Fundamental of Welding Science and Technology
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Lecture - 09
Physics of Welding

In last lecture, I have completed the different power source used in welding technology and their characteristics in details. Today, I will start a new topic that is Physics of Welding.

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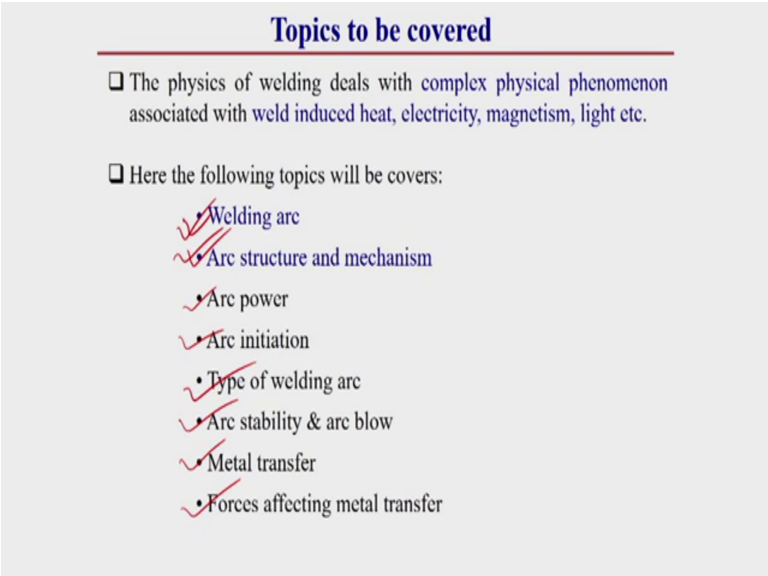

I will cover the following topics that is the actually, first of all we should know what is physics of welding? Generally, physics of welding deal with a very complex physical phenomena which associated with weld induced heat, electricity, magnetism, light etcetera.

So, in physics of welding, we will fill the topics of different science subject. Especially, the physics oriented subject and its topics like here we will fill the test of physics of heat, physics of electricity, physics of magnetism, physics of light source. So, all this physics generally required and it is involved in physics of welding, welding process (Refer Time: 01:32) physics of welding process. Here, the following topics actually I will cover that is first of all, I will cover the following topic that is; welding arc, its structure, welding arc structure and its mechanism, then arc power, then arc initiation, how the arc is initiated, because generally physics of welding lies on arc actually.

So, what happens once we know the arc characteristics in details, then we will get a very good fundamental idea on physics of welding that is why here you see most of the topics is in arc and it is heat source related things. So, here generally, I will cover type of welding arc, then arc stability and arc blow then metal transfer and force affecting the metal transfer. So, in first lecture I will cover these first two topics that is welding arc, arc structure and its mechanism in details. In this first lecture I will cover these two topics in detail that is welding arc and arc structure and its mechanism.

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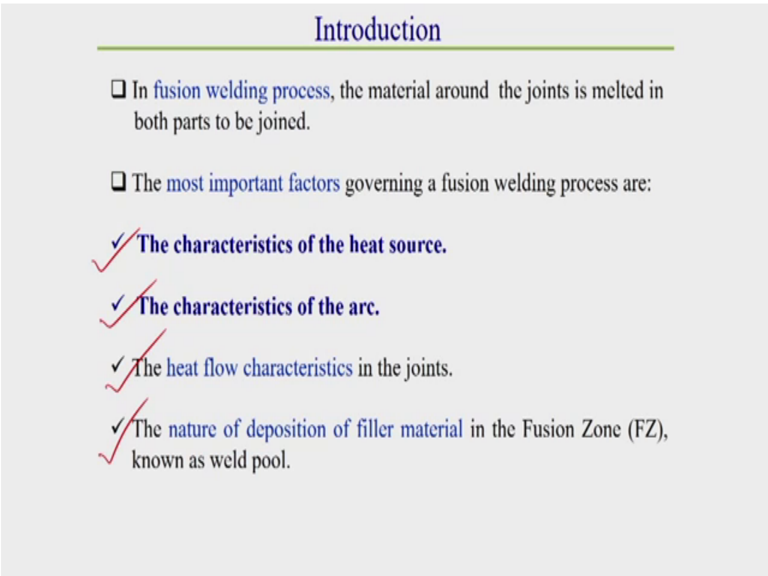

We know that in fusion welding process the material around the joint is melted in both the parts to be joined. That is why here, the most important part governing the fusion welding process are the following thing; that means, the most important factor is governing the fusion welding process are; first one is characteristics of heat source, second one is characteristics of arc, third one is heat flow characteristics in the joint, the last factor is the nature of deposition of filler material in the fusion zone.

So, generally we should know that what is the characteristics of arc in details, then characteristics of power source in details, the heat flow characteristics in the joint and the natural of deposition also. If we know this above factor in details, then we will get a very good idea on physics of welding techniques.

