**Fundamental of Welding Science and Technology**
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**Lecture – 10**
# Physics of Welding

So, in previous class I have started the topics that is physics of welding there I have already discussed about the welding arc and how the welding arc initiated and how the welding arc sustain in between a gap, that I have already discussed in details. And, I have started little bit in welding arc structure related thing also.

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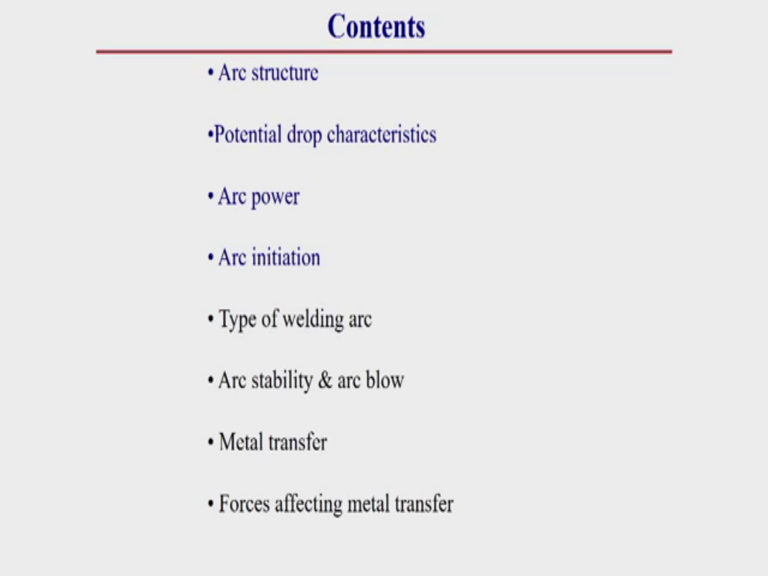


Today, I will first discuss in details about arc structure. Then, I will go for potential drop characteristics of arc; then how to what is arc power, in details I will discuss about arc power, there we will see how to find out a the optimum arc length how to find out the optimum arc power and at the end of this lecture I will discuss arc initiation.

So, first of all last class I have already discussed in arc structure there we have observed that due to the ionization and emission process in between the arc there developed a arc structure. This arc structure due to this emission and ionization of arc gap there generate different zones; zone in the sense that side this arc structure can be categorised arc structure zone can be divided into five different zones.

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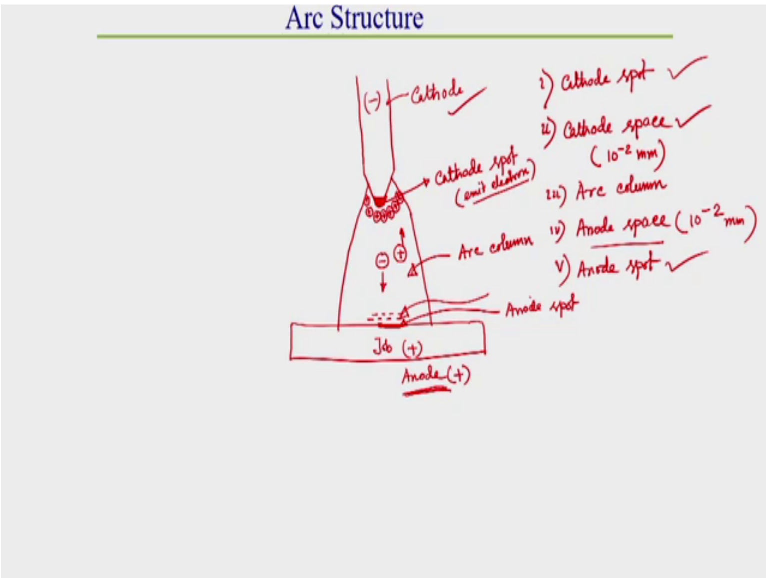


So, here what we observed last class, we have observed that this is a electrode this is a electrode and this is the work piece. So, generally electrode is cathode generally here let us electrode is cathode terminal cathode and work piece is this is job or work piece which is generally positive terminal; so this is generally called anode.

So, what we observed, last class we have discussed let this is a arc. So, then this arc what we observe last class a arc is generated a arc is generally generated between this gap between this gap. So, this is generally arc; so what we observe? So, here what happens here generally in inside this arc due to ionization and emission electron come out from this cathode surface and this electron so, what we will observe here electron is negative charge and there is positive charge ion is a positive charge.

So, what happens in a arc structure these positive charge is attracted by this cathode terminals and this negative charge is attracted by the negative terminal. So, generally due to this flow of this electron and ion and its concentration over the anode surface and cathode surface this arc a structure can be divided into five different zone. What is this five different zone? So, first zone is called cathode a spot zone; what is this five different zone? One is called cathode spot zone one is called cathode spot zone this is relatively very a small area on the cathode surface.

So, this cathode is spot zone is a very small area of this cathode surface which I am generally that this is a in a very small are this is called cathode spot cathode spot zone.

So, this is actually this is relatively very a small area on the cathode surface which generally help for emitting the electron. So, from here generally electron is emitted. So, from here generally electron is. So, emission is taken place from cathode spot zone.

Now, what happens the second zone is called cathode space zone. What is cathode space zone that also we should know. Cathode space zone means what happens as this cathode is negative zone that side this cathode is generally attracted this positive ion. A positive layer concentrate over a space within this cathode surface is there. So, a small zone we get where concentration of this positive ion is there; so this is a actually this cathode space.

This cathode space is a gaseous region which is adjacent to this cathode spot zone and what happens its thickness generally within a range of this cathode space thickness generally within a range of 10 to the 5 power minus 2 2 millimetre or we can say 0.01 millimetre within this generally a small gaseous zone is created; where generally a positive layer of ion concentrate in front of this cathode spot zone.

So, it is a gaseous space actually this region generally have positive a space charge. So, voltage drop here will be necessary because cathode space cathode space emit electron. Starting with the electron coming out from this cathode spot that electron generally have to penetrate penetrate this cathode space because this electron is attracted by this anode surface which is generally positive because as electron is negative that is why what happens? This is generally attracted by job or anode which is generally positive positive charge or positive terminal such of this positive terminal attracted this emitted electron towards the job.

