Welding Engineering
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Module - 2
Physics of Welding Arc
Lecture - 2
Fundamentals of Arc Initiation

In this presentation on the physics of the welding arc will be looking into the various aspects related with the arc. Like the electrical aspects affecting the heat generation in the different zones of the welding arc the way by which arc is initiated for the welding purpose and the need of the maintaining the arc. So, that the heat generated by the welding arc can be used for melting of the faying surfaces. And at the same time, we will also see that how the arc length affects the heat generation in welding arc and other aspects.

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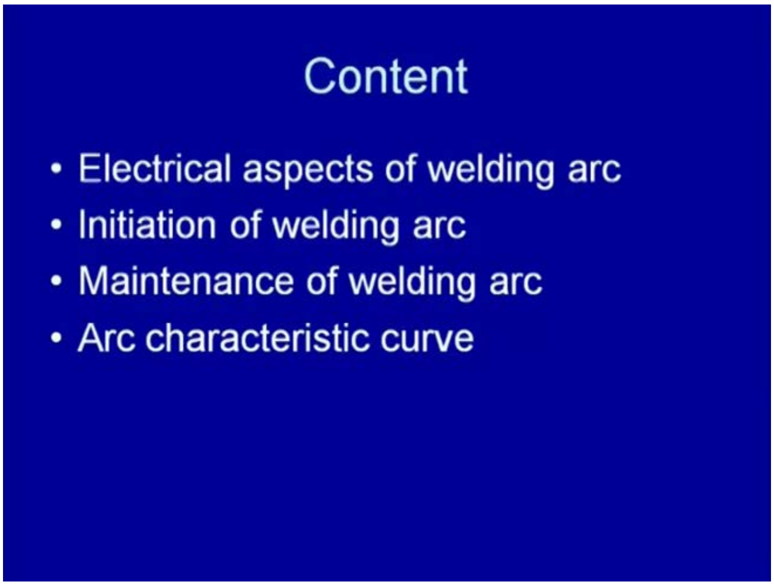

As far as content is concern in this presentation will be looking into electrical aspect of the welding arc, initiation of the welding arc. And the methods which are used for initiating the welding arc and the important conditions, which are necessary to maintain the welding arc. Then arc characteristics, which is basically about the relationship between the arc voltage and the welding current and when the arc length is changed then how the relationship between the arc voltage and the welding current is changed. What is it is effects on the heat generation? And performance of a particular welding process as far as development of the sound weld joint is concern. So, if we see here in the electrical aspects, we know that the flow of current is important for stabilizing and for having a smooth welding arc.

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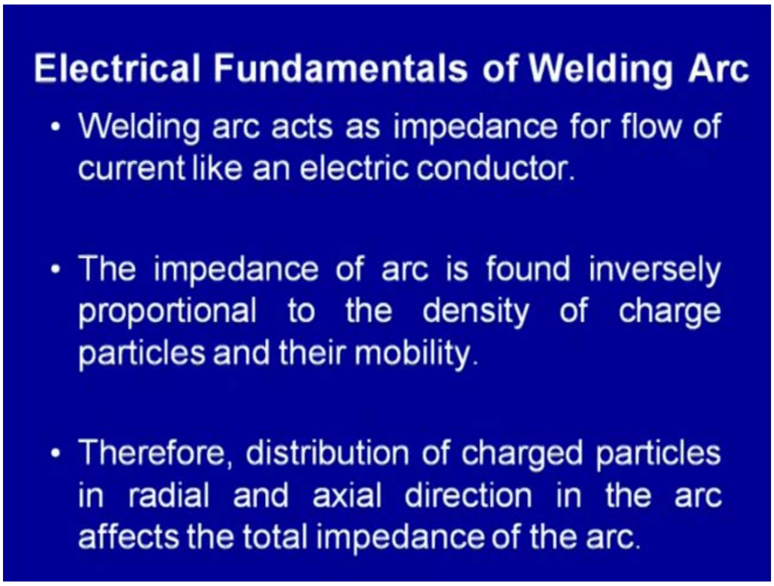

So, that the heat can be generated for melting the faying surfaces, but when the current flows, the gap between the electrode and work piece mainly acts as a impedance for the flow of the current. This resistance for the flow of current results in the generation of the heat, here the impedance for the flow of the current in the welding arc is influenced mainly by the density of the charged particles and the way by which they are moving in the arc gap. The higher is the density easier will be the flow of the current and grater is if under the similarly, the grater is the mobility better will be the flow of current.

So, if the charge particles are uniformly distributed between the electrode and the work piece, then the impedance between the electrode and work piece in the gap will be uniform. Accordingly for given flow of current the generation of heat will also be uniform. But it has been observed that the distribution of charge particles in the radial and axial direction in the welding arc is not found uniform. Accordingly the impedance varies along the length from the electrode tip to the work piece and from the center of the arc to the outer surface of the arc.

Therefore, because of the variation in distribution of the charge particles, in radial and axial directions, impedance is affected which intern affects the heat generation in the different zones. Varying from the electrode tip to the work piece or from the center of the arc to the outer surface of the arc and accordingly temperature variation is observed in the arc zone.

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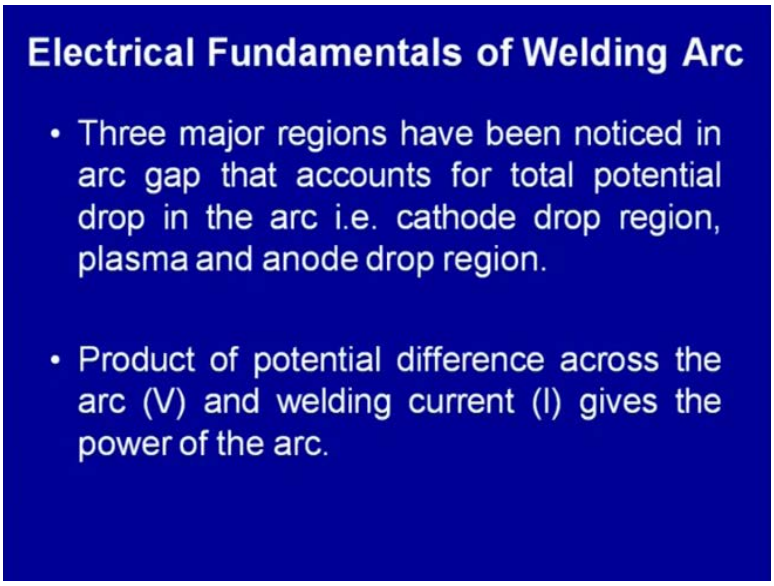

So, three main zones have been identified and which are commonly observed based on the kind of voltage drop takes place in the arc. These zones are cathode drop region and cathode drop region plasma zone and the anode drop region. The reasons for the voltage drop in these three zones have already been explained in the previous presentation, but the voltage drop in each of the region effects the heat generation associated with that zone. Under the product of the difference, potential difference across the arc and the welding current gives the total power of the arc.

So, when we multiply the arc voltage, which is basically the difference in the voltage across the electrode tip and the work piece, the welding current, which is flowing between the electrode and work piece giving the developing the arc. The product of these two arc voltage and the welding current gives the power of arc and it governs the amount of heat being generated by the arc in unit time, where the arc voltage is obtained from the sum of the voltage drop in the cathode drop region plasma region and anode drop region.

