Fundamental of Welding Science and Technology
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Lecture - 13
Physics of Welding -5 (Metal Transfer-1)

So, at the end of last lecture, I was discussing about what are the different forces acting in metal transfer. There what we have seen today I will start from that metal transfer. After, that I will discuss about what are the different metal transfer generally occurs in details.

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So, first of all this is the today's topics content that means force affecting the metal transfer and details about metal transfer.

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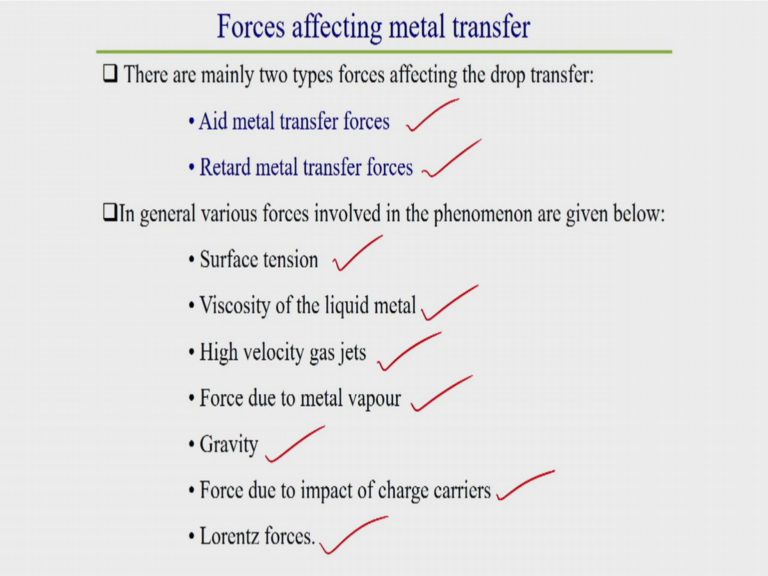

So, before going to metal transfer I have already told you in yesterday lecture also that, we should know in details what are the different force generally acting in metal transfer? Yesterday itself I was discussing that there is generally 2 different types of forces acting on metal transfer; that means, all the forces generally we can group into 2 different categories; one is called aid metal transfer forces, another one is called retard metal transfer.

Aid metal transfer forces means this force is generally help in neck formation and metal detachment from the electrode. And it is generally help in metal transfer; that means, transfer from electrode to work piece that is called aid metal transfer. And retard metal transfer forces are those forces means oppose this neck formation and metal detachment phenomena, this types of force are generally called retard metal transfer forces.

In general there are different types of forces we observe in welding metal transform, these are the forces like around 7 8 different categories forces are there like this forces can be due to surface tension that is force is called surface tension force. This force can be due to the viscosity of liquid metal. So, whatever the force generated due to the viscosity, that is called viscosity force. And this force can be due to high velocity gadget, this force can be due to molten metal vapour, this force can be due to gravity, this force can be due to impact of charge carrier and this force can be Lorentz force also this Lorentz force.

So, these are the different categories of forces generally which act during metal transfer. So, among this force generally some force act as aid metal transfer force, some force act as retard metal transfer. Now, we will discuss in details about metal transfer forces in details, then we will see which force generally act as aid metal transfer force and with force is act as a retard metal transfer force. So, first of all we will discuss about surface tension force. Surface tension force it is a retarding force, we generally try to keep the drop in its position.

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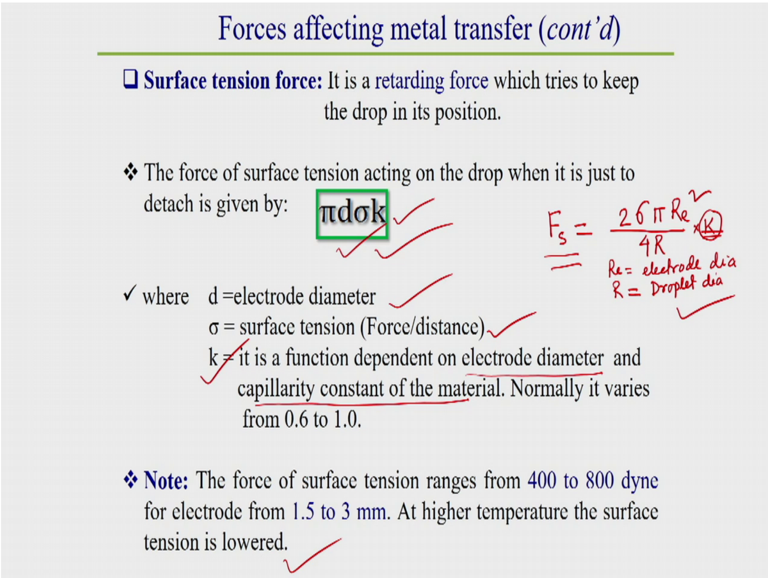

That means, which oppose the drop detachment from electrode diameter definitely surface tension forces it is function is like that only. Now, here generally the surface tension force we can represented like this, that is surface tension force generally can be phi d sigma k, where d is the general electrode diameter, sigma is the surface tension, then case it is a function depends on electrode diameter and capillary constant of the material. This k this is generally so, function defends on or we can say this a coefficient itself, its a function which is depends on electrode diameter and capillary constant of the material.