So, what happens as this cathode surface is covered by a cathode space region which is generally positive charge here so, the voltage drop is necessary as the electron are to pulled from this region. So, here what happens whatever the electron is emitted from this cathode spot region that is have to pulled from this cathode space region and flow towards this anode surface. So, as the electron is getting some resistance over this region so, what happens here generally develops a sharp drop of voltage. So, here generally develop some voltage. So, here we get a sharp drop of voltage region; so this is generally called cathode space region.

The third zone is called arc column. It is the visible portion actually; arc column. It is the visible portion of the arc a structure. Here generally we get the arc plasma; arc plasma is generally the ionized gas. So, whatever the visible portion we are getting that is generally called this is the arc column. So, here you what happens ionization is occur in this zone generally ionization is occur. So, in this zone the voltage drop is not that much of sharp like cathode cathode space zone. Here generally voltage drop is not sharp in nature. So, here marginal voltage drop also is a occur so, due to this arc length.

Now, forth zone is called anode space zone, anode space zone. Anode space means here a this is also a gaseous zone where negative charges generally concentrate in on the top of this anode surface, this negative charge it is also a gaseous a space. This anode space is a gaseous space where generally concentration of negative charge that is electron is generally concentrated over the surface zone.

Now, here also a sharp drop off voltage is occur because here generally during emission whatever the electron develop from this anode surface this electron create a repulsion force with this anode space. Because here from during emission what happens from both the surface both cathode as well as anode due to this metallic these boiling generally electron is a start emitting.

So, what happens as the due to emission electron is a start emitting from this anode surface as well as cathode surface. So, whatever the electron is a start emitting from this anode surface this pull back to this anode surface itself. So, now whatever the electron coming out due to the ionized electron that electron and this emitted electron generally create some repulsion force over this anode space region.

Due to this repulsion force of this emitted electron from anode surface and the ionized electron from this arc column so, there generally create some sort of voltage drop in this anode space zone. So, generally in anode a space due to this repulsion force of emitted electron and ionize electron there create a sharp drop off voltage in this region.

Now, this last or fifth reason of this arc structure is called anode spot; anode spot zone. Generally, anode spot is the zone this is the anode spot zone anode spot zone where this electron absorb. So, it is also a base or surface over the generally anode surface where the electron is absorbed. It is this region generally little bit bigger than this cathode a spot region. So, this anode space also have a thickness within a range of 10 to the power minus 2 mm.

So, you due to this; that means, what we observe; that means, in case of a arc column they are generally create five different zone. So, as one is called cathode spot zone, another one is called cathode space zone, another one is called arc column zone, fourth one is anode space and fifth one is called anode spot zone. So, we have observed the due to the why this different zone is there? These different zone generally create due to this emitted electron and ionization; that means, ion and electron due to this that; that means, these different zone is created due to this emission as ion ionization of the arc column.

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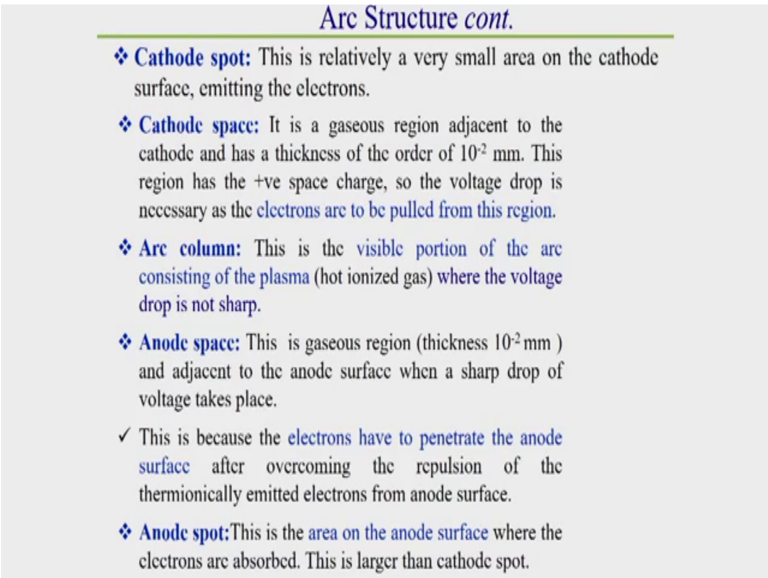


So, after that actually detail about this thing is discuss in next slides; that means, about this different zone; that means, what is cathode spot zone cathode space zone, I have already explain in details. What is arc column zone, in case of cathode space and cathode anode space zone there we observe sharp drop off voltage change, but in case of arc column zone which is voltage drop is not that much of high or sharp drop off voltage is not observe in case of arc column zone,.

So, this is the details about this different zone is describing in this slides.

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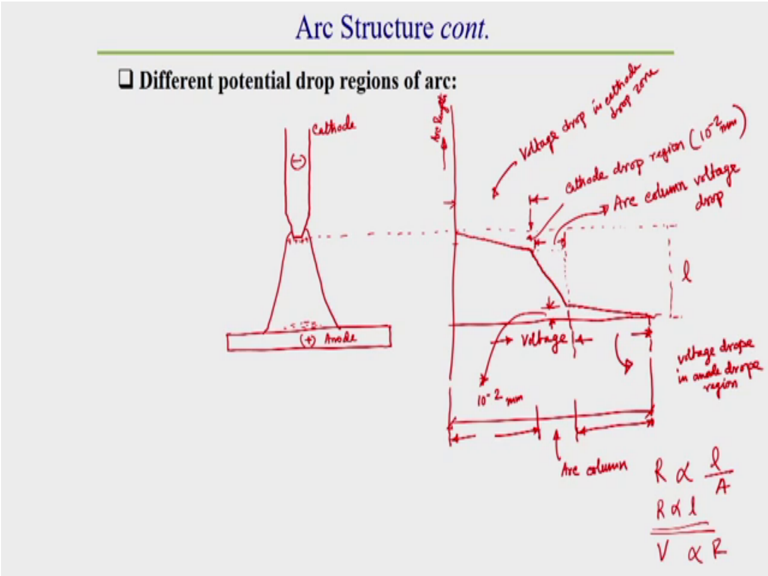


In next we will see due to this different zone how the voltage drop is occur in a arc structure. So, here we will say see what is the voltage drop region and what is the range of voltage generally drop voltage drop what is the range of voltage we observe in different zone that we will now discuss.