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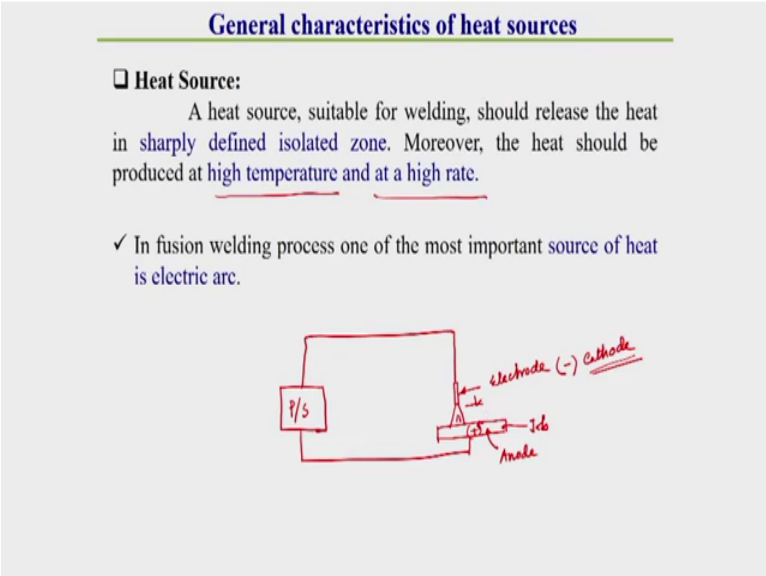

So, first of all one by one we will discuss about all these above topics and its characteristics in details. So, here first of all we should know what is heat source in welding technology? So, especially here we will cover the physics of welding of traditional welding techniques especially, those welding techniques which is widely applied in industry especially the electric arc welding techniques we say widely used in (Refer Time: 04:03) that related thing generally here I will cover.

So, the so, here first of all we should know what is heat source? Generally, the source of it can be different. I have already discussed in initial lecture, for welding there is different-different source, but here actually we will cover the electric arc welding related things. So, here we will cover, we will discuss about the heat source, which is generally required in case of, electric arc welding technique.

So, first of all what is a, what is a welding heat source that we should know. A heat source suitable for welding should release the heat in sharply defined isolated zone. Moreover; so, here one important things we should know that heat should sharply define in a isolated zone. Moreover, this heat should be produced at high temperature and at high rate. So, these are the very important part of this heat source and important characteristics also. In case of welding one things, you should know that heat should produce in a very sharply a defined isolated zone; that means, we have to produce the heat in such a position where it is required and that should have high temperature, because this heat source should have should release a temperature, we should melt that.

Actually here, we are discussing about fusion welding techniques. So, here the this heat should release a temperature we should melt the parent material or job or work piece and this heat should be at high rate, because not only it will melting the plate, it should fuse and it should penetrate the material also. So, these are the characteristics of heat source should require.

So, here main characteristics of heat source is it should produce high temperature and at high rate. Generally, in fusion welding process one of the most important source of heat is electric arc. Here, I am just how the, how the actually arc is generated, how where the arc is (Refer Time: 06:16) required that little bit I am symmetrically, I will show little bit, but in details, I will tell in subsequent slides.

This is called power source, this power source one terminal is connected to a electrode and another terminal generally connected to one terminal connected to the electrode, another terminal connected to the job or work piece this is generally called job or work piece. Generally, what are the thing required here? Generally, this is called electrode, I have already told in about this thing, but here again we should know, but here what are the thing required; that in between this work piece and electrode generally a arc is to be generated this arc generally deliver, such a these arc generally act as a heat source in case of electric arc welding technique.

So, here I (Refer Time: 07:36) so, first of all we should know what is arc then we will subsequently, we will go in details about this arc characteristics, how this arc is initiated, how the arc is sustained in between this gap; that means, there is a gap. So, in between this gap, how the arc is sustained; that means, in between this gap, how the electricity generally flow? How the current flow in between this two gap? That also we will see, because if there will be gap then only there will be arc. So, how this arc will remain in between a gap that also I will discuss in this details.

So, here generally, first of all we should know what is a welding arc especially, weld welding arc. Then we will go in details, how this arc is initiated and the, how the arc is remains in between a gap; that means, in between gap means in between a electrode and a work piece. There is a gap, in between gap, how the electric arc is sustained in between these two gap that I will discuss in details in this lecture.

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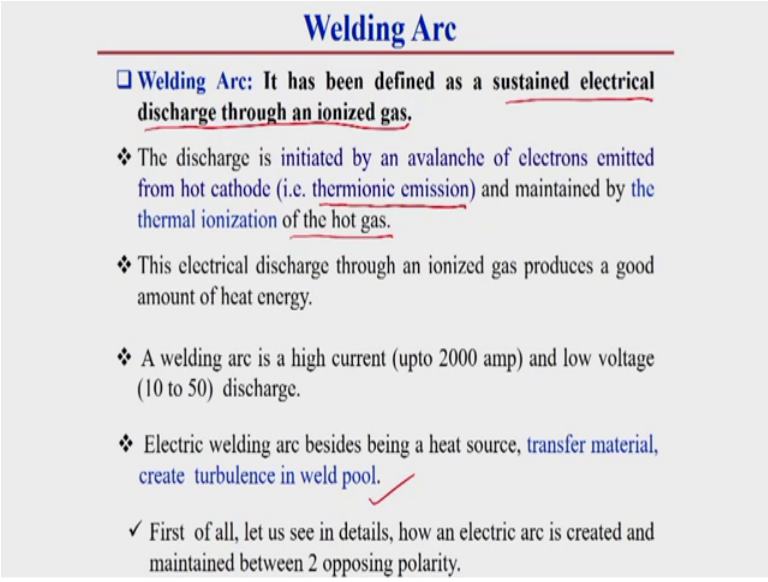

So, first of all we should know what is welding arc? Welding arc, it has been defined as a sustained electrical discharge through an ionized gas. So, here what is the things? It is a sustained electrical discharge through an ionized gas.

Now, the discharge is generally initiated by a process, whose name is thermo ionic emission; that means, this discharge is initiated by thermionic emission. This thermionic emission generally here, generally (Refer Time: 09:08) how it started? This discharge is initiated by a by an a avalanche of electron emitted from hot cathode; that means, from hot cathode generally, these electric discharges started and is maintained by the thermal ionization pushes of the hot gas; that means, what does it means? That means, first of all we should know.