Generally this k value varies from that we know; that means, surface tension in details actually. So, we already studied in b tech second year level courses about surface tension forces. So, normally its this k vales varying from this 0.6 to 1 in case of welding droplet.

So, it is so, here one things we should keep it in mind what is the range of the surface tension force. Generally surface tension force depends on droplet diameter or we can say electrode diameters. If electrode diameter sees higher then generally surface tension force also higher, that is so, it has observed that surface tension force ranges from 400 to 800 dyne, for a electrode diameter of around 1.5 to 3 millimeter diameter. That means, for 1.5 millimeter diameters we can have a surface tension force around 400 dyne for a 3 millimeter diameter electrode, we can have a surface tension force which is around 800 dyne.

Now, apart from this thing we should know generally surface tension force also depends on temperature generally temperature of the droplet especially. So, higher the temperature of the molten metal lower will be the surface tension force. Then only higher the temperature lower is the surface tension for that. So, that also we should keep it in mind. This formula generally we use if the drop diameter and electrode diameter is almost similar to each other.

Now, if the drop diameter and droplet diameter and electrode diameter if it will be different, then surface tension force we can represent in some other form also, like what happens? It can be represented as 2 sigma pi R e square divided by 4 R, where this into this K constant is there, this K generally this is a function generally which depends on electrode diameter and capillary constant this is there generally this is there.

So, here generally this R e is called electrode diameter electrode dia and R e called generally droplet diameter. Droplet diameter from here itself we can get the idea, if R e is equal to R then we can get a formula like this we can get a formula like pi d sigma k, but if diameter of electrode and diameter of droplet us will be different then the surface tension force is generally will be like this.

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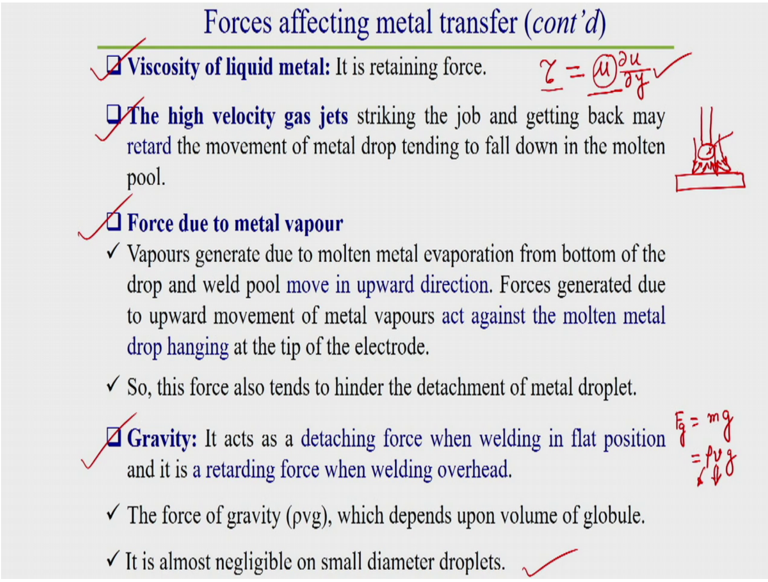

Now, we will go to other forces like viscosity of liquid metals. Generally viscosity due to the viscosity whatever the force generated in molten droplet that is generally also act as a retarding force. Because, generally we know from Newton's law of viscosity that we share new from Newton law of viscosity we know that shear stress between 2 adjacent layer is equal to viscosity into velocity gradient.

So, what happen ratio of the shear stress? So, this is generally called Newton law of viscosity, where generally shear stress between 2 adjacent layer of liquid can be represented as velocity gradient in between these 2 layer. Like this del u by del y or this is generally sometimes called as shear rate actually del u by dell t. So, what we observe that shear stress between 2 adjacent layer of liquid is proportional to velocity gradient dell u by dell y.

So, now generally this once we equal then we get a constant this constant is called viscosity generally from here what we observe that these viscosity. Generally is constant for a particular temperature and for a particular pressure displace of this mu is generally constant.

Now, this mu means viscosity from here what we observe that this shear stress in between 2 layer is proportional to viscosity that another way we can say. So, higher the viscosity higher will be the shear stress. So, what happens its also act as a retarding force, because if the viscosity will increase, then that drop data spent rate will decreases definitely. Because what happens, here generally drop takes more time to detach, because due to this more shear stress in the drop droplet.