So, here we will see that; that means, in between this column in between this gap; that means, cathode and anode how much voltage drop is taken total how much voltage drop is taken place that I will explain here. And that voltage drop is actually is called welding voltage; that means, whatever the voltage is supplied from the power source that is not actually the welding voltage. The voltage drop which we observe in between this arc column that is generally called welding voltage.

Now, how this welding voltage is created and how it is distributed in arc column that now I will explain here. So, generally here also I will show you let us this is the electrode or cathode terminal and this is work piece or let us this is your cathode terminal this is your job or anode terminal here generally the arc is developed. Now, this arc how the voltage drop is look like that I will explain here in details.

So, this is generally the total arc length; this is generally total arc length l. Now, this axis this horizontal axis or abscissa represent the voltage drop per this is also generally called as a potential drop zone; this represent the voltage or potential and this axis represent the arc column; that means, this axis represent the arc column, arc length.

Now, generally how the voltage is taken place? So, here in cathode drop region this cathode drop region is occurred due to what? Due to cathode spot and cathode space, that what I have explained. This cathode drop region which has a thickness which is around cathode drop region which have a thickness around; just here I am just drawing cathode drop region here generally a sharp drop of voltage is taken place. This thickness of this cathode drop region generally this is called cathode drop region or you can say this is called generally cathode drop zone.

So, here how much voltage drop is taken place? So, here we observe this mass of voltage drop. So, how much voltage we got here? We got a voltage drop of around this much we have at sharp change of voltage drop is taken place in this zone. Then this is called here also a gaseous space is there negative terminal generally a negative terminal generally here positive a space is there that I have already explained in previous slide.

At the end also in arc column here let us this is my arc column where voltage drop is not sharp, after that generally we get another voltage drop zone. These voltage drop zone or these voltage drop is occur of these voltage drops generally occur because this axis I have already told this horizontal axis represent the voltage are potential. Or so, here generally this is called anode voltage drop or you can say anode space voltage drop this is called cathode space voltage drop or you can say this is called anode space voltage drop and or other way also we can say this is generally voltage drop in cathode drop zone.

This is generally voltage drop cathode drop zone. This is voltage drop this we can write in these way also voltage drop in anode drop region or we can say zone whatever it is anode drop region or anode drop zone. So, here whatever the voltage we observe this voltage drop; that means, from here to here ; this voltage drop is called arc column voltage drop. This voltage drop is called arc column voltage drop.

So, you see in case of arc column generally voltage drop is not that much of sharp whereas, in case of this cathode spot region and anode drop region, in case of cathode drop region here generally we get sharp change of voltage drop. This length of anode drop region this length of anode drop region is also within a range of this is also within a range of 10 to the power 2 milli metre. Whereas this cathode drop region whatever distance cathode drop region is also a range of around 10 to the power 2 millimetre.

Now, here one things we can observe from here, voltage drop if this means work piece material and cathode material is remains same; then this generally this voltage drop generally this in anode drop region and cathode drop region generally will be remain constant. So, generally voltage drop is generally here if this cathode material and anode material is constant then this voltage drop generally will be depends on only arc length. Here whatever the arc length if this arc length will be varying then our voltage drop will change, but cathode cathode drop and anode drop voltage drop generally will be remain constant if the material of cathode and anode will be same.

So, what we observe? So, in case of a welding arc the welding voltage is how much? So, welding voltage here generally we are getting. So, this much of voltage we are getting due to anode drop region; this much of voltage we are getting generally cathode drop region and this is due to this voltage drop we are getting due to the arc column. So, this total voltage; that means, this anode drop voltage, cathode drop voltage drop, that cathode drop voltage, anode drop voltage and arc column voltage this total voltage is called welding voltage.

So, how the voltage drop is taken place that you understand because I have explained what is the reason of this voltage drop that also I have explained. Because, this voltage drop in cathode drop region is occur because there is a create a resistance due to this positive ion concentration and emission of electron. Similarly, in anode drop region also how why this voltage drop is taken place? Because in anode drop region generally they are also create some electron due to this emission process and the electron attracted from the ionized gas generally what happens?

So, there generally create a repulsion. So, in this anode drop region due to this repulsion there create some resistance. So, as there create some resistance so, there will be some voltage drop. So, how the voltage is created in welding regions that you understand.

And, in arc column why this voltage is voltage is coming? This arc column is a voltage is coming we know that resistance is proportional to what we know resistance is proportional to l, length of the arc, that we know what we know l by cross sectional area l by A. So, what we observe that the resistance of arc length depends on length, l. So, if the arc length change then what happens resistance will change. If the resistance will change then when we know that voltage is depends on generally directly proportional to

R. Voltage is depends on R value that we know voltage is proportional to this resistance R that we know.

So, if the resistance increase then the voltage will increase definitely. So, in arc column why the voltage drop is taken place, why the voltage change is taken place because arc column have a length. So, there will be some voltage. So, how the total voltage is coming that we understand. So, how the total welding voltage is generated in case of welding arc that idea we get from this different voltage drop region, drop region characteristics plot from this voltage potential drop region of arc. So, different potential drop region of arc. So, from here we get the idea how the total welding voltage is generated in a arc.

Generally these voltage is responsible for generating the heat energy how the because the that also I will explain in subsequent; that means, how the arc power is generated. This also arc power is depends on this voltage as well what about the current is flowing on current also that I will explain in subsequent slide. So, this is the voltage drop characteristics in a arc column and how the voltage drop is taken place that also we understand.