Generally, in case of electric arc welding techniques most of the cases generally, this electrode is kept as negative and generally work piece is kept at positive. Generally, some other polarity also is there sometimes, it can be positive in current. Generally, what is preferable I mean in case of arc welding techniques that is this thing; that means, electrode is generally kept as negative terminal and work piece kept as positive, this negative terminal, this is called cathode and this positive terminal is called generally anode.

So, how the arc is initiated? How? The arc is initiated generally, from this cathode terminal generally which is initiated by a avalanche of electron from this cathode terminal and which is emitted from this cathode terminal. This emission of this electron from this cathode terminal is called thermionic emission. In details, I will discuss in this lecture about thermo ionic emission and what happens in between this gap; generally, this arc is maintained in between this arc is maintained by a process that is called thermionic ionization. So, it details about these two, I will discuss in this lecture.

So, first of all I have already told you that discharge of, is initiated by avalanche of electron emitted from hot cathode; that means, this emission of electron which is generally termed as, which is known as thermo ionic emission process and this arc is maintained in between gas by a process which is known as thermal ionic or thermal ionization.

Now, this electric discharge generally through an ionized gas, once this electric discharge passed through an ionized gas then it produces a good amount of heat energy. Here, one things we should keep it in mind generally electric discharge is a very high current and low voltage discharge. Here, the current can be up to 2000 ampere, but voltage range is varying from, this is a low voltage case. Generally, here voltage range is varying from 10 to 50 volt within this range.

Now, here one thing we should keep it in mind here, electric arc not only supply the heat to the work piece, but also it supplies generally, it supplies, it generally help. So, so here electric welding are beside being a heat source. Generally, it helps to transfer material and its helps to create turbulence in weld pool. So, electric arc not only act as a heat source, it also helps to supply molten droplet from electrode to base material as well as it create some turbulence.

This turbulence also is very much essential in welding process with energies turbulence generally, helps in penetration of the work piece. So, this electric arc have very important characteristic; that means, it not only supply heat, it also produce some turbulence in the weld pool as well as it also generally helps in material transfer; whatever the droplet form in case of consumable electrode welding that generally droplet transformation, in case of droplet transformation also this electric arc helps a lot.

Now, first of all let us see in details, how this electric arc is created and maintain between two opposite polarity? That details actually now I will discuss in subsequent slides. So, here generally arc is initiated, what I generally initially told that by a process that is called thermionic mission and this arc is maintained by a process that is called ionization. Now, what is thermionic emission and first of all we will see what is thermionic emission, then we will go for what is thermal ionization that also we will discuss in subsequent slides in details.

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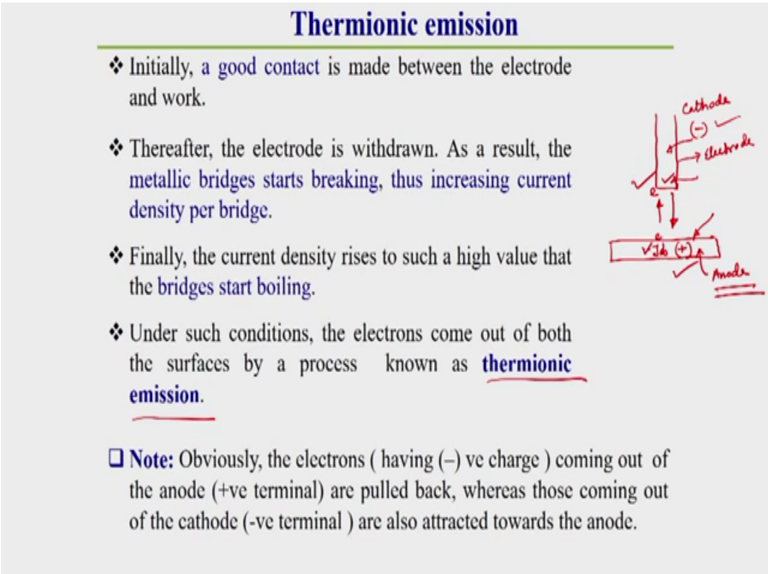

So, first of all we should know what is thermionic emission. How the thermionic emission is started? How this, how this thermionic emission process taking place, taken place? That we should know in detail. Generally, first of all let this is the work piece and let this is the electrode cathode actually; this is generally job or work piece job or work piece, this is generally positive time this anode terminal. So, what happens in case of thermionic emission?

First of all this electrode is generally initially a good contact is (Refer Time: 14:44) this electrode generally momentarily tasks with this job first of all. So, a good contact is made between this electrode and the work piece. So, first of all a good task is made between this electrode and work piece, a good contact is made between this electrode and work piece. Thereafter, the electrode is generally after that generally this electrode is withdrawn.

As a result the metallic bridge start breaking of this electrode as well as work piece. So, here whatever the metallic bridge is there, in case, in electrode as well as in work peice that metallic bridge due to this momentarily task and flow of current generally this metallic bridge start breaking. Thus, the increase in the current density so, if this metallic bridge start breaking of this electrode and work piece then what happens?

Here generally, here generally what happens due to this metallic bridge breaking generally there the current density increased; that means, once metallic breeze breaking means electron density increases say electron density increased means if the electron per unit area is more then what happens current flow will be also more general what we know, generally the direction of current flow is opposite to the direction of electron flow that we know and generally that current is also generally proportional to number of electron that also we can say. Rather their current magnitude also generally proportional to number of electrons there.