So, higher the viscosity higher the drop detachment rate actually or we can say higher the drop detachment time actually, higher the drop detachment time; that means, lower the rate of metal transfer; that means, per second metal transfer rate will be lower. So, higher viscosity means lower rate of metal transfer, because higher viscosity because viscosity act as a air generally retarding force. Generally which oppose the detachment of metal from electrode to workpiece.

Now, the other types of forces generally this is viscosity force, now will go for another force that is called the high velocity gas jet force. This high velocity gas jet force also generally this high velocity gas jet is striking the job or workpiece and getting back may retard the movement of the metal drop tending to fall down in the molten pool. That means, let us let this is the electrode from here let us molten droplet is forming, this high velocity gadget is due to this types of gas slow up let us.

So, this gas can strike to the surface and what happens this gas can this gas can actually getting back to the molten droplet direction. And it can prevent the molten droplet detachment from the electrode.

So, it also act as a generally retarding force. So, the reason of this high velocity gadget is here initially striking to the job, after that it generally getting back to the molten droplet direction and which generally oppose the droplet detachment actually. So, here also generally higher this forces lower will be the droplet detachment rate actually; that means, drop detachment rate will be lower.

Now, the other forces is generally other force. So, this also act as a retarding force. So, whatever the force I told here along this all the forces are generally retarding force. Generally, which generally oppose the drop detachment or neck formation in the droplet.

Now, force due to metal vapor this is also another forces, which develop due to this bottom up molten droplet and weld pool region; that means, on the molten droplet drop down to molten pool. From this molten pool region this molten and droplet region, that develop some gases. This gas generally tends to move upward direction; that means, once it move upward direction, its also generally oppose the molten droplet detachment from electrode.

So, this forces also act this force due to metal vapour this force also act as a retarding forces. So, this force also tend to hinder the detachment of the molten droplet, so, this is also act as a retarding force.

The other forces this is called gravity force, it act as a detaching force or you can say aid metal transfer for sometimes it acts as a retarding force. So, it generally in which case it act as a aid force and in which case it act as a retarding force that we should know. Generally, once the welding is carried out in down hand direction that or you can say flat position welding. Generally, this droplet direction, droplet formation and detachment direction is along that gravitational direction. Due to that what happens whatever the here the gravity force generally act as a aid metal transfer force.

But, once we do the welding in upward direction in the do the welding in upward direction. Here the gravity direction and metal droplet transfer direction is opposite to each other. So, in this case generally it act as a retarding metal transfer forces.

Now, generally this gravity force its depends on it is size of means mass of the volume of droplet; that means, it is generally this gravity force is depends on volume of the droplet. Because, we know gravity force F g is equal to mass into gravitational acceleration; that means, g where mass we know density into volume of the droplet.

So, generally if this so, this rho is generally density of molten droplet. And molten metal droplet and v is the volume of the molten droplet; that means, droplet volume v is the droplet volume. In case of what we can say, that in case of generally lower diameter electrode this gravitational force is very small generally.

So, what happens in case? So, lower the electrode diameter or lower the droplet size lower will be the gravitational force in molten droplet. So, this is only one force among all this force whatever I have told, this is only one force its only sometimes act as a aid metal transfer force. Apart from this gravity force others other forces generally always act as a retarding force.

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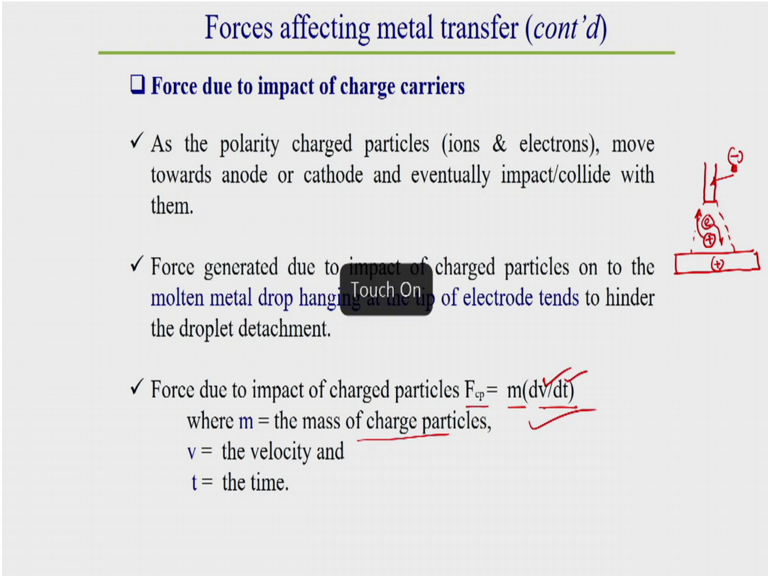

Now, we will see force due to impact of charge carriers. This force due to impact of charge carrier this is a happen, because what happens due to ionisation and emission of electron due to ionisation what happens in between this in between the gap of this in between the gap of this arc. So, in between this gap of this electrode and workpiece, what happens here generally develop electron and electron and ion?