So, from here we got the idea that this anode a space and cathode a space voltage drop zone or cathode voltage drop zone generally voltage drop is remain constants if the material is constant if the; that means, cathode material and anode material is constant. But, this so, voltage generally change where voltage generally change in arc length. How it is changed that I will explain in subsequent slide.

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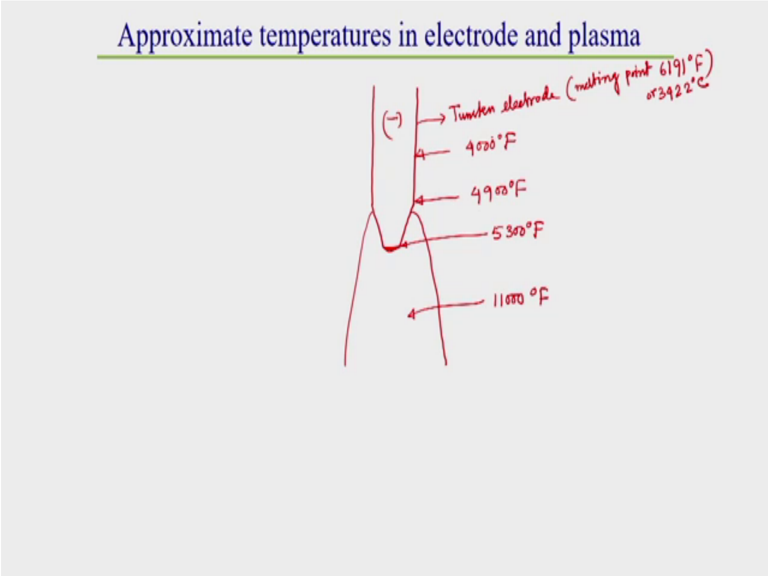


So, before going to this voltage drop change in arc column first of all here I will you should know actually what is the temperature distribution in a arc column as well as in electrode because that idea also here you should know. Because then also then only you will get some fairly good idea how much temperature generally generated in due to the due to a electric arc. Here just approximately I will just show you the how the temperature distribution in case of a GTAW welding process.

Let this is a let this is a tungsten electrode. So, this a let us tungsten electrode tungsten electrode. Now, generally how the temperature is varying over the range of one arc column as well as electrode that we should know. So, generally let this is the arc here I am just showing you that how the temperature is varying. In a arc column the temperature is within a range of 11000 degree Fahrenheit just approximately I am just telling if the temperature in a arc column is within a 11000 degree Fahrenheit then tip of this; that means, in cathode spot zone the temperature is coming around 5300 degree Fahrenheit.

It is generally little bit; that means, it just outside this arc outside this arc the temperature is rise around just approximately I am showing so that you can get a fill around 5000 degree centigrade if it is just little bit away from this arc region generally it has a temperature around 4000 degree Fahrenheit. So, this 11000 degree let us tungsten electrode, this tungsten have a melting 0.6191 degree Fahrenheit or in terms of centigrade this is generally 34 3422 degree centigrade or 3422 degree centigrade.

So, what idea we got generally how the temperature changes from electrode tip to away from the electrode tip, that idea you got. It is generally this electrode does not go beyond it is melting point in case of tungsten electrode because if it is go beyond it is melting point then it will boil melted and what happens this tungsten will we deposited with weld material. So, that will be a problem now that will be the defect of material, but here generally the temperature does not go beyond it is melting point if it is done then what happens this electrode will be melted; that means, electrode will be melted then that will create some defect in weld zone. So, we should keep our temperature within this range.

So, if a arc temperature is within a range of 11000 degree centigrade then how much degree eleventh degree Fahrenheit then we get a temperature in case of cathode spot within a range of around 5300 degree Fahrenheit which is around 1000 degree lesser than 1000 degree Fahrenheit lesser than the melting point of that tungsten electrode.

So, here why this is required because this is required because you can say you can feel that in a arc the temperature is 11000 degree centigrade then how much temperature rise in case of a tungsten electrode that also we should know na. So, what happens from here we get a very fairly good idea. Though here the temperature is rising in a arc around 11000 degree centigrade temperature, but in case of electrode tip it is temperature is coming around half of that. Why because it is conduct the heat; that means, in electrode as it is colder than that arc region.

So, what happens this tungsten generally immediately conduct and dissipate the heat. So, it cannot it generate it generally not allow the temperature to rise beyond its melting point temperature. Definitely it if the temperature will be higher in arc, then what happen and if it so, here we are not allowing actually what we can say here generally we are not allowing to raise the temperature beyond it is melting point of the electrode. Why because if it is allowed to go beyond it is melting point then what happens this electrode will melt and it will generally what happen deposited over the surface over the deposited with weld material. So, then that will create a problem such.

So, from here you get a fairly good idea; that means, though the temperature is coming around 11000 degree centigrade in a in a arc, but the temperature is coming around tip of the electrode is around half of that that is 5300 degree Fahrenheit temperature approximately here I am telling which is not goes beyond it is melting point. So, which is not gone beyond its melting point of electrode, ok. So, generally, why because, here generally heat immediately dissipated to this electrode, so, it is not allowed to rise the temperature,.

Now, we will go how to what is arc power? So, before going to arc power here one things we should know how the potential drop taken place due to change of current and voltage in a particular arc length that we will see first. After that we will go for finding out the arc power.

