.

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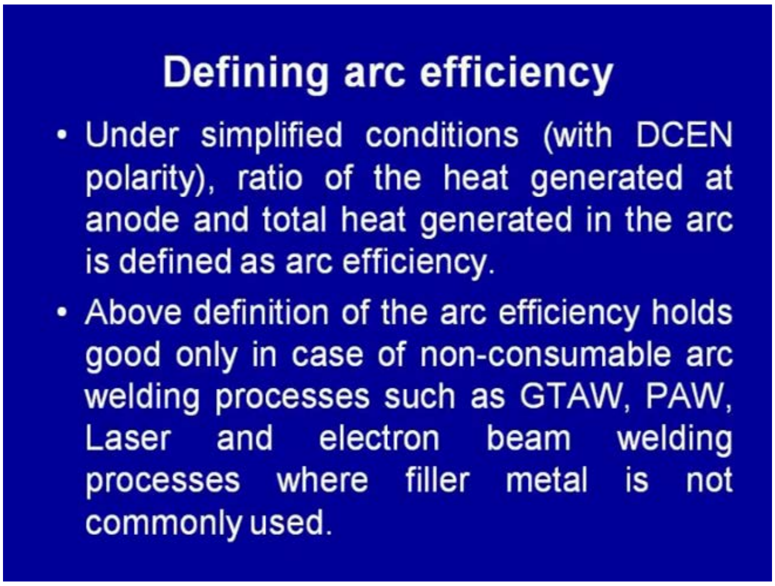

So, most of the heat with a DCEN polarity is used for melting of the work piece and melting of the fence surfaces for development of the weld joint. If we see lot of heat is also lost by the conduction to the electrode by convection and radiation to the atmosphere and also to the base metal by the conduction.

So, to define the arc efficiency under the simplified conditions the ratio of heat generated at the anode side and the total heat generated in the welding arc can be defined as arc efficiency. Because, this is the portion of heat which is generated in the anode side and most of this is used for melting of the faying surfaces. But this definition is applicable only in case of the non consumable arc welding process with the DCEN polarity. ((Refer Time: 41:20)) of the definition of the arc efficiency holds good only in case of non consumable arc welding process, like GTA welding, plasma arc welding, laser and electron beam welding.

Because, heat being generated in the cathode side is not being considered and the heat being and heat generated in the cathode side is not actually effectively used in non consumable arc welding process. That is why this kind of a definition for arc efficiency is good for non consumable arc welding processes where filler material is not commonly used.

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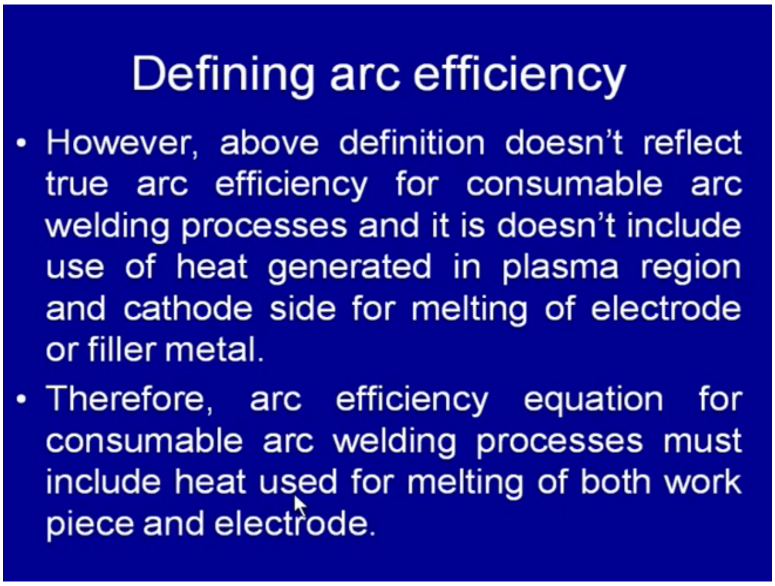

However, our definition does not reflect the true arc efficiency for the consumable arc welding process. Because, it does not include the use of heat generated in the plasma region this is one and the heat generated in the cathode side is used for melting of the electrode or melting of the filler material. So, in consumable arc welding process heat generated in the arc region is also used for melting of the filler metal or melting of the electrode as well as a part of the heat generated in the plasma zone is also used in development of the weld joint.

So, the ratio of just heat generated in the anode side and the heat generated total heat generated in the arc, is not a good way of calculating the arc efficiency, for calculating arc efficiency of the consumable arc welding process. Therefore, to calculate the arc efficiency for consumable arc welding process we must use the heat as being generated in the arc. As well as the amount of the heat being used for melting of the both work piece as well as in electrode. So, if heat is being used for melting of the electrode and the work piece both, then we will be getting the better way of representing the arc efficiency of the consumable arc welding process.