So, while this metallic bridge start breaking then generally what happens this current density increase; that means, concentration of electron both anode and cathode increase. So, what happens? So, finally, this current density rises to such a high value that bridge start boiling; that means whatever the metallic bridge is there. So, first of all they are in metallic bridge current density increase, then due to this increase of current density there generally increase the temperature. How this temperature increase? That I will discuss in subsequently next slide itself.

So, generally the increase the temperature; so once the temperature increase then this metallic breeze start boiling. So, once this metallic breeze start boiling then the electron start emitting from this surface; that means, from this surface of the electrode. So, from the surface of the electrode as well as from the work piece also. So, what happens? So, the electron is start emitting from the electrode.

So, once this electrode is start emitting this process; that means, due to this high current density, this temperature also increase and due to this increase temperature, the material is metallic bridge start boiling due to this boiling of metallic bridge; the electrons start emitting from the electrode surface that process is known as thermionic emission. That means, once this metallic bridge start boiling; that means, then this in this condition the electron come out from both the surface both the surface means both cathode as well as anode; that means, both electrode as well as work piece by a process known as thermionic emission.

Now, here one things we should keep it in mind as it is positive electrode is here electrode a (Refer Time: 18:23) electrode is negative terminal cathode and job is positive (Refer Time: 18:29) terminal, whatever the electron generally start emitting from cathode surface as well as anode surface, this generally start concentration over the anode surface generally, this is attracted. Actually, this electron is generally whatever the electron coming out from the anode surface its pull back to anode itself and whatever the electron coming out from this cathode surface this is generally attracted to the anode surface.

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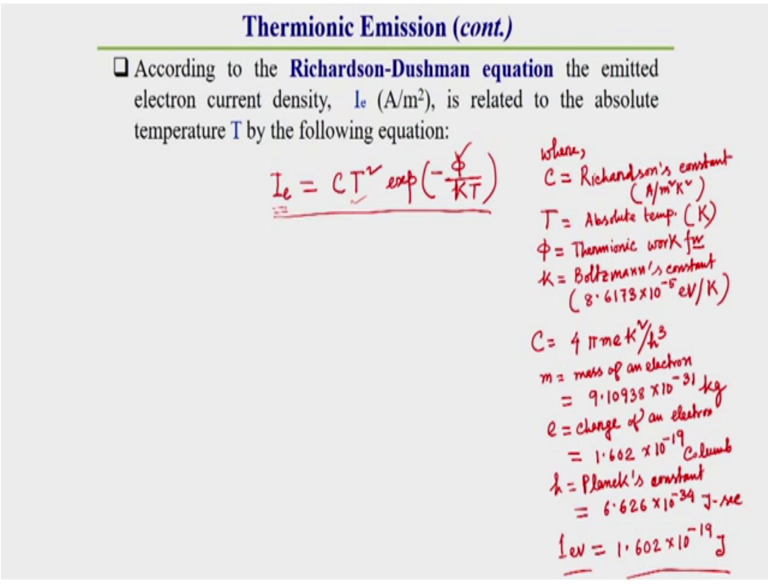

Now, how this boiling taking place; that means, how the temperature rise taken place due to the high concentration of high concentration of electron or high increase of current density, how the temperature is increases that general we should know. This is generally described by Richardson and Dushman, that is why according to Richardson and Dushman the emitted electron current density is related to the absolute temperature T by the following equation.

So, here we can get a very interesting relationship between; that means, this current density I e with the absolute temperature it has observed that that current density is proportional to generally absolute temperature how it is that is described by Richardson and Dushman. That is why this equation which is provided by them is known as

Richardson Dushman's equation. How its look like? They generally provide that the current density Ie is equal to generally C T square exponential to the power minus phi by K T, where generally is an every terms, I will explain in details where C is called Richardson constant.

Its unit generally ampere per meter square Kelvin square; T is called absolute temperature in Kelvin, phi is called thermionic work function, this is called work function. What is thermionic work function? In details, I will explain it. K is called Boltzmann constant. Generally, this K magnitude is 8.0 generally, K value is 8.617 into 10 to the power minus 5 electron volt per Kelvin.

Then this T, T is already I have explained. Now, this C generally this Richardson coefficient generally is a function of, this Richardson coefficient can be represented as 4 pi m e K square divided by h cube, where m is mass of an electron. Generally, we know this thing the mass of an electron is generally 9.109 into 10 to the power minus 31 kg that we know, then what is e electrical charge of an electron. This magnitude generally, 1.602 into 10 to the power minus 19 Coulomb and this, what are the other things is there, this h is called Planck constant. This Planck constant value is generally, we know that is also we know 6.626 into 10 to the power minus 34 Joule second Joule second.

So, these generally we know; that means, everything is known to us. So, generally this Richarson coefficient value, this magnitude once, we put this thing this is this magnitude generally is within a range of around 1200 to 2 milli ampere per meter square the per millimeter square per Kelvin square.

Generally, this C value we can get. Now, here from this equation one things we can easily observe that here one things, you should know; that means, this K generally electron volt per Kelvin. Generally, we know 1 electron volt is related to electron volt is a managed means the unit of energy. So, 1 electron volts generally we know 1.602 into 10 to the power minus 19 Joule. This we know actually we have already studied in details over this thing. So, what happens? So, 1 electron volt generally, its electron volt is a unit of energy. So, 1 electron volt is 1.602 into 10 to the power minus 19 Joule that we know.

So, and this Coulomb, Coulomb is the generally, this Coulomb unit also we know, this Coulomb also generally, generally coulomb we can define, because this we should know, because this is a very much essential for our case. Coulomb generally, 1 Coulomb generally, it is the charge transported by a constant current of 1, 1 ampere per 1 second. So, what we can say this 1 Coulomb generally, 1 Coulomb is equal to we can write, 1 Coulomb is equal to 1 ampere second that also, because this will be required in subsequent discussion this will be required, because we should know in details about this. So, Coulomb means it is the charge transported by a constant current of 1 ampere in 1 second; generally, this is called 1 coulomb.