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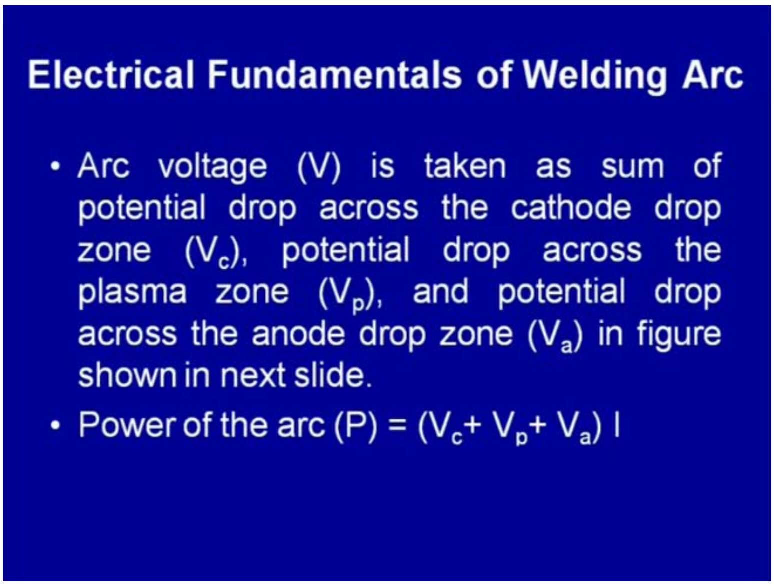

We will see in the next slide this arc voltage here is considered as a sum of the potential drop across the cathode drop region, which is termed as V c, designated as V c. Voltage drop across the plasma zone is designated as V p and the potential drop across the anode drop region is designated as V a. The sum of all these three the voltage drop in these three zones that is V c, V p and V a forms the arc voltage. When this arc voltage is multiplied with the welding current we can obtained the power of arc, which directly indicates the amount of heat being generated. So, here you can see the power of arc can be obtained from the sum of the arc voltage. Arc voltage, which is a sum of voltage drop in cathode drop region plus voltage drop in the plasma region plus voltage drop in the anode drop region multiplied by the welding current.

Here we can see that the typical electrode, this electrode tip and the region very close through the electrode that is cathode is the cathode drop region indicating the voltage V c. The slightly away from the cathode drop region and the anode drop zone, here in between we have the plasma region indicating the voltage drop in the plasma region V p and the anode drop zone having the voltage drop of the V a. So, sum of these three voltage drops in the three different zones gives them arc voltage.

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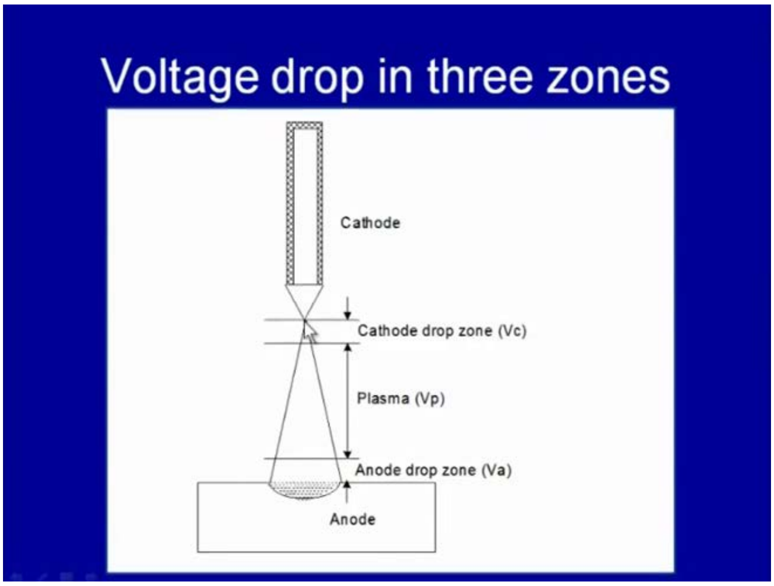

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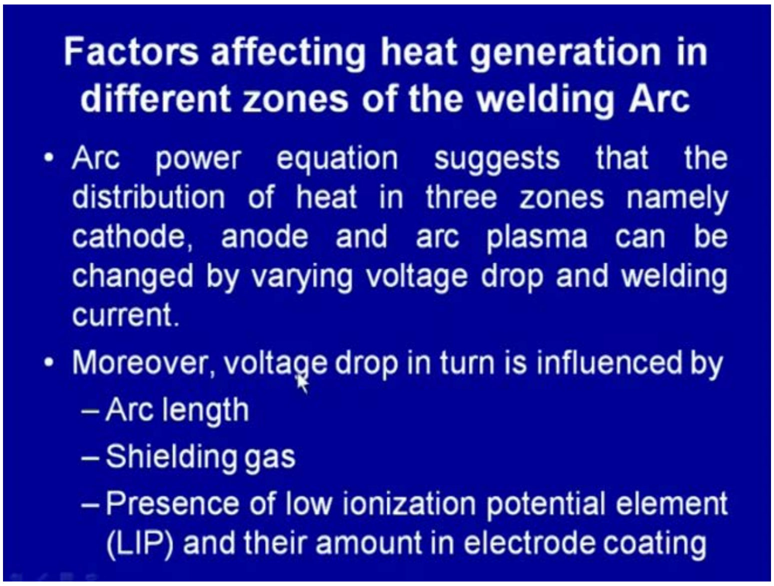

So, to if we see the equation of the equation which is used to determined power of arc having the arc voltage multiplied by the welding current. This arc voltage is composed of the voltage drop in the three different zones, these equations just that the distribution of the heat in the three different zones that is cathode drop region, anode drop region and the plasma zone can be changed by varying. If these voltage is, are affected then the voltage drop is also arc voltage is also affected.

So, in order to regulate the heat generated in the three different zones for a given welding current it is important to change or to regulate the voltage drop in the desired zone, whether it is a cathode drop zone, anode drop zone or the plasma zone. For example, if we increase the arc voltage, voltage drop in the cathode zone for a given welding current, then the heat generation in the cathode drop zone will increase. Similarly, if the voltage drop in the in the anode drop zone is decreased for a given welding current the heat generation in the anode drop zone will be reduced.

So, if we see that the distribution in these three zones, distribution of the heat in a three zones can be regulated by varying the voltage drop in a specific zone for a given welding current. The factors that affect the voltage drops in the particular zone, is influenced by the number of the factors. So, if you see in totality the arc voltage drop between the electrode and work piece is influenced by the three main factors. One is the arc length, second is the shielding gas and the third is the use of a, the low ionization potential elements and there amount present in the electrode coating.

This third factor basically effecting these of the availability of the free electrons required for initiation and maintenance of the arc. So, if we see here in general if the arc length is increased and the arc voltage increases. But they say increase in arc length primarily increases, the voltage drop in the plasma region, because of the increased gap between the electrode and the work piece. While the shielding gas if change of the shielding gas affects the ionization potential of the gaseous medium between the electrode and work piece.

So, the gas is having the higher ionization potential they will be offering the higher arc voltage. Therefore the selection of the shielding gas affects the arc voltage. For example, instead of a the organ if the helium is used, which offers the higher ionization potential results in the higher arc voltage, under the identical welding conditions of the gap and the current. Similarly, if the low ionization potential elements are present in the electrode coating, which are providing easy release of the electrons for initiations and maintenance of the arc.

Then the presence of the free electrons in the large quantity and in the large number between the electrode and work piece decreases the impedance and facilitate the easy flow of the current, which intern decreases the arc voltage. So, the presence of the low ionization potential elements and presence under the use of the shielding gas means the type of the shielding gas and the arc length. Affects the arc voltage in total that is the difference, I means arc voltage between the electrode tip and the work piece. But the each factor has a specific affect on the cathode drop zone or the plasma zone or the anode drop zone.