This electron and ion generally this electron and ion generally move let this is negative cathode terminal, let this is anode terminal. So, this electron generally come to workpiece direction and this ion generally moved to cathode direction or electrode direction.

So, what happens once this ion move and its if it is negative then generally so, what happens here generally positive ion moves towards negative terminal of electrode and electron generally move towards positive terminal of that connection.

So, what happens here due to this movement of this electron and ion generally this creates some impact forces on molten droplet, because if the ion is move toward a molten droplet direction then this ion will create some impact force on this droplet. If the electron is move toward what it is call if the electron is moved toward droplet direction, then it is collides with this droplet us and it create some impact forces on the droplet. Generally, which also act as a generally retarding force. Generally which oppose the detachment of droplet from electrode to workpiece because which creates some opposing force.

So, what happens this force due to impact of charge carriers also act as a retarding force. This charged particle forces we can represent in terms of m in to dv by d t, where generally m is the mass of the charged particle or m is the generally mass of the charged particle, where v is the velocity of the charged particle and t is called time. Generally the this is actually the representation mass into acceleration that we know simple thing.

So, here the mass of the mass is the mass of that charged particle and dv by dt is the acceleration of the charged particle.

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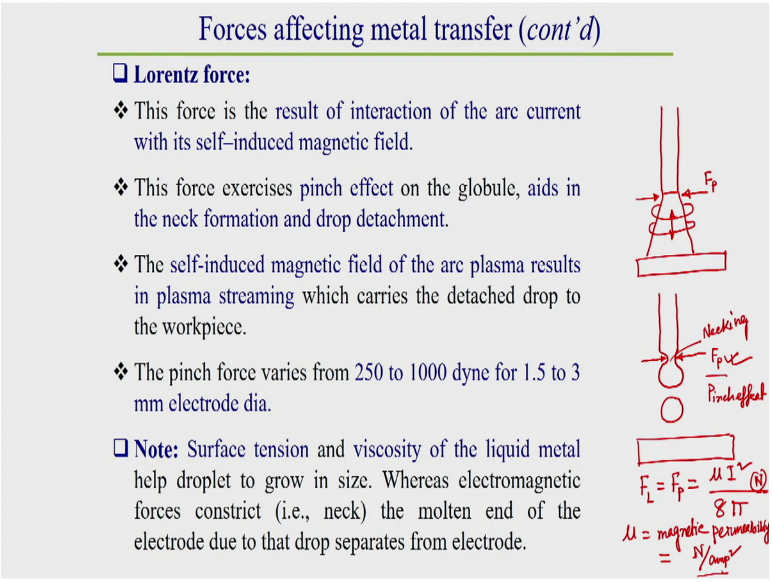

Now, we will go the Lorentz forces. This Lorentz forces, which is only one force, which act as a generally this act as aid metal term, this Lorentz force is the only one force which main function is neck formation and metal detachment from the electrode to workpiece. This, Lorentz force generally generate due to the introduction of flow of current and its self-induced electromagnetic field.

What happens due to the flow of current and self-induced electromagnetic what I have already told you, generally the function or the what is the function of a current flow, that I have told you in details in last class. Here also the similar thing, but here I am telling this in terms some forces actually. So, this force actually how it is generate, this is generally due to the flow of current and it is self-induced; and it is self-induced magnetic field.

This generally what happens when the current is flow generally through the arc, generally they are develop the magnetic field which is they are generally develop the magnetic field which is like this. Last class I have told you this magnetic field density or magnetic field strength, we can say or current density, current density or magnetic field listed in generally varies from top of the electrode to work field direction, that I have already told you. So, this magnetic field generally create some radial create some radial directional; that means, radial directional force towards the arc. So, this radial directional force this force generally create some pinch effect; pinch effect on the molten droplet.

What is pinch effect, how it look like? Generally, if due to this pinch effect generally whatever the let us what happens here some droplet is formed. So, once the droplet is form then what happens? Here generally due to this radial force here necking is start, here you see here generally necking start; necking start in the molten droplet. This molten droplet necking a start due to this pinch force, for you can say due to the due to this radial force. This radial force how it generate it, this radial forces generating due to this interaction of current flow and it is self-induced magnetic field.

So, what happens these create some compressive force on the molten droplet due to this what happen they are create some necking. So, once they are create some necking then what happens, after certain necking formation what happens this drop detach from the electrode and its fall down to work piece. So, this is the only one force which generally help in neck formation and metal and what it is called droplet detachment from electrode to workpiece.