So, generally 1 coulomb generally, carried by 1 ampere current in 1 second that you should keep it in mind. So, Coulomb we can tell that took a Coulomb generally a equivalent to or equal to generally, we can write it as 1 ampere second or ampere second it is a coulomb is equivalent to ampere second also we can write, because this will be required for subsequent discussion. So, here one things you can observe; that means, this current density; that means, concentration of electron concentration of electron is proportional to T and it is generally, inversely proportional to this work function phi, it is inversely proportional to this work function this phi ok.

So, this; so one things here we can say that these this above equation generally above equation say, if the temperature increase, then the current density increases as well as if the current density increase then the temperature also increase. Generally and one things here, keep it in mind this rise in temperature or emission of electron also depends on this phi value. Here, one things you can see that concentration of electron increase, if the phi value is less.

So, phi is work function value if it is less then what happens a electron can easily emit from the surface. So, lower the work function higher the concentration of the higher the concentration of the electron that will higher the chances of emission of electron. So, generally, so from here what we can say? That low value of this phi and high value of T make the emission of the electron easier generally. So, make the emission of the electron easier how? If this low value of phi is there and high value of T is there.

So, alternately we can say if the higher the current density, higher the temperature will be there, that will also we can say. Now, here what we should know what is this phi what is the phi represent what does it means generally phi is the is called work function. It is the minimum amount of kinetic energy this phi we can define in this way it is the minimum amount of kinetic energy required to generally, leave a electron from work piece surface or material surface; that means, what is the minimum amount of energy required to emit an electron from a material surface that is known as generally this phi or work function.

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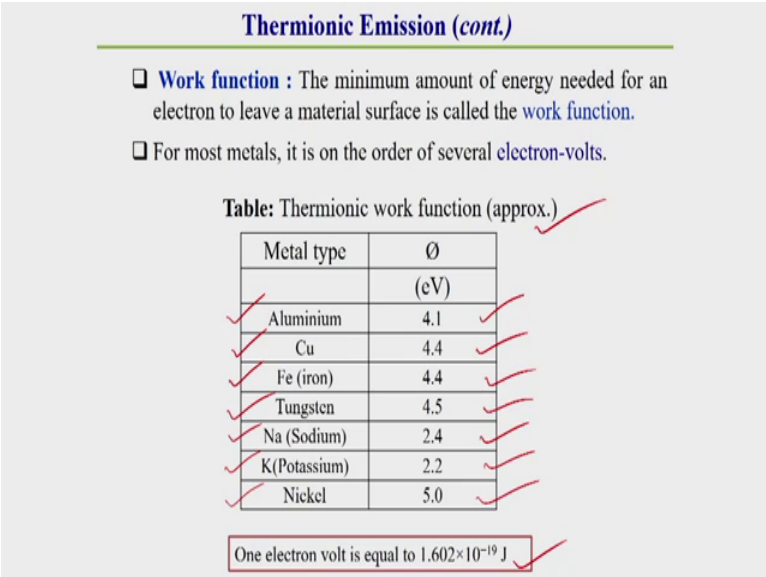

Generally, next slide I will show you what is this value of this work function for the commercially available material which generally, related to welding technology, where generally in welding technology these types of material we will see generally very frequently.

So, that I will show, that I will show in a table here. That here, one things you can see with most of the material this work function value is within range of some electron volt; that means, some electron volt and I have already told you electron volt means it is a very small, on electron volt is a very small amount of energy, which is a general equal to 1.602 that I have written here 602 into 10 to the minus 19 Joule; that means, it is the energy.

So, generally what is this minimum amount of kinetic energy or minimum amount of energy to emit an electron from different material that generally is representing in this table. Here, in case of aluminum generally, it has a value of around 4.1 electron volt; that means, if a electron; that means, if a like generally; that means, 2 emit an electron. This mass of energy is required actually this much of energy is required to emit an electron, if this energy within this range then the electron can easily emit from the surface of the of the aluminum material.

Similarly, in case of copper this work function value is 4.4, iron also within a range of 4.4, this tungsten also within a range of 4.5, electron volt sodium also it has a value of around 2.4, potassium also a value of 2.2, nickel also a value of around 5 electron (Refer Time: 30:31) of these actually these types of materials names we will very frequently see actually once will in welding industry. That is why I am just showing here some work function value. What is the function value of different-different types of material, which is generally widely used in welding industry.

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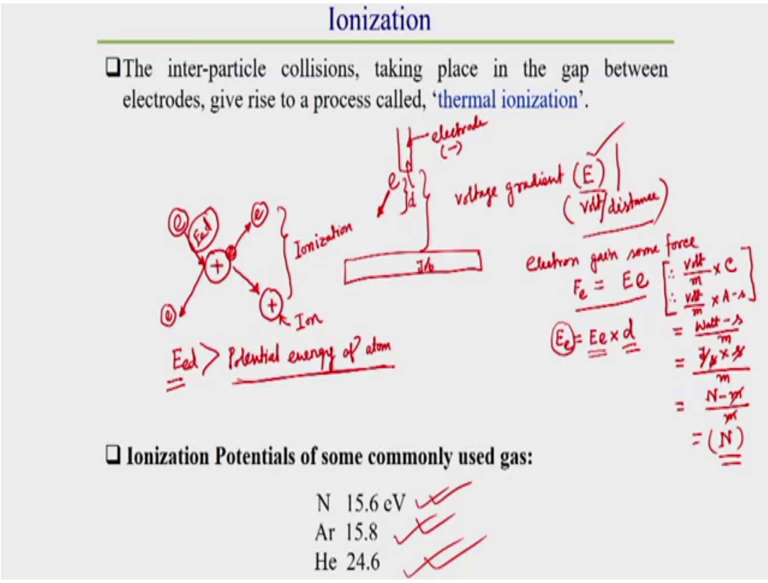

Now, next is we should know ionization how the ionization happen? This, because now we got actually how the a the emission started; that means, how the arc is started. So, arc is arc is started by emission of electron ok. Now, we will see how the ionization how the arc sustained how the arc maintained in between gap that also we should know. That generally, does maintenance of the arc in between this gap is taken place by a process that process known as ionization.