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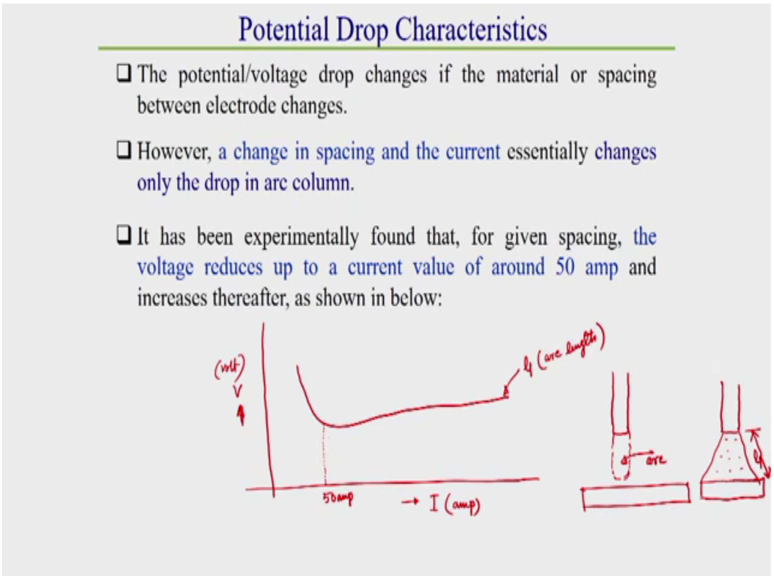


So, first of all we will see, so, potential drop characteristics here we will discuss for a particular arc length how the potential drop characteristics is look like that actually already I have discussed little bit, but here I will discuss in details. Generally, potential drop characteristics in a particular arc length in a voltage in a voltage current in a voltage current plot in a voltage current plot for a particular arc length how the voltage drop taken place if we change the current, that first of all we will see.

The potential or voltage drop changes if the material or a spacing between the electrodes changes. However, a change in spacing and the current essentially change only the drop in the column arc column. So, here one things we should keep it in mind this voltage drop change if we change the current that voltage drop is changed due to change of current in which region? In arc column only. This is not change in cathode cathode drop region or anode drop region. This is change in which region? This is changed in arc column region only; how it is changing that I will explain now.

Here what we can see for a particular arc length generally for a particular arc length generally voltage drop characteristics is look like this. Initially with increase of current for a this is a particular arc length l 1 this characteristic curve represent for a arc length for a arc length l 1. Generally, this particular characteristic curve represent for a particular arc length l 1 how the voltage drop change; that means, voltage changes if we increase the current.

So, what we observe from this curve it is around 50 degree 50 ampere current it is around 50 ampere current this voltage drop generally that voltage decreases. After that if we increase the current generally then for a particular arc length the voltage increases. So, why it is occur that you should know. So, generally till a particular; that means, till 50 ampere current so, whatever the arc is generated that arc shapes look like cylindrical shape; that means, that this arc length this is your electrode let this is arc. So, this arc generally look like cylindrical shape.

So, what happens, here as this arc is look like cylindrical shape, so, if we increase the current inside this cylindrical region the concentration of electron increase. So, concentration of electron increase means here generally resistance of the arc decrease. So, resistance of the arc decrease means voltage also will decrease because what we know from ohms law we know voltage is directly proportional to resistance. So, due to this concentration of more electron with increase of current generally resistance decreases. So, resistance decrease means voltage also will be decreased. So, till 50 ampere current this shape is generally remains almost cylindrical in nature.

So, but above 50 ampere generally if it is goes above 50 ampere current these arc once it is goes beyond 50 ampere current this generally this arc is not able to get it shape like cylindrical shape. So, what happens here this arc bulge out. So, what happens here generally the arc bulge out and what happens here generally current path increase, this arc generally bulge out. So, in this case so, in this case so, what happens here this concentration of electron increase as well as due to this bulge out of arc generally this bulge out of arc has current path we can say current path length increases.

So, as the current path length increases for a particular arc gap generally here what resistance increase that we know. That with a once resistance we will increase here again resistance increase means then voltage drop also we will increase. So, that is why you see after 50 ampere current this voltage drop is little bit increasing in nature; that means, you see from this curve itself we can observe this initially till 50 ampere current it is decreasing here after that generally it is increasing, but this increasing also marginal.

Why? this increasing of voltage is marginal because here generally two opposite phenomenon taken place; opposite phenomenon means here two phenomenon taken place. One is higher temperature if we observe here as well as a higher current carrying path we observe; higher current carrying path means higher resistance we observe here. So, due to this two effect, that means, high temperature and high resistance here generally here generally voltage drop is not that much very high. So, here generally voltage drop remain almost constant for a particular range of current.

So, this is the generally voltage drop characteristics. Why it is happened that we understand. This voltage drop till 50 ampere around 50 ampere current, here shape of the arc column is remains cylindrical in nature. Beyond this 50 ampere generally current generally this arc generally a start bulge out. So, what happens on arc starts bulging then what happens it is current carrying path length increase. So, current carrying path length increase means here generally and its cross sectional area also increase; that means, a electron density also decrease. So, what happens due to this here generally resistance increase.

So, due to this increase of resistance after 50 ampere due to bulging out of that arc generally what happens this voltage drop little bit increase, but that increment is not very high because what happens here generally due to here generally high temperature is there due to this high temperature and high current carrying path what happens here generally voltage drop cannot increase high. So, here voltage drop remain almost constant for a particular range of current.

So, we got this idea how the voltage drop characteristic is taken place due to this change of arc length. Generally, characteristic for a particular arc length we got how it is look like now we will see if we increase the voltage drop if we increase the arc length then what will be the voltage drop that also we will see.

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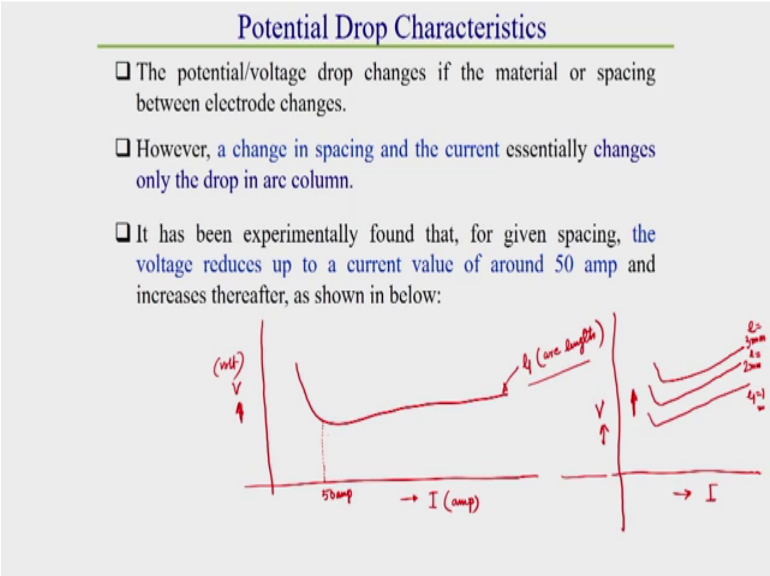


Here what we see for different arc length if the arc length increase then the voltage drop increase that we know; that means, arc length increase means gap increase gap increase means resistance increase because resistance is proportional to length. So, length increase voltage is also proportional to arc. So, what happens if the length increase arc gap increase then generally what happens voltage drop also increase in arc column.