Now, apart from this radial force so, this radial force or necking is forming this effect is call generally pinch effect. What is the name of this effect this effect is called generally pinch effect; pinch effect. So, this pinch effect force or we can say this Lorentz force or we can say this is pinch effect force, this can be represented as mu into I square divided by 8 5. Where I mu is called magnetic permeability, what its called magnetic permeability.

This mu is generally called magnetic permeability. It is unit generally we know this unit of this magnetic permeability is Newton per amp square ampere square current square actually from here we can get that means,so, it is a you know what will be the unit of this it is unit will be generally the unit of force; that means Newton.

So, what happens? So, from here what we got this pinch effect or we can say this Lorentz force proportional to a square of the current flow through the arc. Now, due to this current flow other force also develop that what I have discussed in previous lecture that is called generally axial force. Because, generally in arc they are create some pressure gradient, why pressure gradient is creating? Because, generally in arc generally this current density or magnetic field extend generally decreases towards workpiece direction why I have told you.

Because, generally due to this bulging effect of this arc; that means, because arc cross section generally increase from electrode to workpiece direction. Due to that generally they are create some pressure gradient through the arc length. Due to this pressure gradient generally, they are create some axial pressure also. The this axial pressure generally create some gradient, this axial they are develop some axial pressure gradient along the arc.

Due to this axial pressure gradient generally this axial pressure gradient create some streaming effect actually on arc. This is streaming effect generally helps metal transfer from electrode to workpiece. As well as it transfer the heat from electrode to workpiece.

And this axial pressure generally create some turbulence and some pressure on the molten pool also. Due to this turbulence and pressure on molten pool what happens this axial pressure increase the penetration, which helps in improvement the penetration of in welded plates. So, it generally helps both in penetration as well as metal transfer that axial pressure.

So, from this effect of different forces on metal transfer what we observe among this 7 different categories of forces, 5 different categories is lying on retard force category and only 2 different categories is lying on aid metal transfer force categories, that 2 different forces one forced is called Lorentz force, that is actually radial force on the molten droplet. And another force is gravitational force. This gravitational force also act sometime as aid force, sometime act as retarding force, because this gravitational force will act as aid force once the welding is down hand or in flat position.

Now, we will go to different metal transfer actual, what are the different categories of metal transfer are there in welding, that we will discuss now. Now, before discussing this metal transfer here one very important things we should know that is called polarity in welding process. Generally in case of direct current there is 2 different polarity are there and another polar in case of AC power source or you can see is AC types of welding technique, there is a combination of this 2 different DC polarity are there.

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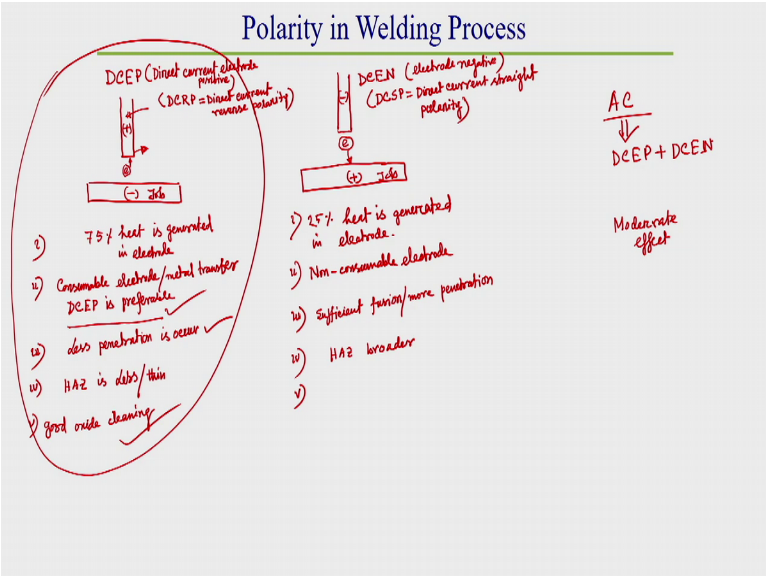

So, polarity generally how the polarity is dependent that polarity there is 2 different types of polarity are there; one is DC EP in case of DC power source another one is called what is DC EP? DC EP means here generally electrode is here generally DCEP means direct current; Direct Current Electrode Positive DCEP. Here generally this electrode is positive this is negative, another polarity is called generally DCEN; DCEN this is generally call this is the full form of DCEN Direct Current here generally Electrode Negative.

So, here generally negative terminal is connected to electrode and let this job or workpiece, this is generally job or workpiece positive terminal is connected. So, what we got. So, this 2 different types of polarity generally we have observed in case of welding technique in case of direct current power source.