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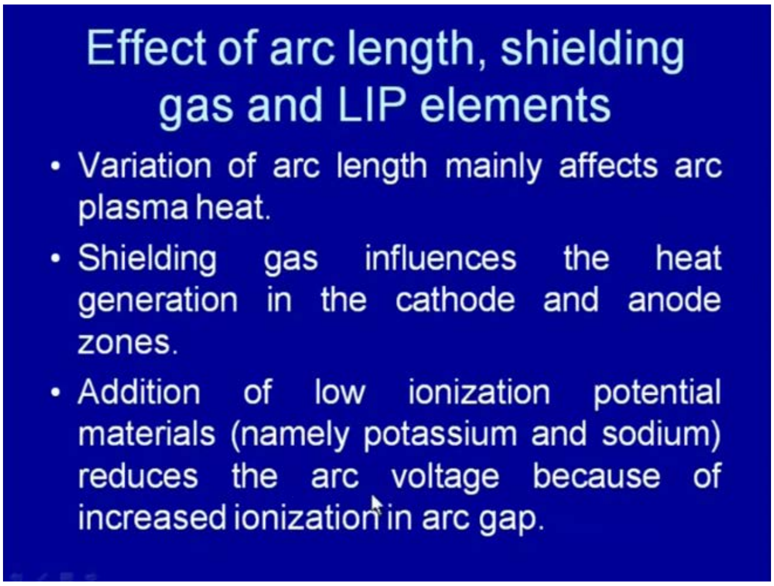

We see here, the affect of each of these factors on the variation in the voltage drops in a specific zone. The variation in arc length as I said mainly affects the arc voltage drop in the plasma region and accordingly heat generation in the plasma region is influenced. Basically, increase in arc length increases the distance between the electrode and the work piece and which directly increases the plasma zone size or the length of the plasma zone.

And which intern increases the resistance for the flow of current between the electrode and work piece and that is why the voltage drop in the plasma region increases which intern increases the heat being generated in the plasma zone. While the shielding gases, the selection of the shielding gas affect the heat generation in cathode and the anode drop zones. Because, it affects a directly these factor is directly affected by the ionization potential of a the shielding gas.

Those gases which offer higher the higher ionization potential they result in the higher anode or cathode drop zones means higher drop in the voltage in the cathode. The anode drop regions the addition of the low ionization potential elements like sodium and potassium in the electrode coatings or in the flux reduces the arc voltage, because these elements provide the easy release of the free electrons after the ionization in the arc gap. The presence of the large number of the charge particles in the arc gap decreases the resistance for the flow of the current and increases the electrical conductivity and which intern reduces the resistance for the flow of current. So, the arc voltage decreases when the low ionization potential elements are used with the electrode coatings. So, if we see here the arc voltage is affected by the various factors like arc length, shielding gas, low ionization potential, elements.

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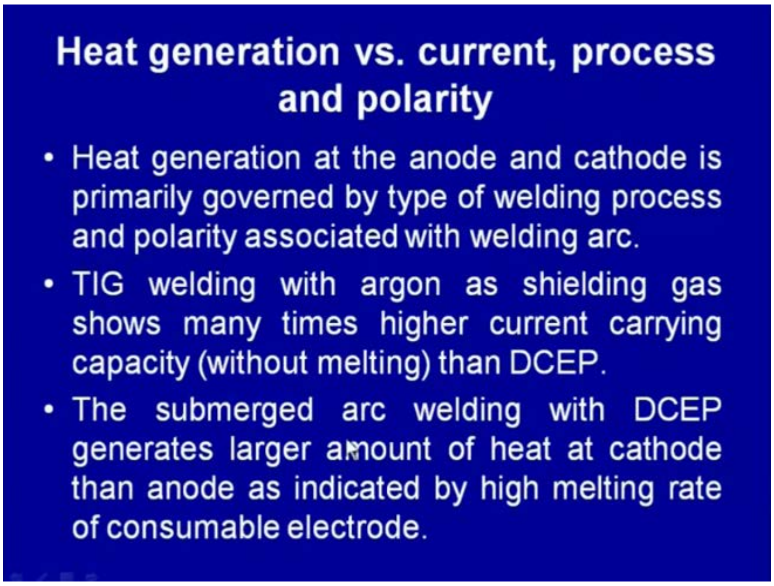

So, an according the heat generation in the arc gap will is affected, because arc voltage multiplied by the welding current directly gives the power of arc, which indicates the amount of heat being generated heat will be which will be generated in unit time. The generation of the heat and heat at the anode and the cathode is primarily governed by the welding processes and the polarity. If we see for given flow of the welding current the variation in anode voltage and the cathode voltage directly affects the heat generation in these zones.

But how to regulate the amount of heat being generated in the anode and in the cathode side that can be done easily by changing the polarity. With the change of polarity electrode can be electrode, which was cathode earlier can be made anode and the work piece which was earlier anode can be made cathode. So, the change of polarity affects which size which side will be the anode or cathode and accordingly heat generation will be regulated.

So, and the similarly, the amount of the welding current, which can be used that primarily depends up on the size of the electrode, which is being used and the type of welding process, in question. So, he for a regulating the heat or to control the amount of heat generation it is important to see that what kind of polarity can be used associated with the particular process. For example, the TIG welding when used with the argon as a shielding gas offers the higher current capacity, when the DCEN is used that is an electrode is made negative as compare to those situation, when the electrode is made the positive, because when electrode is made positive the tungsten led to tends to melt, because of the high heat generation in the electrode side.

So, that is why when is the TIG is used normally it works with the low welding current and the tungsten provides the easy release of the electrons. In these factors intern real tin the low arc voltage and the working with the low welding current results in the low heat input and that is why the TIG in general is not as the low heat welding process.

But the amount of heat generation generated in the anode side or in the cathode side that is either in the work piece side or in the electrode side can be easily regulated by using the proper polarity. With the TIG welding normally it is required to have the generation of the less heat in the electrode side. So, that the tungsten electrode does not melt and it remains, they have for long means it of so that it offers the longer life. That is why the with the tungsten inert gas welding is common to use the DCEP polarity.

So, that less heat is generated in the electrode side and more heat is generated the work piece side for melting of the faying surfaces. While in case of the submerged arc welding lot of heat is a is generated by use of the high current, but when the DCEP is used that is electrode is made positive. So, heat generation in the large amount the cathode side that is in the electrode side results in the higher melting rate and which intern result in the higher deposition rate by the submerged arc welding process.

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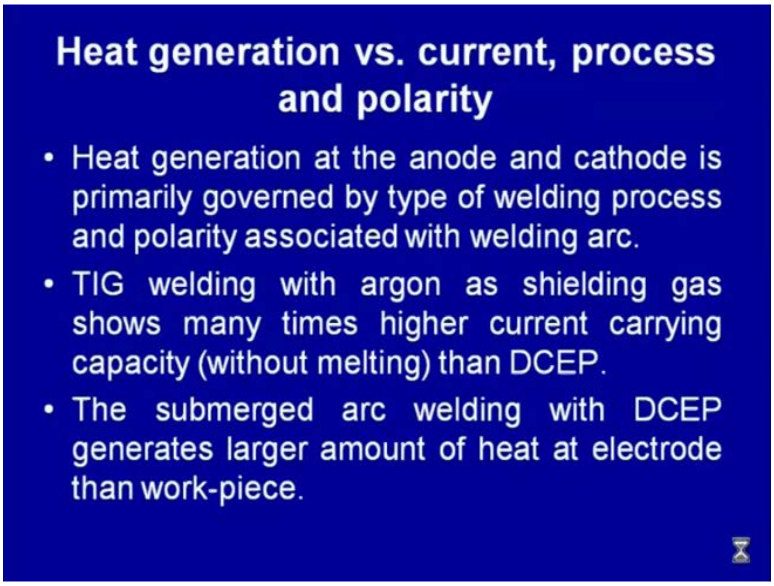

So, now if we see that in case of the submerged arc welding process, the application of the electrode positive polarity that is the DCEP generates the more amount of the heat in a electrode side and facilitates the high melting rate as compare to that of work piece, so the use of the DCEP results in the higher melting rate of the electrodes. So, the higher deposition it in higher welding speed if we see these two aspects that is the polarity and the welding process, the TIG works with the low welding current.

The use of the DCEP in results in low heat to have the longer life of the tungsten electrode, while in case of submerged arc welding to generate more amount of heat electrode is made positive, the use of the high welding current associated to the submerged arc welding results in the higher melting rate of the electrode and which in terns offers the higher deposition rate and the higher productivity of the submerged arc welding.