So, how it is look like; so, for different voltage for different arc length how the voltage drop characteristics is look like that I am showing. Let us this is for l 1 is equal to let us 1 mm arc length, this is for 2 mm, then this is for 3 mm. So, what happens arc length this is for different arc length actually I am showing. So, for different arc length how the voltage drop is generally taken place that I am showing here. Just let us what happens if the arc length increase then generally this voltage drop voltage voltage in the arc column increase from this we can observe.

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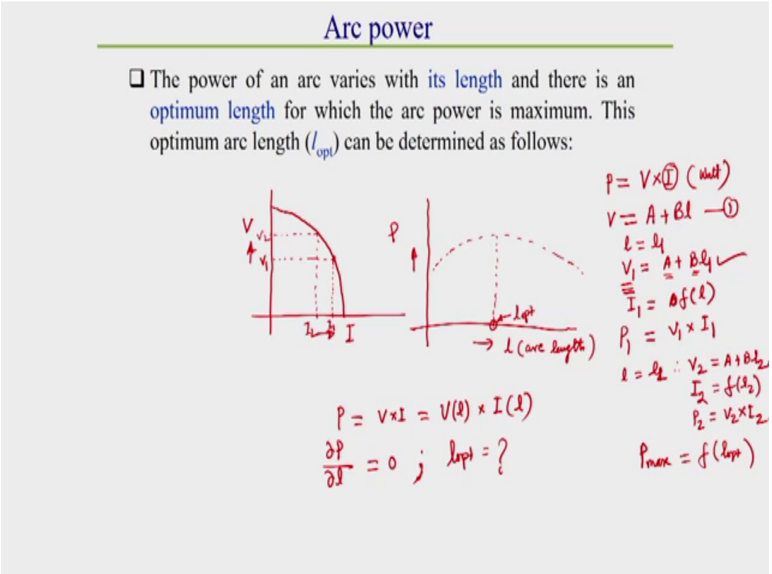


Now, we will go for how to find out the arc power; that means, so, arc power what is arc power arc power means we know that arc power is equal to voltage drop in arc column whatever that total voltage drop or welding that is that arc column whatever the total voltage drop is taken place or the that is called the welding voltage. So, arc power is equal to voltage drop in arc into supply of current from the power source; that means, this is called welding current.

So, power is equal to generally voltage into current that we know that generally power is equal to arc power is equal to this is in generally watt, that we know. If voltage is in volt and I is in current ampere then this unit is generally power unit is watt, that we know.

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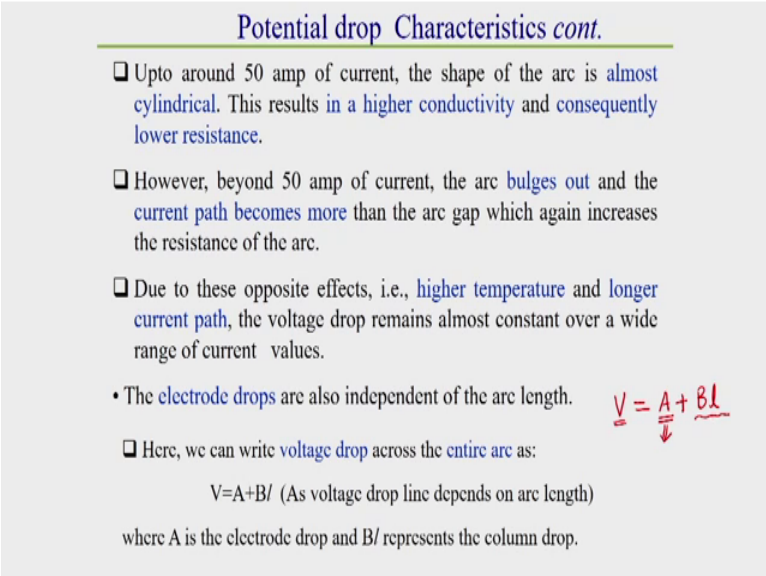


Now, so, here before that; so, here one things we should know voltage drop characteristic for a particular arc length we can write; that means, welding voltage we can write as A plus B into l. What is A? A represent whatever the voltage drop taken place in cathode drop region and anode drop region. So, this is not depends on arc length, but this Bl is voltage drop in arc gap; that means, gap between two electrode, gap between gap between electrode and workpiece.

So, as it is depends on l so, that is why it is represent in Bl. So, it is it is a function of l, but this electrode; that means, cathode drop and anode drop region as it is not depends on l or l it is remain constant if the material is constant that is we that is why we kept it as a constant value. So, voltage so, that means, total voltage drop in arc column we can represent as A plus Bl. So, A A is constant and Bl is depends on length of the arc; that means, gap between electrode and work piece. By this equation so, we got voltage welding voltage is equal to we get as a plus Bl. So, from previous discussion we got that idea.

So, now, how to find out this I; welding power how to find out this arc I? Generally, this I is find out from the working point how the working point is find out for a particular arc length let us for a particular arc length l is equal to l 1 we can easily get V 1; that means, V 1 will be a plus Bl 1 because a and B is constant it depends on only arc length. So, V 1 we can easily calculate.