So, what happens here we should know what is the function of this 2 different polarity that we should know. So, what happens here one things you keep it in mind, that this DCEP this polarity is also called generally reverse polarity. This is also sometimes term as DC RP; RP means this is Direct Current; direct current Reverse Polarity; reverse polarity. Why it is called reverse polarity that also I will discuss, this DCEN is called direct current SP. So, this is called Direct Current; direct current Straight Polarity straight; polarity always keep this thing in mind actually. DCEP is called direct current reverse polarity DCEN is called direct current straight polarity.

Why it is called generally in case of this positive terminal of electrode, generally here electron flow toward this positive terminal direction. And in this case; in this case due to this negative terminal connection and electrode. Here generally electrode electron flow toward positive direction.

So, what happens, due to this movement of electron from that mean towards movement of electron towards this toward electrode direction. Generally here bombardment of the electron will take place; here electron bombardment will be taken place generally one electrode. And whereas, due to this motion of this what it is called motion of this electron towards workpiece direction this high impact velocity; that means, high impact velocity electron impact the workpiece with high very very high high acceleration or we can say high velocity impact the workpiece. So, that what happens here the bombardment of electron is taken place in workpiece due to in DCEN.

So, due to the bombardment of electron in case of DCEP as it is occur in electrode. Here generally 75 percent heat around two-third of this heat; that means, 75 percent of heat is generate in electrode, in case of DCEP. So, this is one point we are getting from direct current electrode positive because why, because here as the electron bombardment high velocity high impact force generally create in electrode. So, what happens here in this case generally 75 percent heat is generated in electrode.

Whereas in DCEN; DCEN 25 percent heat is generated, it is generated in electrode. And 75 percent heat is generated in this case generally DCEN generally 75 percent heat is generated in workpiece.

Now, here one thing we should keep it in mind. So, for consumable electrode what we have to do, we have to melt the electrode. So, for consumable electrode where there is a metal droplet formation and metal detachment generally worker. In case of consumable in case of non-consumable electrode generally what happen this we do not want actually, because what happens in case of non-consumable electrodes, generally in electrode generally less it we should generate.

So, for that region generally in case of consumable electrode; consumable electrode that means, for metal transfer; metal transfer generally this DCEC DCEP is preferable prefer preferable definitely, this will be preferable, because we want more metal to melt and more heat should generate in electrode in case of consumable electrode. So, more metal will melt and molten droplet transfer will be taken place.

So, generally for consumable electrode DCEP is preferable, but this is generally this types of polarity is preferable generally is preferable for non-consumable consumable electrode or non-consumable electrode, because what happens here we do not want that electrode to melt. That is why if lesser heat will generate what happen that will be safe for electrode that is why general in case of reverse polarity or we can say DCEN generally non consumable. So, what happens? So, whatever the metal transfer related things we will discuss now, they are generally we will discuss where we generally use DCEP as the polarity.

Now, DCEP and DC an has different advantage and drawbacks, what are disadvantage and drawback I should tell you, then only it will be more clear to you. Now, here one things you can see. So, in case of as the bombardment in case of DCEN as the bombardment is taken place on workpiece. So, what happens here generally; here generally more penetration you can get; that means, DCEN you get sufficient fusion. Here generally you get sufficient fusion or you can say more penetration, because more heat is generating in workpiece here. So, more fusion more heat due to this more heat better fusion another thing generally walkers in case of this.

Whereas, in case of DCEP generally insufficient; that means, comparatively less less penetration is occur , in case less penetration is occur. So, why less penetration that you understand, because in this case generally drop heat is generally applied here for drop formation and drop transfer. So, what happens here less heat is generating in workpiece, due to that generally a less penetration; that means, bombardment is not taken place on workpiece. So, less penetration is taken place in this case.

So, in case of DCEP due to this less penetration and less heat generation on workpiece, here generally heat affected zone is less or you can say heat affected zone is thin. Here generally as the heat generation is more in workpiece that is why here generally heat affected zone is broader or generally here heat affected zone psi generally thicker is there as the bombardment of electron is taken place in workpiece. So, there is a chance of cutting of the plate, if the plate thickness is generally thin in nature; that means, for thinner plate thickness generally this DCEN is not preferable. For thinner section generally DCEP is more preferable.

Why because in case of DCEN generally as the bombardment is taken place and workpiece there is a chances of cutting of the plate, because what happen high impact velocity electrode instead of welding on that thin plate there can be cutting operation. So, this types of things can occurs in case of DCEN, but this thing generally cannot occurs in case of DCEP. Apart from this thing here one things we keep it in mind how this then you all if the bombardment of electron is taken place on workpiece or electrode due to this generally 75 percent heat is generating.

Then how this 25 percent heat is also generating in the in case of DCEP, how this 25 percent heat is generating in case of job and how that in 75 percent heat is generating in case of electrode in case of DCEN that also we should know.