So, the heat generation is directly influence with the welding current the kind of polarity, which is being used and the welding current is dictated by the process which is being used. However, the apart from the current and the polarity the other factors has describe earlier the arc length, the presence of the low ionization potential elements and the shielding gets also affects the heat generation in the arc gap.

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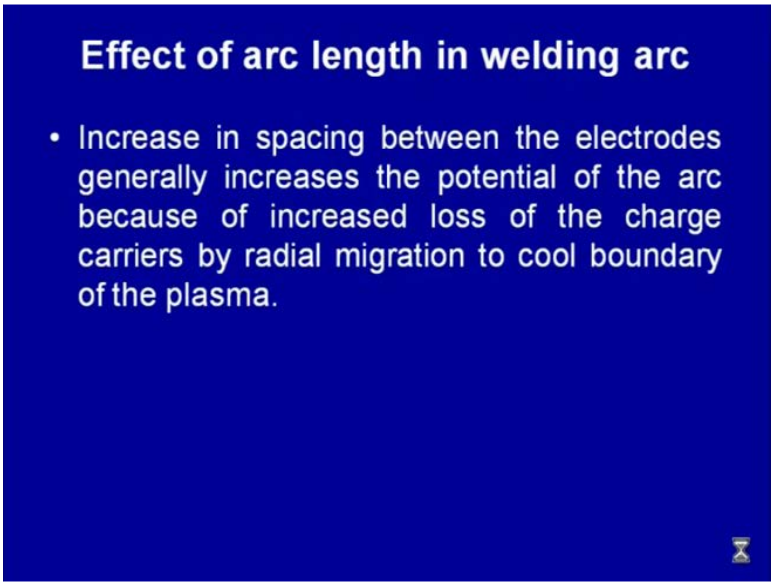

So, to look in to the greater detailed that how arc length affects the various aspects related with the arc welding, the if we see that increase in arc length. Basically, increases the potential of the arc because of the increased loss of the charge carrier by the radial migration to the cool surface of the plasma. So if we see here in this diagram that if we have one electrode and arc is established between the electrode and the work piece.

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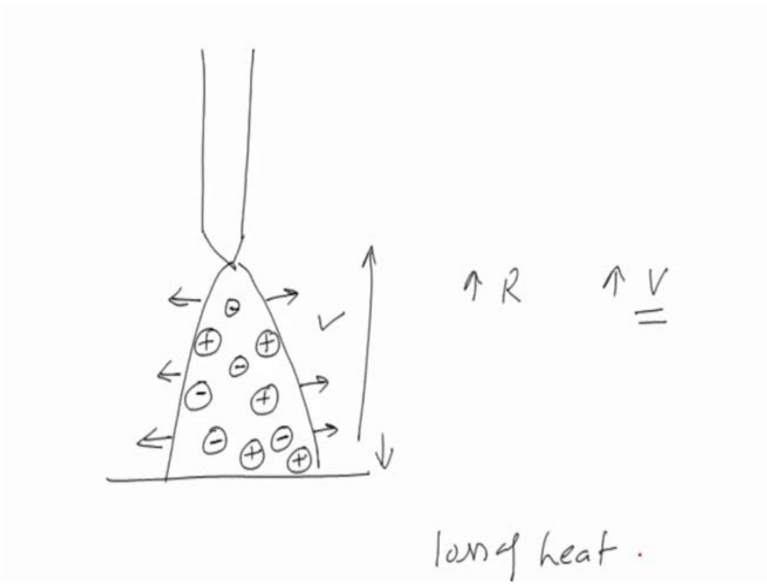

So, here to have the smooth and stable arc it is necessary that there is sufficient presence of the charge particle in the arc gap. More the numbers of the charge particles are present in the arc gap, better will be the conductivity and easier will be the flow of the electrons. This gap is increased then it will decrease the charge particle density and decrease in the charge particle density intern will increase the resistance to the flow of the current and increased in the resistance to the flow of current will increased the voltage.

So, and this the decrease in the density of the charged particles in the arc gap, mainly occurs due to the increased losses of these charged particles from the arc surface. This is one reason there the charged particles are lost to the surrounding from the arc surface. The second one is that the arc surface, because of the increased arc length the loss of heat from the arc surface increases with the increase of the arc length. This increase the lots of heat, increases the… decreases the temperature and decrease in temperature, decreases the number of charge particles, because of the reduced thermal decomposition possibilities, which contribute significantly in generation of the charge particles in the arc gap.

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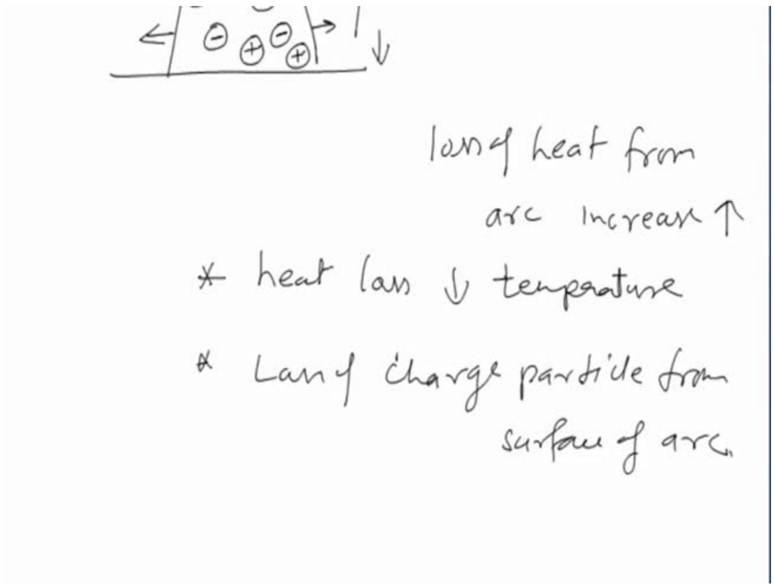

So, there are basically the two reasons one is the heat loss decreasing temperature this is one and the second one the loss of charged particles from the surface of arc, so because of the reduction in temperature of the arc zone due to the heat loss from the arc surface to the surrounding. The reduction in the number of charge particles in the arc zone with the increase of arc length, the charged particle density decreases. The decreasing the charged particle density in the arc gap increases the resistance to the flow of current and increased the resistance to the flow of current increases the arc voltage. So, this is one simple thing which happens with the increase of the arc voltage.

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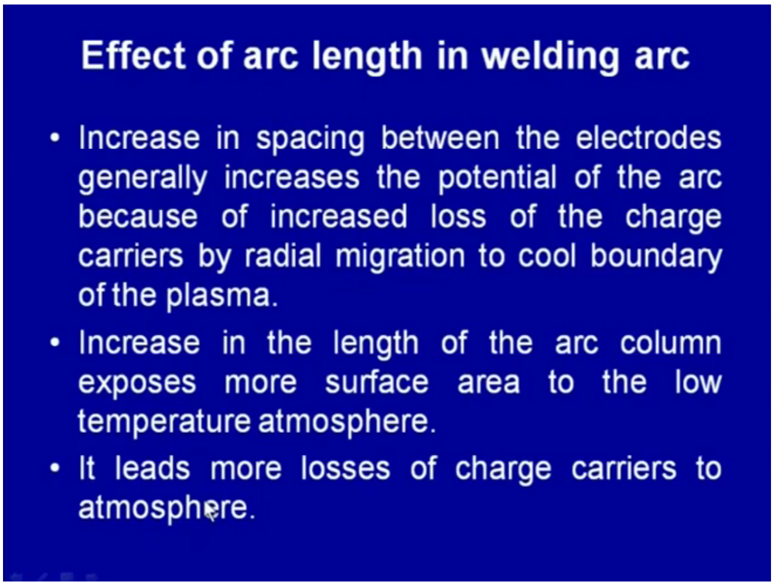