Now, from this constant voltage or constant current power source characteristic are what we know always you keep it mind vertical line represent voltage and horizontal line represent current. So, there we observe that for generally a power source characteristic curves, how it is look like? It is look like this for a constant current power source characteristic.

Now, what is working point? For a particular arc length generally working point actually I have already explained for a particular arc length where this arc length characteristic curves and this power source characteristics curve crossing that point is called working point.

So, so, from first of all, how to calculate the power? First of all, for a particular arc length we have to find out the V 1. So, corresponding to this V 1 let this is V 1 let this is V 1; corresponding to this V 1 we have to find out I 1 value. So, we can easily find out I 1 value. Here V 1 is a function of l similarly I 1 also will be a function of I 1 also will be a function of l. So, what happens? So, we can easily find out what is P 1 value? P 1 we can easily find out; P 1 will be your generally P 1 will be your V 1 into I 1, ok. So, this way we can easily find out.

Similarly, for another l is equal to l 2; l 2 by using this equation one we can get V is equal to A plus Bl 2, ok. So, whatever the V 2 we got. So, based on this V 2 let this is this is my V 2. So, based on this V 2 from the power source characteristic curve we can get I 2. So, we can get I 2 from this power source character I I 2. So, I 2 is also a function of l 2. So, we get P 2 value. What will be the P 2 will be? P 2 into I 2. So, in this way generally for different different arc length we can get different different arc power.

So, if we plot this arc length versus arc power let this is my arc length arc length and let this is my arc power P, then we will get a curve which is look like this. It does not means that if we increase the length then power will increase, not like that we will observe that this characteristic curves is look like this; that means, first it can increase after certain arc length what happen it can decrease. So, what happens for a particular arc length generally where we will get the maximum power that arc length is called optimum arc length; so here we will get a optimum arc length.

So, how to find out the optimum arc length? That we I get the idea; that means, first of all by using this voltage drop equation we have to find the voltage, that voltage we have to generally put in power source characteristic curve from this power source characteristic curve we have to find out the I 1 I value. So, multiplication of V and I will give the power. So, what happen based on this power if we just plot power versus arc length then there we observe that for a particular arc length we will get maximum power that maximum power generally corresponding to which arc length we are getting that arc length is called optimum arc length. So, generally we should use optimum arc length. So, that we can get a optimum power over there, this is one way.

So, by finding out the power for different arc length and plot in a curve from there we can find out the arc length. Another way also we can do. Like here generally here power is a function of V into I, where V is a function l as well as I is a function of l. So, what happens if we just derivative this with respect to l and make it equal to 0, from here also we can get l optimum value this way also we can. So, this is the a step how to find out the optimum arc power so, that we can get optimum arc length; so that we can use this optimum arc length during our actual welding process.

So, we understand how to find out the optimum arc length and this is generally the procedure for finding of the optimum arc length.

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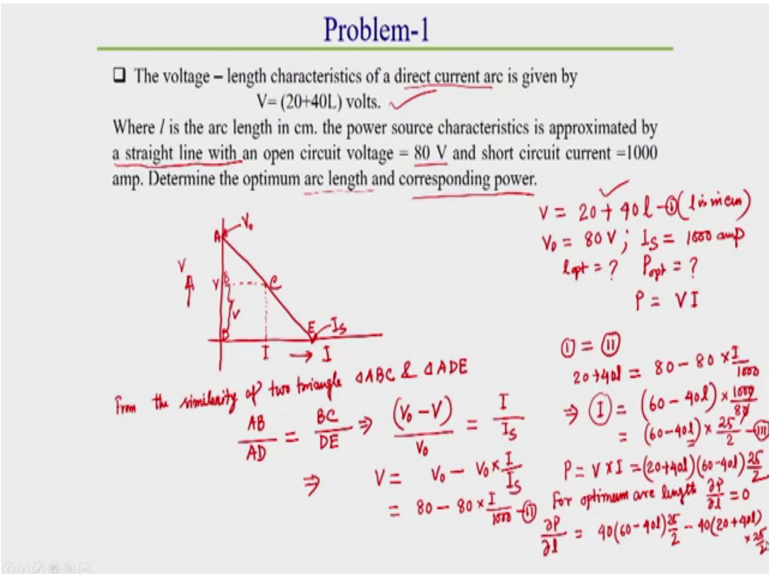


Now, we will solve one – two problem one this optimum arc length then our idea will be very clear. So, here one problem just first of all I will solve after that generally one – two problem if I will solve then it will be very clear. So, one problem let us this is a problem 1, for finding out the optimum power and optimum arc length.

Let us the problem is look like here; the voltage arc length characteristics of a direct current here is a DC current arc is given by V equal to 20 plus. So, here V is equal to given as A plus Bl. So, A is 20, here B is 40 and l is generally length of the arc, ok. See this here what is the thing given l is in centimetre this is given, l is in centimetre here it is given.

Now, the power source characteristics is approximated by a straight line. This is a very interesting terms here it is used. Generally, power source characteristic what we observe generally in case of constant current it is curve in nature in, but here it is consider this power source characteristic curve means there is a current and voltage; that means, ordinate is voltage and abscissa is current.

So, it it is a a straight line characteristic; instead of curve characteristics here what it is consider? Here instead of curve here it is consider as a straight line characteristics. Here we know this thing this this is called generally open circuit voltage V o. We are representing this in V o open circuit voltage. This open circuit voltage is given as 80 volt and this is called generally short circuit current I s which is generally given as it is V o is given as here V o is given as 80 volt and I s is given as of short circuit current is given as 1000 ampere 1000 ampere ok; this is given.

So, by this information I have to find out what what is the optimum arc length and what is the optimum power; that means, where here what of the things I have to find what is the optimum arc length and what is the P optimum these two things I have to find out. How to find out this thing? So, we know this we have given this voltage drop equation which is a function of l, now we have to find out we know that power is what power is generally is equal to V into I.

So, first of all V is a function of l we got, now I is I also we have to find out which will be a function of l. How we can find out? For that let us for a particular voltage by using this power source characteristics we can get I. Let this I am representing in terms of that this is your A point, this is your B point and this is C point, this is D point and this is E point, this point is E point.