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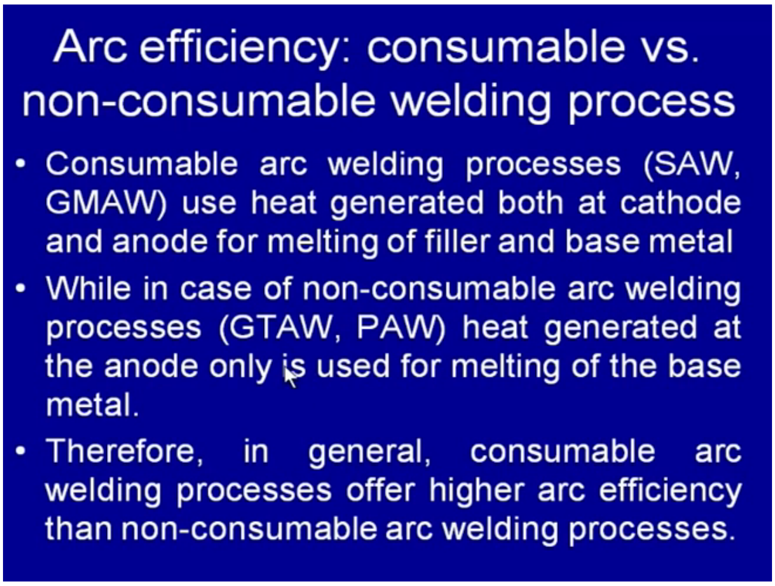

So, if we look into the details of the arc efficiency in respect of the consumable and the non consumable arc welding process. Then the consumable arc welding process use the heat generated both at the anode and the cathode side for melting of the electrode or the filler material and the base metal. Well in case of the non consumable arc welding process only the heat generated in the anode side is used for melting of the base metal. So, this is the big difference, as far as the arc efficiency calculation is concerned. That the heat generated both at the anode and cathode side is used for melting of the filler material as well as base material, in case of consumable arc welding processes.

Well in case of non consumable arc welding process heat generated only at the anode side s used for melting of the base metal and it is faying surfaces for developing the weld joint. That is why the in general consumable arc welding processes offer higher arc efficiency, than the non consumable arc welding processes. So, this is the one big factor that brings in the difference between the arc efficiencies of the consumable and arc consumable arc welding processes and non consumable arc welding process. That difference is mainly because of the heat being used, heat generated in the cathode side is also being effectively used for developing the weld joint.

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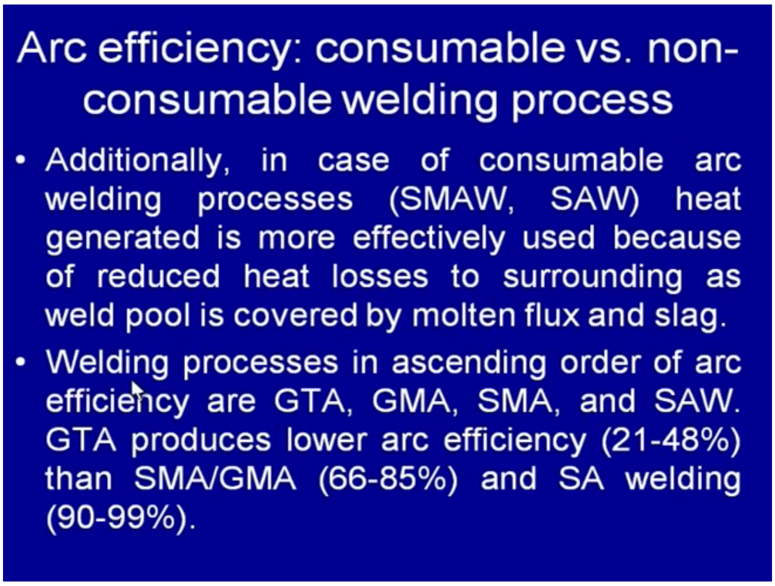

In continuing with this comparison irrespective of the arc efficiencies of the consumable, as well as the non consumable arc welding process. If we see in case of the consumable arc welding process, like ((Refer Time: 45:15)) arc welding and shield metal arc welding. Heat is more effectively used then the non consumable arc welding process like plasma and the tungsten inert gas welding process. So, in those processes, because mainly flux is not formed and the slag is not formed.