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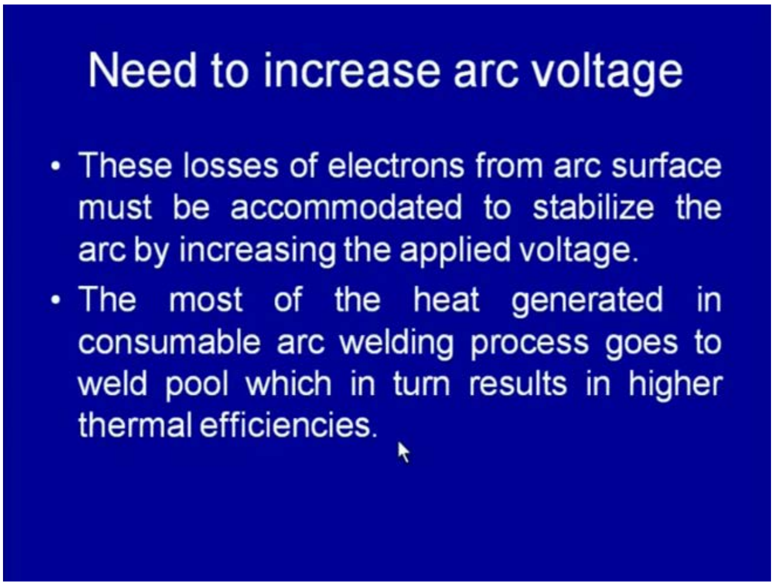

So, now we will see that increases in spacing between the electrodes and work piece generally increases the potential of the arc, because of the increased loss of the charge carriers by the radial migration to the cool boundary of the plasma. The increase in arc length of the arc column further exposes the more surface area to the low temperature atmosphere, which intern results in the lot of heat losses to the surrounding and it is leads to the loss of the charge carriers to the atmosphere.

These losses of the electrons from the arc surface must be accommodated to stabilize the arc by increasing the arc voltage. So, if arc voltage is not increased then it becomes difficult for to maintain the flow of current. So, automatically with the reduction in density of the charged particle due to the losses of the charged particles to the surroundings and reduction in temperature of the arc the arc voltage is increased automatically.

So, the most of the heat generated in case of the consumable arc welding process goes to the weld pool which intern results in the higher thermal efficiencies. This is the another aspect like when for a given welding current in the arc voltage is increased, this in case of the consumable arc welding processes results in the higher thermal efficiency. Because, thermal efficiency is about the heat being generated in the arc, what fraction of the heat is actually being used for melting of the faying surfaces and melting of the filler material?

So, that the fusion weld can be produced in case of the consumable arc welding process, the heat generated in the cathode side is also used for melting of the consumable electrodes and the heat generated in anode side is used for melting of the work piece. So, the heat generated in the both anode side and the cathode side is affectively used for melting the electrode as well as to the work piece. Both these heats are affectively used for melting purpose and for the development of the weld joint.

Well in case of the heat generated in the plasma is not affectively used even in case of the consumable arc welding processes. Therefore the thermal efficiency offered by the arc consumable arc welding processes generally becomes higher than the then that of the non consumable arc welding process. Now, we will see that the, with the change of the welding process, how the welding thermal efficiency is affected? The great difference in the thermal efficiency of the welding process or the arc efficiency of a, the welding process is a found in case of the consumable and a non consumable arc welding process.

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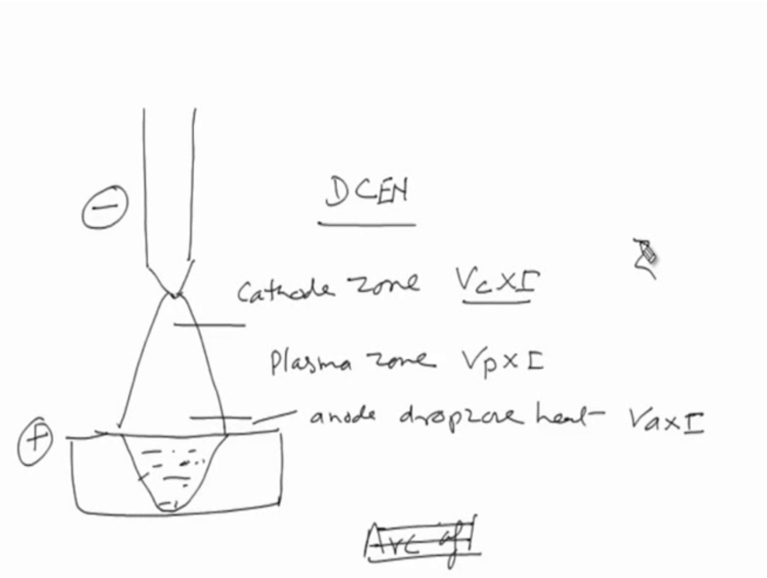

For to understand this, if we see here if there is a non consumable arc welding process, where electrode does not melt, then the arc is established between the electrode and work piece. Where work piece melts, because of the heat of the welding arc, but the electrode does not melt, because of non consumable nature. But the heat generated in the same way in three different zones that is the anode drop zone, heat in the plasma zone and heat in the cathode drop zone, when especially DCEN is used.

Means, electrodes in made negative and work piece is made positive. This situation the heat generated in the cathode drop zone is given by V c into I. So, this heat in non consumable arc welding process is not used. Similarly, the heat generated in the plasma drop zone given by V p is also not used for melting of the base material, heat generated in the anode drop zone given by V a in to the welding current. This is the only position of the heat which is effectively used for melting of the faying surfaces into develop the weld joint. So, if you see the heat generated by heat of the arc if we see here there is no scope for cutting.

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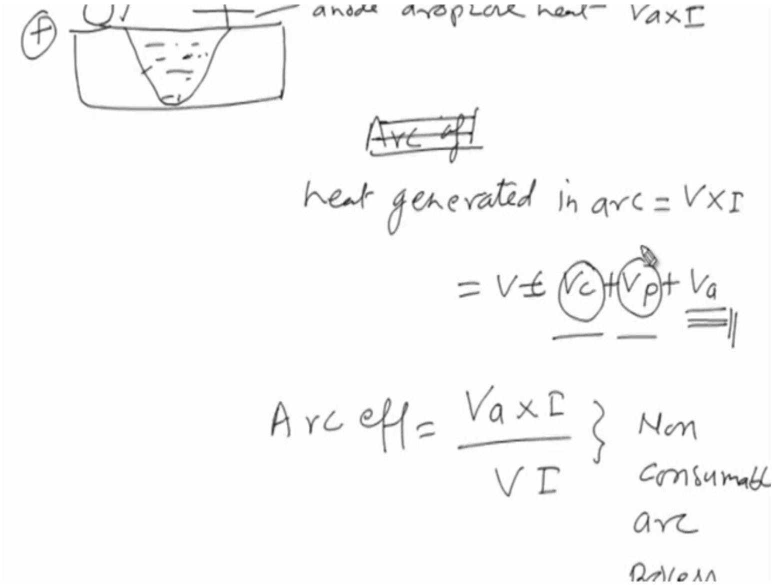

So, heat generated in arc is given by V into I, where V is the sum of V includes C c plus V p plus V a. So, only this portion of the heat, this portion of the heat is not used effectively in case of the non consumable arc welding process, while the heat generated due to the anode drop region, due to the voltage drop in anode drop zone is used in case of for melting of the base material.