What is ionization; in details now, I will tell here generally the inter particle collision taken place in the gap between electrode give rise to a process, this process known as thermionic thermal ionization this process known as thermal ionization. How this is taken place that I will now, explain. Generally, once the electron start emitting then generally, once the electrons start emitting from the electrode; that means, once the electron, it start emitting from this electron then generally this electron pass through a voltage drop region; that means, after emission of this electron from this led this electrode.

So, from this electrode let this is negative terminal. So, this from this electrode or cathode once the electron start emission is when the electron emit from this electrode then what happens? It enter in a voltage drop region. Generally here, in between this work piece and the electrode, there is a voltage drop region is there here, we will get a some voltage drop region here. Generally, in this region in between this gap there is a voltage drop region.

So, once happens once a electron emit from this electrode then generally enter in a voltage drop region. So, once it enter in a voltage drop region then it is gain some kinetic energy; that means, what happens once it is enter in the voltage drop region, it gained some kinetic how this kinetic energy gained that I will explain here in details. So, this kinetic energy, once this kinetic energy of this electron goes beyond the potential energy of the gas available, of the atom available in between this gap then what happened that gas or these gas molecules generally start ionization. How it is that I will that, I will explain in details.

Let us see a electron which generally, which generally move through a gap, which generally voltage gradient we have a in this gap, in this gap. Let this electrode and work piece job, this two have a let us this two have a voltage gradient. Let us, in this zone there is a voltage gradient, this voltage gradient here I am representing in terms of P voltage gradient means volt per distance; that means, there is a change of voltage from electrode to work piece. Let this change of voltage or this change of voltage or voltage gradient is this E volt for distance.

So, if this electron of charge E if it enter in a voltage gradient space E then what happens with this electron gain some force. So, what will be the force of this electron. So, that the force of the electron let us I am representing in terms of Fe force of electron force of electron this will be generally E into charge of electron. How it is that also you should know generally here one things you will see; that means, here generally unit of E is volt per distance, let's volt per meter. Let's unit is volt per meter and discharged electron of charge that we C is the charge of electron, this is generally coulomb that you know charge of electron is Coulomb.

So, these generally this generally how we can write, this general you can write volt per meter and this Coulomb you can write as ampere and second ampere second that you know now, you know V into I; that means, voltage into current you know that what that you know voltage into current is watt. So, watt second per meter you are getting. So, watt what is watt means Joule per second, what means Joule per second what you know that Joule per second; so then this second is there will be meter.

So, Joule second will be cancel out and these Joule you know that Newton meter, Joule you know that Newton meter. So, at the bottom also there is a meter is there. So, meter will be cancelled out. So, finally, what is the unit you are getting E into e we are getting the unit of force; that means, once the electron enter in a voltage gradient region then its gained a voltage gradient region of E volt for distance then it gained a force, this force of this electron will be a (Refer Time: 36:42) force of the electron will be generally E into e.

Now, if this electron move a distance in between this gap, if this electron now let this electron move a distance d. So, if its move a distance d generally then it gain a kinetic energy, because its be first its generally so, if it is generally this energy of this electron, if it is moved through this gap a distance d then it is gained, a generally energy. This energy will be generally force into distance that you know; so this force into distance.

So, this will gain energy, that is that is generally E into e this force into distance, because if this electron moves in a distance (Refer Time: 37:31) then this it is gain a energy this is actually what? This is actually the kinetic energy. Now, this kinetic energy once this energy; that means, once this E; that means, energy of the electron on this energy of the electron is greater than potential energy, potential energy of atom atom between this gap whatever the gas atom is there in between this electrode and work piece, if this energy is greater than potential energy of this atom, then general this atom ionized what I am telling understand. So, this atom ionized means this atom generally converted to electron and ion.

So, this is atom generally converted to positive and negative charges. So, what happens. So, let this electron let this electron is heated a molecules or a atoms; that means, a generally gas atom. Let us it is heat a heat a, let this is a electron it is coming out from this electrode and it is gain a energy, which is generally E into e into d and if this E into e into d E into e into d is more than that; that means, electron energy is more than the potential energy of this atom or these neutral molecules, then what happens this atom generally break it generally break and its converted to ion, it converted to ion and electron.

So, this process is called ionization process this process is called ionization process and this electron generally re bounce back to other direction. It is generally this electron again start gaining energy and it is it generally hitting another atom. So, these types of generally think so, so what happens? So, if this energy of this electron; that means, E into e into d, if this energy of the electron is more than potential energy of this atom, then this atom generally break and what happens is converted to electron and ion; that means, here generally it is converted to electron and ion.

So, the process of breaking of a neutral atom to ion and electron is known as ionization process. This process is taken place generally in between this electrode and work piece, due to this ionization process generally they are in between this gap. They are generally create huge amount of electron due to this electron and there is generally create a huge amount of flow of electron in between electrode and workpiece. So, whatever the electron is generally generated, this electron is generally attracted by the job or work piece which is generally anode surface. So, this electron generally flow towards the direction from cathode to anode direction due to this electron flow, there is a continuous flow of current.