So, in those cases there is no protection of the heat available with the weld pool which is last to the surrounding. But these heats are effectively capped within the base and within the arc and those losses are reduced. So, in case of consumable arc welding process the losses of heat to the surrounding from the weld pool is reduced by molten flux cover or the cover being formed by the slag. These two types of covers effectively check the heat transfer from the weld pool and therefore, reduce the heat losses.

These things further increase the melting efficiency and the way by which melting takes place in that case of consumable arc welding process, but this kind of aspect is not present in case of non consumable arc welding process. Then therefore the welding processes in ascending order of the arc efficiency are GTA, GTA offers the lowest arc efficiency, as far as the common arc welding processes are concerned. Thereafter we have gas metal arc welding then ((Refer Time: 46:45)) arc, shielded metal arc welding and then ((Refer Time: 46:48)) arc welding.

GTA produces the arc efficiency about 21 to 48 percent, while the SMA/GMAW the arc efficiency varies in from 66 to 85 percent, well some as dark welding offers the for through higher arc efficiency 90 to 99 percent. This difference is basically the higher efficiency offer the ((Refer Time: 47:10)) arc welding process, then the other welding process is mainly attributed to the cover of the molten flux around the arc around the weld pool, which effectively protects the losses of heat. From the weld pool and the arc to the surrounding and in turn brings in the great difference in the arc efficiency.

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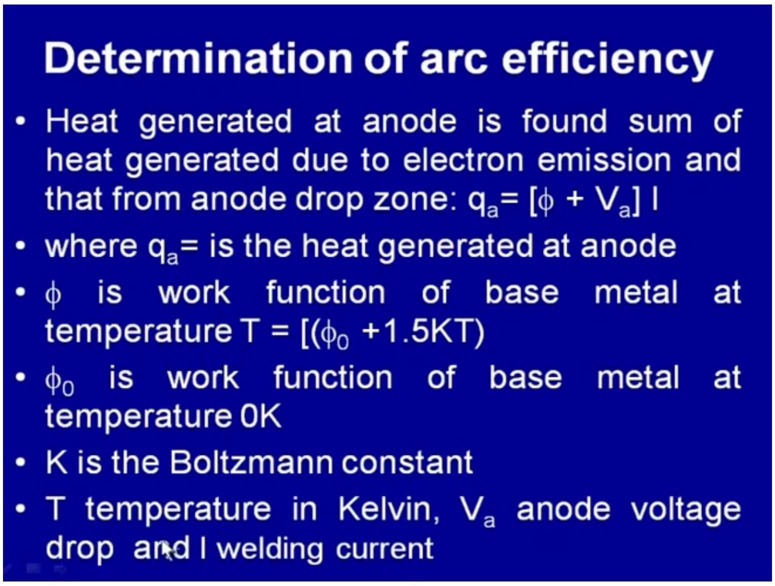

So, to calculate the arc efficiency, in next two slides mainly we will be seeing that how to calculate the arc efficiency using the various voltage drops and the welding currents.

We know that heat generated at the anode is found sum of the heat generated due to the electron emission and that from the anode drop zone and that we can determine from q a is equal to the phi plus the voltage drop in the anode drop zone into the welding current. Where q a is a heat generated at the anode and the phi is work function of the base metal at the anode temperature, which is found a function of a the phi naught plus 1.5 times K into T.

So, here work phi naught is the work function of the base metal at the 0 K temperature and K is the Boltzmann coefficient. So, the temperature, T is the temperature in Kelvin and V a is the anode voltage drop and I is the welding current. This is how we can determine calculate the heat generated in the anode side and this can be used for calculating the arc efficiency.

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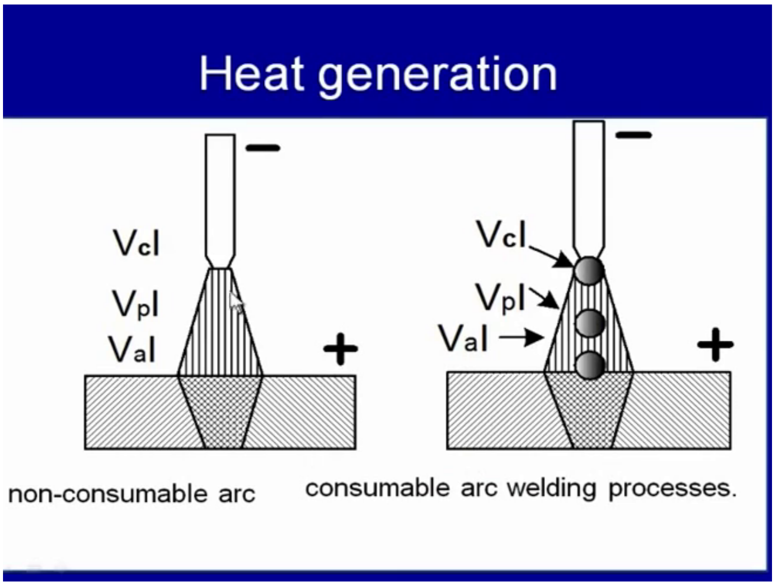