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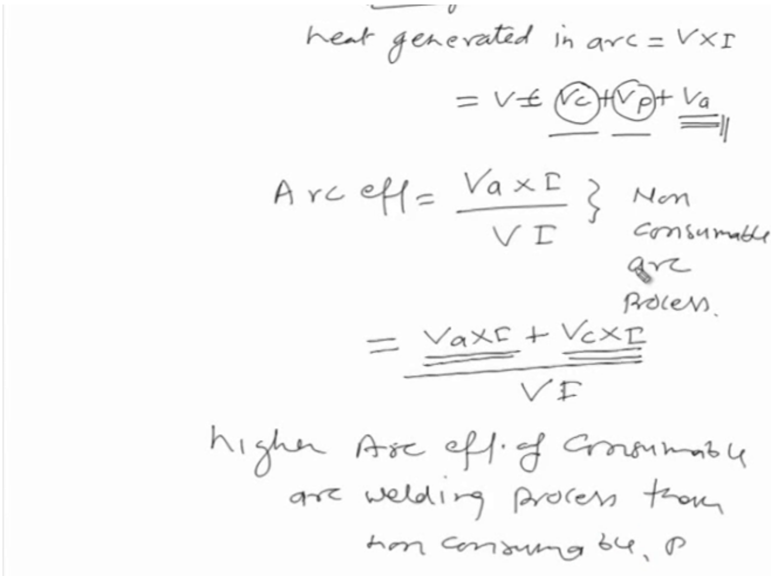

Well in case of the consumable arc welding process heat generated in the cathode drop zone, heat generated in the anode drop zone both are effectively used and that is why the arc efficiency, which is given from the ratio of the heat being used in the anode drop region divided by the heat generated in the welding arc.

This gives the arc efficiency for non consumable arc processes while the arc efficiency for consumable arc welding processes is given by V a into I plus V c into I divided by V i. Because, of this use of the heat generated in the cathode drop zone and the heat generated in anode drop zone, use of both these heats for melting of the faying surfaces. The electrode results in the higher arc efficiency of consumable arc welding processes then the non consumable processes.

This is the main reason behind the low thermal efficiency of the tungsten inert gas welding process, the plasma arc welding process, as compare to that of the shielding metal arc welding submerged arc welding process. So, we will see further that how the thermal efficiencies of the varies with the nature of the welding process.

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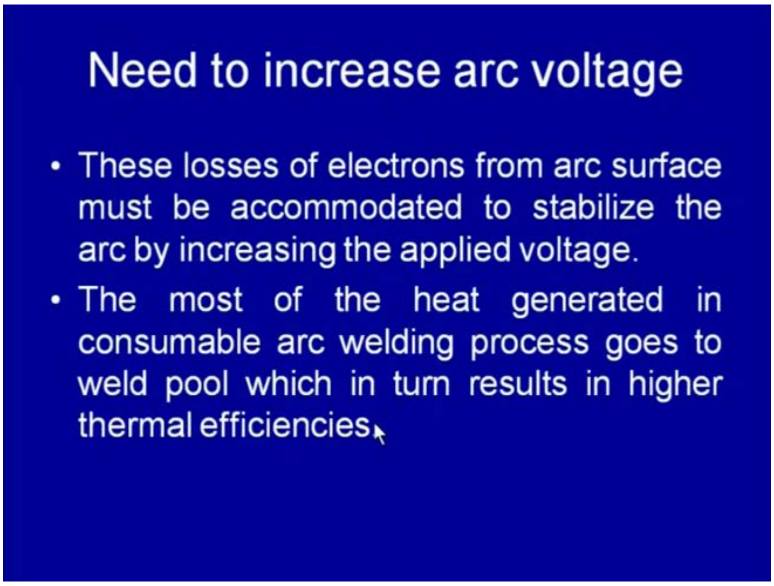

Here we can see the most of the heat generated in the consumable arc welding process goes to the weld pool, which intern results in the higher thermal efficiencies of the consumable arc welding process.

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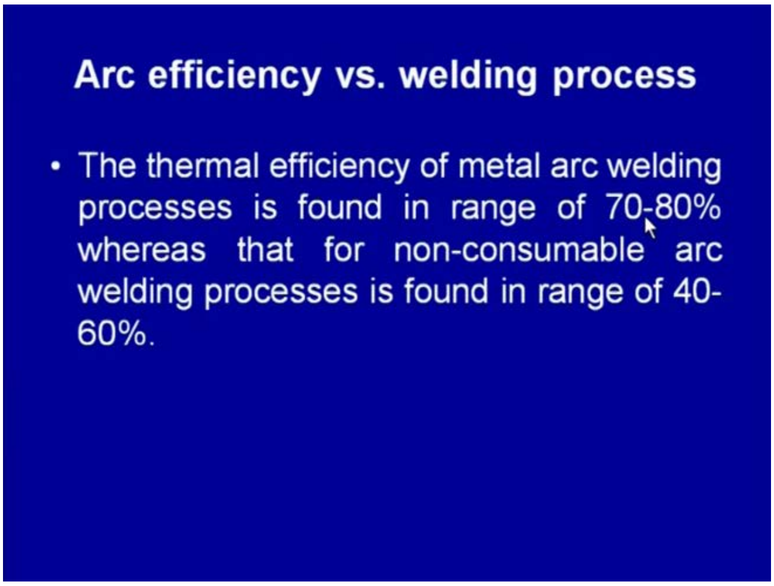

Similarly, the thermal efficiency of the metal arc welding process is also found higher than the non consumable arc welding process like tedium. In case of the non consumable arc welding process efficiency is found lower say 40 to 60 percent. While in case of the metal arc welding process and submerged arc welding process, thermal efficiency is found 70 to 80 percent and even higher than the 90 percent in case of the submerged arc welding process.

Because, most of the heat generated in the anode drop zone plasma region and cathode drop zone is a use for melting of the faying surfaces of the base material and for melting of the consumable electrode. So, now we will see that to apply the arc welding arc for effective melting of the faying surfaces and developed weld joint it is necessary that it is initiated in proper manner and stable arc is a maintained. So, that the continues and the uniform heat can be generated for development of the sound weld joint.

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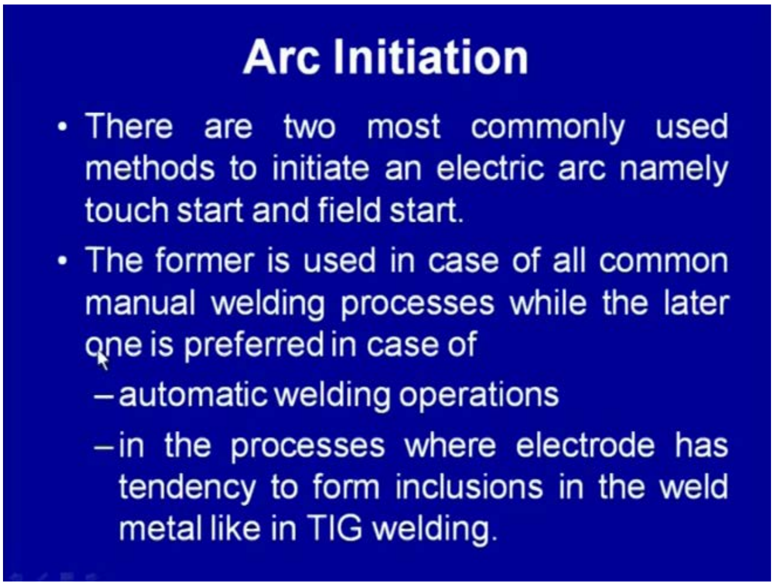

So, the various approaches are used for initiating the welding arc and the two are very commonly used for initiating the welding arc that is the touch start method and the field start method. The application areas of these two methods to initiate the welding arc are different, in touch start invariably electrode is brought in contact with the work piece to initiate the arc. While in case of the field start the high potential difference between the electrode and work piece is established. So, that electrons are released and the flow of current starts from the electrode to the work piece and the arc is initiated.

Maintenance of the arc is a different issue we will look into the greater details of the methods, which are used for initiating the welding arc. If we see the former method that is the touch is start method is used for all common manual welding processes, where electrode is brought in contact with the worked piece initiate the arc. While the later one that is the field start method is preferred under the conditions when either the manual operations are not there that is either the semiautomatic or automatic welding processes are used.

So, where the manual intervention or the manual interference is to be avoided, then the consumable arc welding, then the field start is used like in automatic welding processes. Also in the situations where we do not want to have the contact of the electrode with the work piece to avoid the any kind of contamination of the weld pool from the electrode material due to the melting. Like, it is commonly observed that when the tungsten electrode is brought in contact with the work piece, in case of the TIG welding process for melting of the small amount of the electrode tip.