This 75 percent generally heat is generating due to this movement of ion, actually because what happens this positive ion generally, this positive ion have a motion towards generally negative terminal. This positive ion generally its impact force or we can say it impact velocity comparatively lesser than electron. So, if this positive ion generates some short of heat over, there that heat generally comparatively very smaller than the heat generation due to electron bombardment.

So, you understand so, why DCEP is preferable for consumable electrode because generally for consumable electrode we want droplet formation. So, droplet formation means the droplet formation from the electrode. So, that is why if it is connected to positive terminal, then more heat will be generate in electrode. So, this due to this more heat rate of means molten metal formation will increase.

Now, generally in case of AC current; AC current have a polarity of both DCEP and DC EN. So, what happens in AC polarity generally whatever the changes whatever the heat generation, whatever heat affected zone size and other things happen. Generally in AC current it is moderate of this DCEP and DCEN. In case of AC polarity we get in between property; that means, moderate property of all the things which we got in case of DCEN and DCEP.

So, here what we got, here generally the AC polarity have all moderate effect where generally we will get moderate heat generation like 50 percent it will be in electrode 50 percent will be in workpiece, then here generally less here generally moderate heat affected zone you will get, here generally moderates fusion or depth of fusion here generally moderate depth of fusion all the effect generally in case of AC polarity you get as moderate in nature.

So, now, we will go so, we got the idea about the polarity what is effect. So, well where one things you keep it in mind. In case of generally metal transfer or consumable types of electrode, we generally use DCEP polarity; DC EP polarity we use. Here another point also we should know generally DCEP you have a very good effect in some material, that is called cleaning action. It has generally good or we can see it has good oxide cleaning action it has generally less, but in case of DCEP generally we get good oxide cleaning action in DCEP also we get good oxide cleaning action also.

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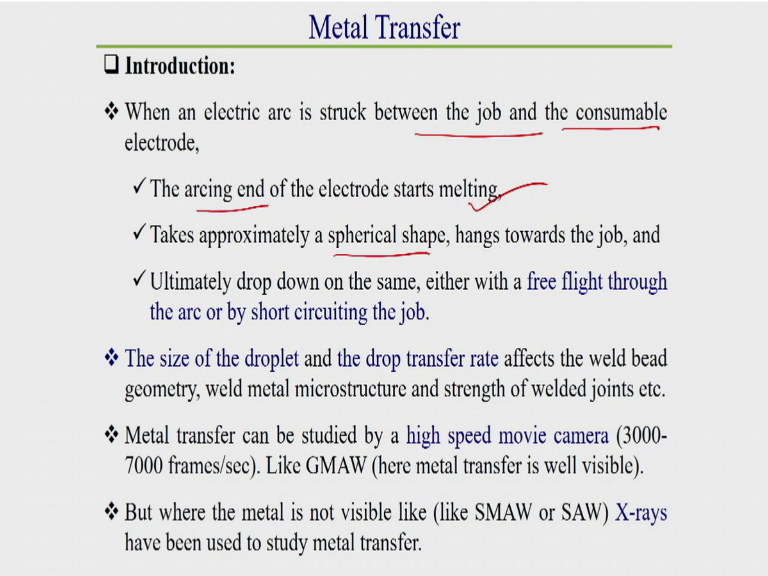

Now, we will go about the metal transfer. So, we got idea about what polarity should use for metal transfer types of or consumable types of metal transfer generally occurs in case of what consumable types of electrode. So, what happens what polarity we should use that we understand now and we got the idea about what are the different generally forces acting in metal transfer.

Now, we will be able to understand the metal transfer in details very good way. Now, how it is generally first of all we should know what is metal transfer how the metal transfer walkers, how we can capture the metal transfer, how we can do research on metal transfer, that initially I will tell after that I will see what are the different categories of metal transfer at there that generally one by one I will discuss.

When an electric arc generally how the metal transfer happen, when an electric arc is struck between the job and the consumable electrode. Here you see once this electric arc developed in between the job and consumable electrode. Then the arcing end, then generally this arcing end of the electrode start melting definitely, as this is consumable electrode that is why here generally due to this arc effect this consumable electrode end start melting.

After so, gradually it is start melting and it takes approximately a spherical shape and its hangs toward the job. And ultimately this drop down on the same either with free flight through the arc or by the short circuiting the job; that means, whatever the drop formation is taken place in electrode, that can freely fall through the gap or this drop itself can hang and it touch the workpiece and there can be shorting of arc.

What happens? So, due to this 2 different way this drop can transfer from electrode to workpiece. So, what is these 2 different one can be this drop can freely drop down from electrode to job through the gap or it can short circuiting this arc gap and it can transfer from electrode to workpiece.

Generally, the size of the droplet and its rate; that means, this droplet and its rate have significant effect why this study is required. Why we are studying this metal transfer. Because, metal transfer have significant effect on welded geometry, weld quality, weld metal microstructure, then weld join distance, that soil generally this is study is very much essential, that is why I am just showing details about the metal transfer.