We know that this is the kind of the heat generated in the cathode side that is the V c into welding current, heat generated in the plasma zone that is the V p voltage drop in the plasma zone multiplied by the welding current. Similarly, V a anode voltage drop in anode zone multiplied by welding current. This gives us the heat generated and when the molten metal drop coming from the electrode tip, it will be carrying some of the heat from all these regions.

Heat generated in the cathode drop zone will be effectively used for melting up the electrode and when this one is moving through the plasma zone also some of the heat is carried away by this in this region. Heat generated and the anode drop zone is effectively used for melting of the base metal.

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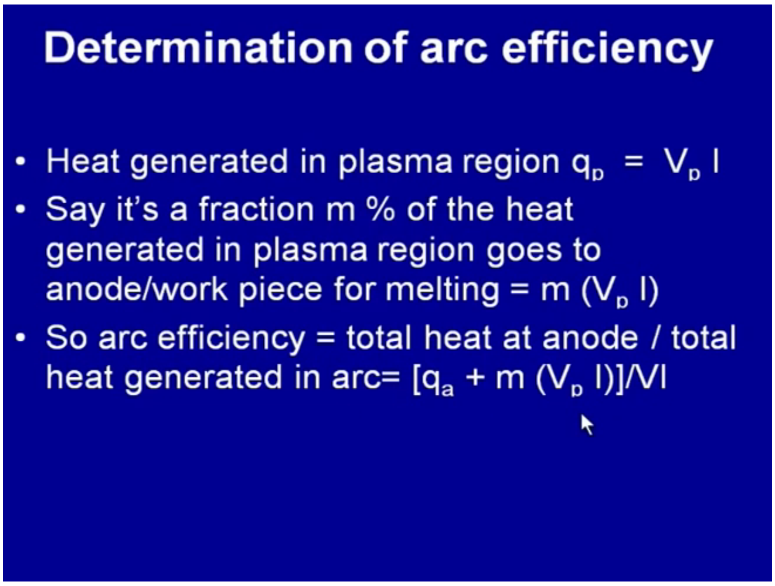

So, this difference leads to the difference in the arc efficiency of the consumable and non consumable arc welding process. So, further if we see the heat generated in the plasma region is say q p is a portion that is the V p into the V I. So, V is the voltage drop in the plasma region, not all heat generated in the plasma zone is effectively used for melting of the base metal or melting of the electrode. But only a fraction of the heat generated in the plasma region goes to the work piece to the anode and say if this fraction is m then m multiplied by V p into I, that is the heat generated in the plasma region.

So, the arc efficiency then can be modified is the total heat generated at the anode divide by the total heat generated in the arc region. So, heat generated in the anode side is the q a plus the heat being which is coming from the plasma zone that is m. Fraction of the heat coming from the plasma zone into the heat generated in the plasma region, that is V p into I and divide by this the V I, V I is above arc voltage and is the welding currents. So, this is how we can calculate the arc efficiency for determining the... this how we can determine the arc efficiency in case of the DC welding.

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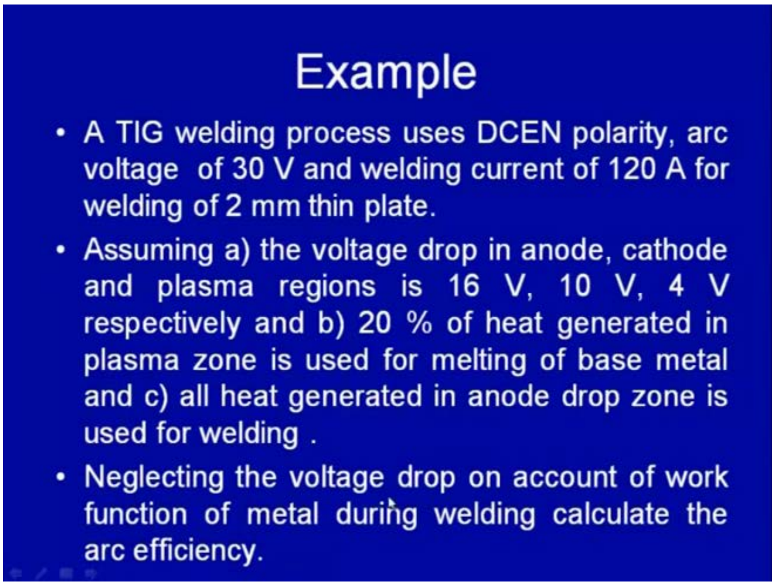