Transfers tungsten particles as a enclosen in the weld joint and which acts as a site for the weakness to the weld joint. So, under those situations where you want to avoid the contact of the electrode with the work piece, under those situations also the field start method is used. It is common to use the field start method when the automatic welding operations are required to be performed. The manual operations are normally, for the manual operations normally touch start method is used, will see that how each the arc initiation method works in.

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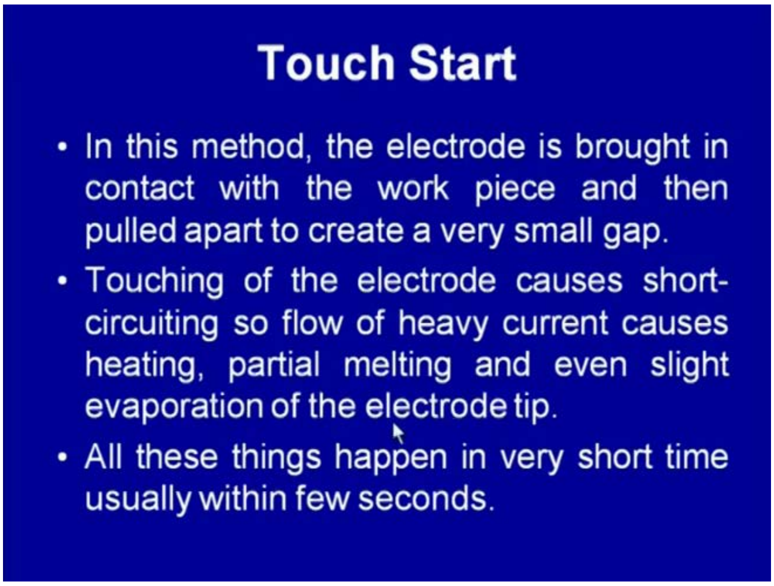

In case of the touch start electrode is brought in contact with the work piece and then it is immediately pilled apart. So, that very small gap is created between the electrode tip and the work piece. The gap is too big then again no arc will be initiated, this is a small gap maintenance of the small gap just after pulling apart from the work piece is important. Once the electrode is touched the and as soon as the electrode touches to the work piece, the flow of current starts from the electrode tip towards the work piece and under this condition short circuiting takes place.

Under the short circuiting conditions when electrode touches to the work piece, the flow of the heavy current is starts and the flow of heavy current results in excessive heating of the electrode tip and the base material surface. So, excessive hating of the electrode tip and the base material results in the partial melting first and even slight evaporation of the electrode tip material takes place. So, generation of the molten metal and even in may very small amount and even generation of the metal vapours at the electrode tip it is produced.

All this short circuiting followed by partial melting and even and even evaporation of the electrode tip material takes place very quickly in very short time, within fraction of a the second. Once this happens electrode tip is pulled apart and as soon as the gap is created the potential difference between the electrode tip and the work piece is established.

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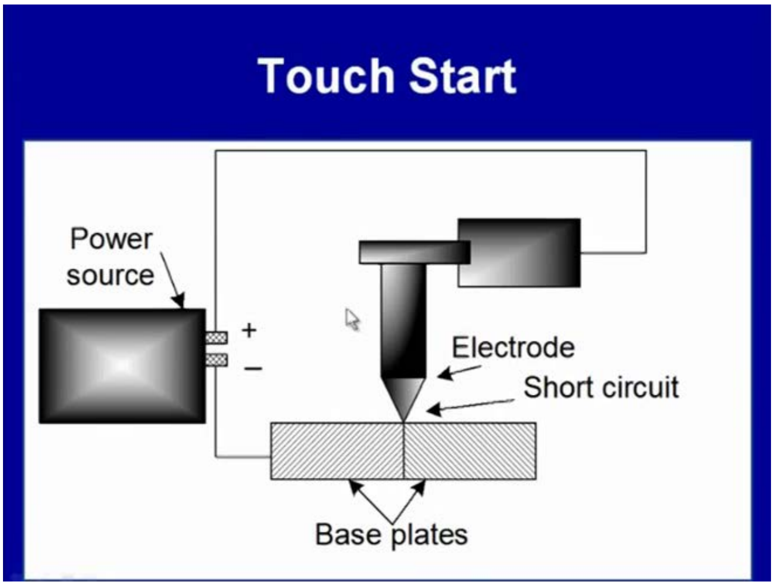

Once, the difference is established the because of the thermal ionization the ions are released by the thermal decomposition of the metal vapours and by heating of the electrode tip, so the presence of and these intern results in the presence of the small amount of the charged particles in the gap between the electrode tip, and the work piece. This circuit diagram basically, shows the that the two plates which are being welded and the electrode.

The electrode is connected to the power source and the work piece is also connected with the power source. When electrode is brought in contact with the work piece saw circuiting takes place flow of current through the electrode tip to the work piece clears in the heavy flow of current, which intern result in the partial melting. Melting of the electrode tip material and base material and even some evaporation also takes place.

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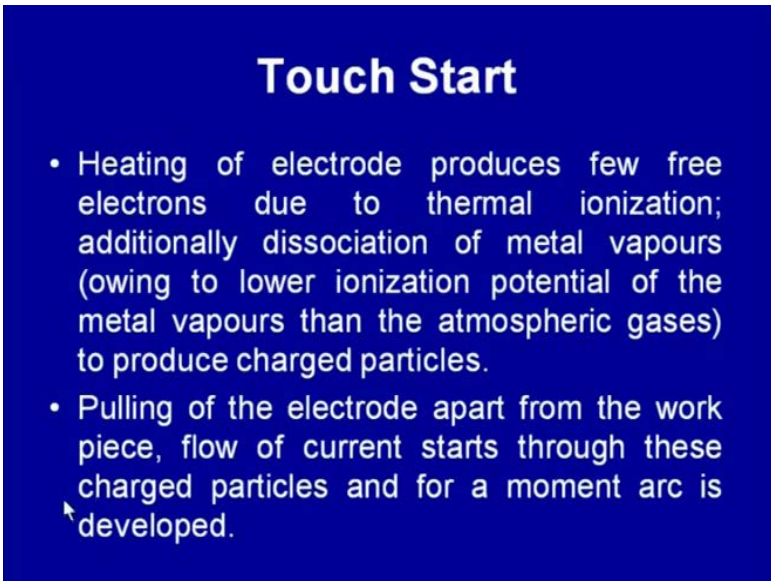

So, this heating and the evaporation results in the thermal ionization of the metal vapours and the electrode tip material. These two phenomena results in the develop production of the charge particle in the arc gap. Once the charge particles are produced and the potential difference established between the electrode and the work piece because of pulling a part of the electrode from the work piece results in the flow of current. Once the flow of current starts through the charge particles the, for a moment arc is developed, this arc will extinguish if the sufficient conditions are not match.

So, the maintenance of the arc is the another aspect, but just to initiate in this approach electrode is brought first in contact with the work piece and then it is pulled apart. This results this in terms results in the saw circuiting for a short while, which in turn develops the lot of heat. Development of heat causes thermal ionization as well as the dissociation of metal vapours to produce the charge particles. This ionization of the metal vapours becomes easier and the atmospheric gases, because of the low ionization potential of the metal vapours. So, the production of the small amount of the metal vapours in the gap between the electrode tip and the work piece also facilitates the easier release of the electrons in the touch start method.

This method if you schematically it has been shown when there was a heavy flow of current results in the generation of the metal vapours and thermal ionization. Thermal ionization of the electrode tip material and the thermal ionization form the metal vapours results in the charge particles in the gap between the electrode and the work piece. The establishment of the sufficient potential difference between the electrode and work piece results in the flow of current through the gap and the arc is initiated.