Now, from similarity of two triangle, so, what happens here; from the similarity of two triangle, what is this two triangle? Triangle ABC and triangle ADE what we got what we can write from the similarity of two triangle we can write as AB by AD because this two triangle is similar to each other is equal to we can as BC by DE, correct. So, generally here everything AB is generally this AB is equal to what we can write V 0 minus V, correct? because from here to here from here to here this is V and total is V 0 open circuit voltage is V 0.

So, we can write V minus V 0 and AD we can write as AD is equal to AD generally is your open circuit voltage. AD because this AD means this is A, this is D,. So, this I am just writing here then it will be more clear. So, so generally so, AD equal to this. So, what is BC? BC means from here we can easily see, BC means I and what is DE? DE is your I s.

So, from here generally we can easily get what is I value? So, I is equal to we can get as. So, so, from here first of we will see what is V directly I am putting this thing. So, V we can write as V is equal to V is equal to we can write as V 0 minus V 0 minus V 0 into I by I s, correct from this equation we can get. So, this equal to V 0 is equal to given as 80 minus this is also 80 into I by 1000. So, so, from this power characteristics also we get is V and from this arc length characteristics also we get the V.

So, now, this is let us equation 1, and let this is equation 2. So, from this equation 1 and 2 so, 1 and if we equate this equation 1 and equation 2 what we will get we will get I in terms of l; how it is, that I am showing. So, what we can write? So, equating equation 1 equal to equation 2 what we get 20 plus 40l will be is equal to your 80 minus 80 into I by 1000,. So, what we got? So, from here I we can get as so, I will be your just 60 minus 40l into 60 minus 40 into 1000 divided by 80, correct.

So, I we got as like this. So, I we got as like this; so, this 80 – 80 cancel this will be cancel out. So, this we can write as 60 minus 40l into what will be the so, if we just cut it 2, 25 20 25,. So, I we got it is like this. So, what will be the power now? So, here we know so, we got this let this equation 3. So, equation number 3 we got.

Now, what will be the power? We know power is equal to generally. So, here what we got; that means, this I is a function of l as well as well as this V is also a function of l, this two things we got correct. So, what will be power here now? Power will be generally

V into I. So, power will be what? V into I. So, this power so, arc power what we can write? V is equal to generally 20 plus 40l and current is how much 60 minus 40l into 25 by 2.

Now, for optimum arc length arc length, what we have to do? We have to do del P by del l and we have to make we have to make it equal to make it equal to 0. So, once we do this things what we will get we will get del P by del l of this equation of that equation, what we will get? We will get what you see we can easily see 40 into 60 minus 40l 25 by 2 minus 40 into 20 plus 40 l into 25 by 2, correct.

And, if we make it equal to 0, if we just; so, I am just erasing this portion erasing this portion and put the things there. So, now, so, del P by del x we got how we got this thing del P by del x; that means, first of all derivative with of this portion this portion and rest of the part will be there and next case derivation of this portion and rest of the part will be there, ok. So, it will be like this.

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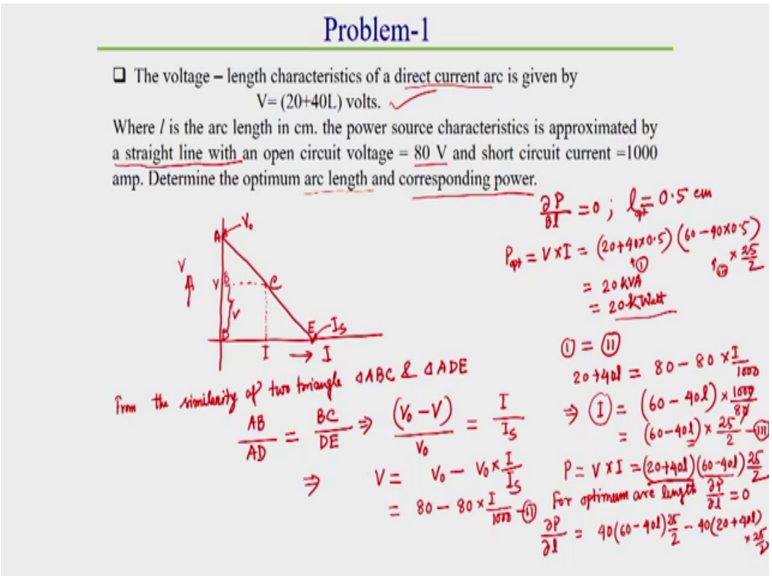


So, if we make del P by del l is equal to 0 then we will get l is equal to how much? 0.5 just you just do the calculation you will get the thing from here itself. Here l is in terms of given here. Here l unit is centimetre. So, here l will be centimetre. So, we got this l value this is generally what? This is generally l optimum we can say this is l optimum value here. What will be the power optimum? So, power optimum optimum power will be your corresponding to this l, if we just multiple this thing; that means, V into I corresponding to this l is equal to 0.5 centimetre if we will do then we will get the optimum power.

So, optimum power power will be how much V into I, V means 20 plus 40 into l means your 0.5 and I optimum or what will be the optimum current optimum current will be from equation 360 minus 40 into 0.5 into what? into 25 by 25 by 2 which is generally 20 kilo volt ampere or you can say this is equal to 20 kilowatt.

So, this is one problem which shows how to calculate the optimum arc length and optimum power of a of a of a of a particular welding operation for a of a particular welding operation that it is showing that. Next class actually also so, I will solve one – two problem on this types of arc power characteristics and we will show generally how to find out the optimum power as well as how to follow it is optimum power is given to us, then how to how to find out these open circuit voltage, how to find out the open circuit voltage or how to find out the short circuit current.

So, that we see and if we have this types of idea with us if we have this types of idea that is how to find out the optimum arc length, then also we can characterize or we can design a welding power source as per our requirement. So, next class I will discuss in details about arc power calculation and arc power related problem. After that we will go for other topics one physics of welding.