Now, we will see one example showing how to calculate the efficiency of arc in case of the TIG welding process. Say, a TIG welding process uses the DCEN polarity and the arc voltage of the 30 volt is used when welding current of the 120 ampere is used for welding the 2 mm thin plate. Assuming that the voltage drop in the anode cathode drop cathode and the plasma region is 20 volt, 10 volt and the 4 volt respectively and 20 percent of the heat generated in the plasma zone is used for melting the base material. All the heat generated in the anode drop zone is used for the welding purpose.

So, by using this data if you want to calculate the arc efficiency and here we can further assume that, the voltage drop on account of the work function of the metal during the welding is neglected. Then how you can calculate the arc efficiency? To see this we need to see that arc efficiency in case of the TIG welding process, where no filler material is used. Basically, is based on, arc efficiency calculation is based on how much heat is effectively used for melting the base material to the and the how much heat is being generated with the flow of the current during the welding conditions.

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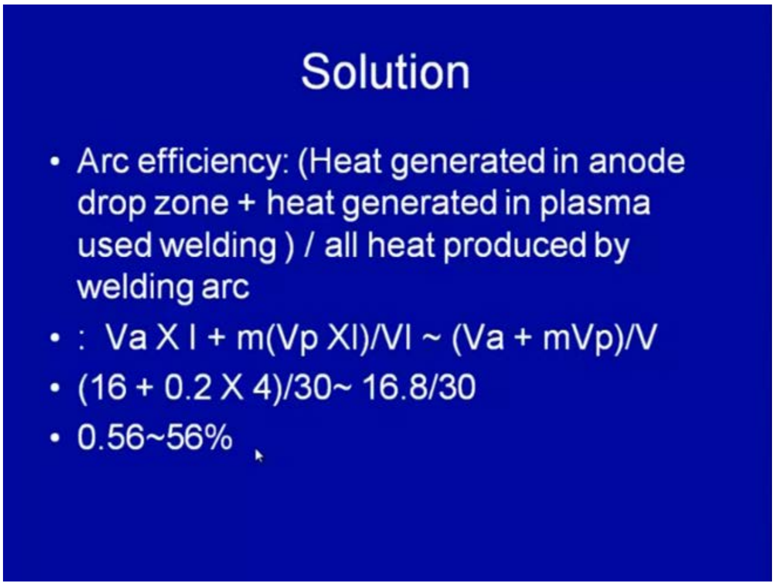

So, for this purpose basically we have to see that heat generated in the anode side and the heat generated in the plasma region being used for melting the base material. We know that the heat generated in case of the DCEN polarity, most of the heat generated in the anode side that is in work piece side is used for melting the base material. Plus it is fraction of the heat generated in the plasma zone is also used for melting, is also used for melting the base material to develop the weld joint.

If some of these two heats is divided by the all hear generated by the welding arc then we can calculate the arc efficiency. We know that V a into I shows the heat generated in the anode drop zone and if m is the fraction and fraction of the heat generated in the plasma zone being used for melting the base material. Heat generated in the plasma zone can be given by the voltage drop in the plasma zone and the welding current I.

So, if its fraction m is being used for melting the base material in the anode side then some of these two V a plus V a into I plus m into V p into I divided by V I. V I shows the total heat generated in the arc region; so if you simplify this equation, then we get V a plus m, V p divided by V. On putting the values for these terms, then we will say anode voltage drop in the anode drop zone is 16 plus say 20 percent of the heat generated in the, heat generated in the plasma zone, it is used for melting the base material in the anode side.

Then the product of these two will give us the heat generated, heat being actually used for melting the base material divided by the 30 that is the voltage drop in the arc zone. So, this will give us on simplification we will get 16.8 divided by 30 on solving this we get 0.65 that is 56 percent. So, this is we can calculate the arc efficiency for the GTAW or TIG welding process, where no filler material is used. If the filler material is used then the approach of the calculation of the arc efficiency will change.

So, here in this presentation mainly, we have observed the arc blow, its effects and the methods which can be used to overcome the arc blow. We have also seen that, what are the different approaches, which are used for defining the arc efficiency? How can we click in clearly identify the arc efficiency of the consumable and non consumable arc welding process? What are the factors that bring in differences in the arc efficiencies of the consumable and non consumable arc welding processes?

So, thank you for your kind attention.