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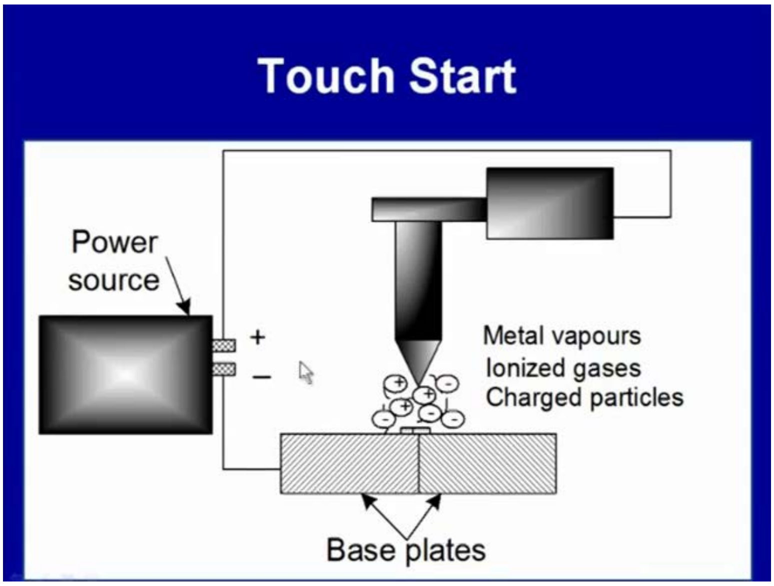

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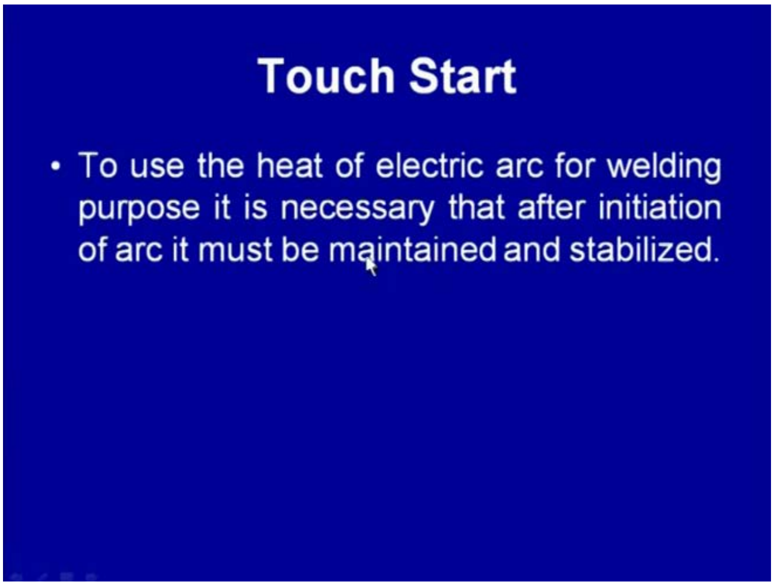

To use the heat of the arc for the welding purpose, it is necessary that whatever arc has been initiated has been developed and initiated it must be maintained. So, that is smooth and stable arc can produce the heat uniformly for melting of the faying surfaces and so has to develop the weld joint.

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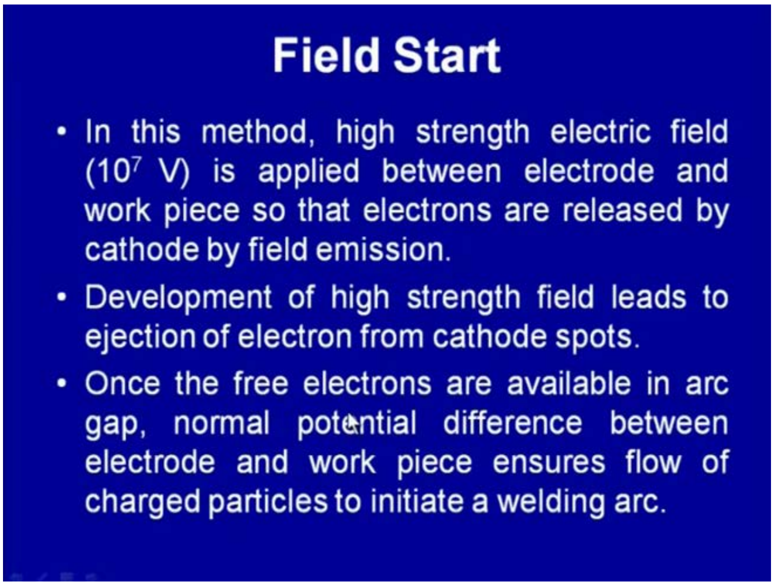

The field start is the another method which is mainly used for the automatic welding processes or those processes we where we want to avoid the direct contact between the electrode and the work piece. In this method basically, high strength electric field is applied between the electrode and the work piece. So, that the electrons are released from the electrode surface and these electrons provide the required in a number of charge particles between electrode and work piece to initiate the flow of the current.

The development of high strength field for ejection of the electrons from the cathode spots is important feature of this method. Once the free electrons are available in the arc gap the establishment of the normal potential difference between electrode and work piece causes the required flow of the current, through the charge particles to initiate the welding arc. In this case no contact between electrode and work piece is made to have which can lead to any of any kind of the contamination of the welding arc from the electrode material. That is why this method is effectively used for the automatic welding processes and where we want to avoid any kind of contact between the electrode and work piece.

Schematically in this diagram we can see high potential difference between electrode tip and the base material is established. So, that is the electrons can be released from the surfaces of electrode in the base material for initiating the arc. Once the electrons are released these are accelerated and moved, moving will result in the secondary emission as well as ionization of the gases present in the arc gap. So, this is how in case of the field start method or case established. So, in this presentation we have seen that the different electrical aspects related welding arc and they role in the generation of the heat.

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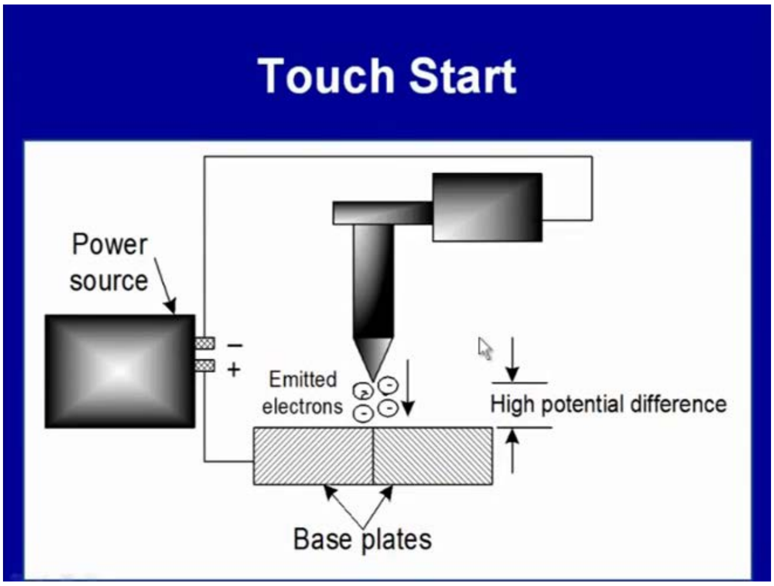

What the various factors that affects the heat generation in the different zones of the welding arc? How to regulate the heat generation in this specific zone, inert to get the higher deposition rate and the development of the sound weld joint? Apart from the electrical aspects of the welding arc we have a also seen that that the two methods of initiating the welding arc the touch starts and the field start. The basic principal of the touch start and the basic principal of the field start along with their other field of applications.

Now, in coming lectures, we will see the characteristics of the arc and their role in development of the sound weld joint, we will also see that how arc can be maintained. So, that heat can be uniformly generated for the consistence and smooth weld joint and we will also see that, what were the different types of the forces which are generated in the arc region? How do they affect the metal transfer in the weld region and a development of the sound weld joint?

So, thank you for your attention.