So, due to this continuous flow of current there is remain a remain this electric ditchers in between the gap. So, what happens due to this collision of electron with these gas molecules or gas atom generally, what happens this kinetic energy of this atom converted to a high amount of heat energy.

So, due to this heat energy its raised the temperature in R column, that is why what you can observe in case of a electric arc welding techniques generally in between this gap can you imagine that; that means, in between the gap the rise of temperature due to this collision of electron with gas molecules or due to this ionization process, they are create a huge amount of temperature. This temperature can be varying from 10000 or 10000

Kelvin to 20000 Kelvin; that means, within distance some cases, it can be 50000 Kelvin also ok.

So, this is here generally a plasma of gas molecule is there. Actually this arc column is a mixture of electron, as well as ion, as well as gas molecule is generally arc column, generally is a combination of all three. So, due to this collision not about the collision taken place between this electron and molecules, due to this collision, this high temperature rise due to this high temperature rise generally this arc generally can made this work piece and which can join the two different work piece by hitting the work piece apart from this stage due to this high velocity of electron generally what happens?

It can penetrate the work piece also, because this high velocity electron generally can you imagine this electron, which gain some energy, this electrons gain some energy. Let's its force we know electron has a mass of only at 9.109 into 10 to the power minus 31 kg. So, if we divided this force by that electron mass then what; that means, how much acceleration its gain, once it enter in this voltage drop region; that means, that much of oscillation is gained by a electron on due to the, because electron has there has a very small mass.

So, what happens is oscillation range is also very high, this mass of acceleration generally by this oscillation. Generally, it heat the molecules and what happens this due to this heating, it generate huge amount of heat energy that by this heat energy generally, it raised the temperature of arc column. So, generally here one things we should know.

So, generally what is the ionization potential commonly used gas molecule. Generally, in case of arc welding techniques, we generally use this types of gas molecule like nitrogen gas, argon gas or helium gas. It has a generally potential; that means, this potential energy of that atom within a range of 15 to 30 electron volt. Like in case of nitrogen it has a value of 15.6 electron volt, in case of argon, it has a value of 15. L 8 electron volt and in case of helium. It has a value of 24.6 electron volt that is why the argon is easy to ionize then compared to this nitrogen, argon and helium. Helium is little bit tough to ionization compared to nitrogen and argon gas. Now, we will see how the current actually, what is the things, how that the current is flowing in between this gap, that I already I have explained, but here little bit little bit.

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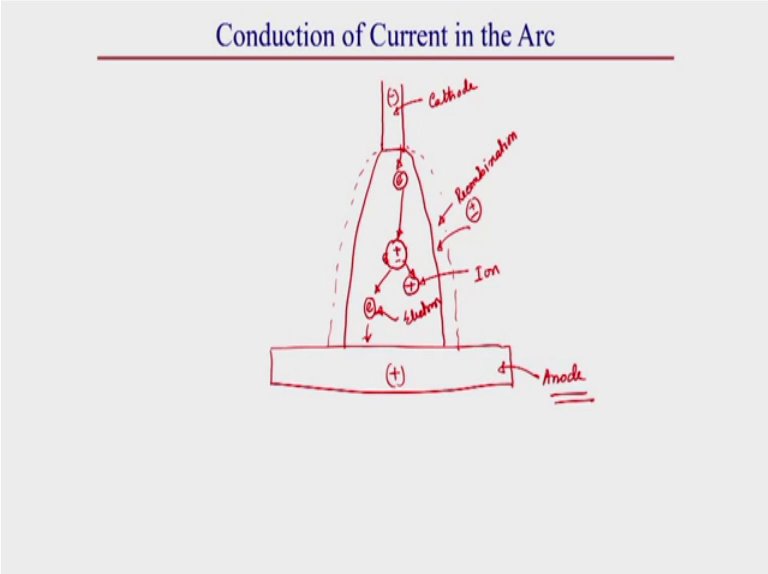

So, little bit so, how the current conducting in between this gap? What happens in arc little bit briefly, I will explain here, what happens in case of a arc? Let us, this is cathode, this is anode. Now, in this gap what are the things in early, in this arc I have told you, there is generally available gas molecule electron ion.

Generally, this electron generally once this electron come out from this cathode, it gained this energy and I have already told you it is generally heat this molecules; that means, (Refer Time: 46:20) here generally in between area I am showing just very few number of electron (Refer Time: 46:24) not like that here means million numbers of electron ion are there that you know actually what happened. So, were there over there generally huge collision huge, collision of ion and electron is taking place. Now, whatever does generally with these electrons on it, heat this ion generates generally converted to electron and this ion positive ion.

So, it is converted generally this electron and electron and ion generally, it generally produced this, this is called ion and this is called electron. Now, here one things we should know this electron, whatever that things electron coming out from this electrode. This electron is attracted by this positive terminal as well as whatever the electron produced by this ionization; that means, produced by this ionization of this molecule gas electron also is attracted by this anode surface.

So, there is a continuous flow of electron in between this cathode and anode surface. So, due to this continuous flow of electron generally this current is continuously flowing over the over the gap between electrode and work piece. Now, here what are the other things also happen here generally recombination also taken place; that means, this some sort of this electron and proton electron and ion generally, it is recombine and it is again produced some gas, that gas a neutral gas molecule.

So, here generally outside this arc this generally boundary region is there they are generally recombination also taking place also taking place. So, what happens these are the thing generally (Refer Time: 48:30) so how the current conducting that we understand.

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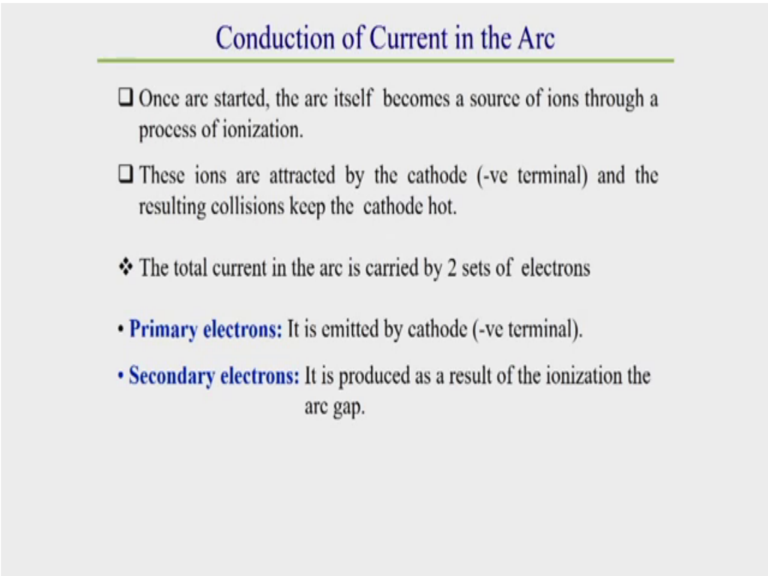

So, here generally two set of electron conduct the current what is this two set of electron, conducting the current this two set of electron is generally categorized as two set of electron is there. One is called primary electron generally, this primary electron is emitted by the cathode itself; that means, it is emitted by cathode and secondary electron, this secondary electron which is produced due to the collision in between gap; that means, in gas molecule or by ionization, whatever the electron is produced that is generally called secondary electrode.

This two set of electron generally, conduct the current in between this electrode and in between this cathode and anode. So, generally this arc, how it is sustained that you understand due to this continuous flow of electron from cathode to anode terminal generally, there these arc remain sustained and because this current is flowing in between gap.

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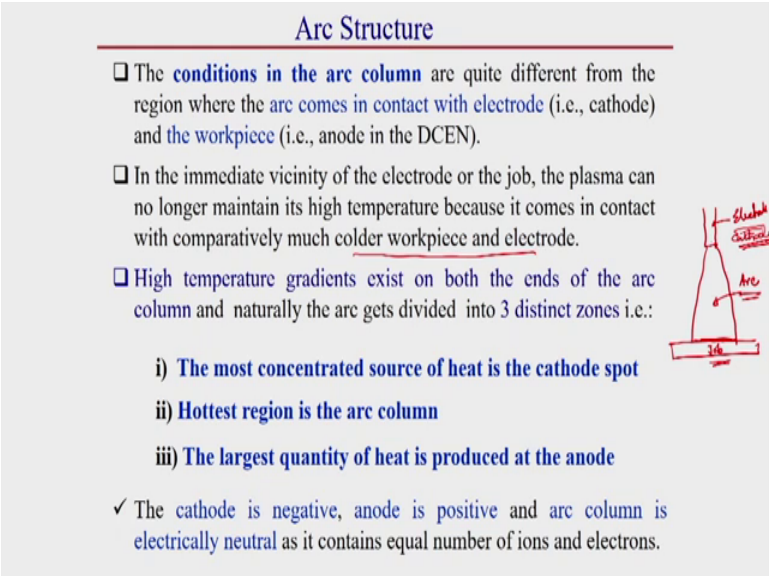

Now, we will see that what is the different arc structure? Now, we will go that; that means, we will understand what is how the arc is initiated and how is sustained in between gap; that idea you got.

Now, we will see what are the what is the arc structure? The condition in the arc column are quite different from region where arc come in contact with electrode and work piece here one things we will keep it in mind what we got now; that means, here is a electrode and here is a work piece in between generally, here I am the little bit bigger I am showing this is generally arc.

This is generally electrode and work piece this is job and this is a job and this is electrode here. One things you keep it in mind, they generally the condition in the arc column, this in this arc column near to this electrode and job the temperature range is different generally what happens here generally in arc column the temperature is within a range of in this middle region generally, temperature is within range of around 10000 Kelvin whereas, in case of electrode and job region contact job contact region.

Here, the temperature range is comparatively very small compared to this arc column middle region why, because generally this deal in the immediate vicinity of the electrode or the job the plasma can no longer maintain its high temperature, because it come in contact with comparatively colder work piece and electrode, because this as this arc is contact with colder electrode as well as work piece that is why here generally it this arc column cannot maintain its high maintain its high temperature. That is why a temperature gradient is observed in being a in between this arc column in between this electrode and job arc column.

So, a high temperature gradient is exist the high temperature gradient exists on both the ends of the arc column and naturally the arc here divided into three distinction. This arc zone is called generally, here this is a cathode. So, generally most concentration source of heat is called cathode spot cathode spot zone this is generally hottest region. This hottest region is called this is generally hottest region, this is called arc column region and the largest quantity of heat we generally deposited on the job this is generally called, this is generally called anode spot region.

So, here generally the; so, these are the following three distinct temperature zone we observe in case of a arc column. Now, one by one I here, I will explain generally in a arc structure due to this, then a arc structure generally we can observe five different zone are there, five different zone are there. What is this 5 different zone that we should know? So, the detail about this arc structure, I will explain in a next lecture, apart from this detail about this arc structure. I will explain how the arc is initiated? How what is the arc power? How we can get a optimized arc power and we will solve different problem on arc power in next lecture.