So, how we can capture this drop transfer rate, drop transfer size, that also we should know. Generally, this we can capture by using some high speed movie camera. High speed movie camera what should be the range of this high speed movie camera? A camera which have a frame rate capacity; that means, capture of frame rate is around 3000 to 7000 frame per second, that types of camera generally we can use to capture the metal transfer rate.

And metal transfer size actually a study the metal transfer actually that types of camera we can use, but this types of; this types of camera generally used for metal transfer in case of GMAW process. GMA means Gas Metal Arc welding, where generally this arc is well visible and this drop transfer is also well visible. So, they are by putting this types of camera we can capture the what it is called droplet metal transfer by this I speed movie camera.

But, generally where this arc is not visible like some process is there, where the arc is generally cover by some flux or by some slag you can say slag or flux generally used to protect the molten pool from atmosphere contamination. So, once this arc is covered by this flux generally what happens, that this movie camera is not sufficient to capture the metal transfer characteristic or rate of metal transfer.

So, they are generally used some other technique. This also, that is called X-ray technique, generally by X-ray we can generally capture the metal transfer characteristic over there.

So, where this arc is not visible its generally walkers in case of submerged arc welding then in SMAW welding also, there is generally cover electrode is there; that means, flux cover electrode is there. Due to this generally what happens here arc is not visible there generally X-ray is use.

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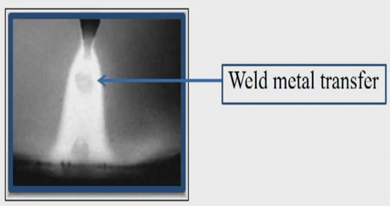

Fig.: Metal Transfer

Now, here just I am showing a just typical capture image of this is a video which I have taken from some site actually Google site. So, this video here you can see how this metal droplet transfer is taken place from electrode tip to workpiece. Here, you see this is capture generally by using this high speed movie camera. From here itself you can easily get the idea about size of the droplet as well as its rate of transfer for second. Now, we will go what are the different categories of metal transfer?

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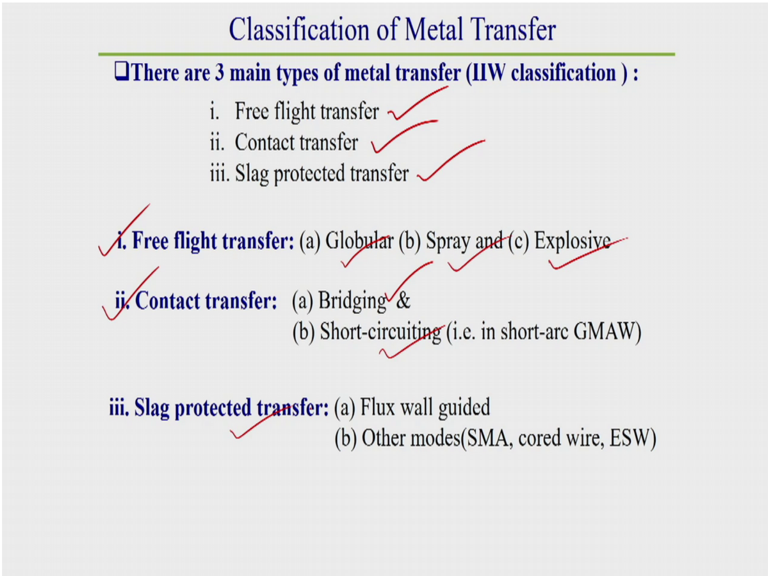

Generally there are 3 main types of metal transfer are there. This category generally classified by IIW this category is also called as IIW classification. IIW means Indian Institute of Welding classification actually. So, where generally this metal transfer can be classified into 3 different categories.

What is this metal transfer categories, one is called free flight transfer, another is called contact transfer, another is called slag protected transfer, detail about all these things I will explain in subsequent slide. Now, this free flight transfer further categories into 3 different categories; one is called globular transfer, another one is called spray transfer, another one is called explosive transfer, this free flight transfer. Generally to free flight means here generally short circuiting is not occur. Here, generally drop form its transfer from electrode, its go through the gap after that its generally drop down to workpiece.

So, here there is a flight of droplet through the air gap is there. So, that is why this is generally called free flight metal transfer. It has 3 different categories are there contact transfer means there is a contact between electrode and workpiece are there it has 2 different categories; one is called bridging category, another one is called short circuiting category.

I will explain in detail in subsequent slides about all these things. And as third one is called slag protected metal transfer, slag protected metal transfer what I have told in case of submerged arc welding, then electrode slag welding, generally cored wire welding, then shielded metal arc welding we get different types of mode of metal transfer. So, some other modes like flux wall guided metal transfer also are there. So, these are all generally slag protected transfer. So, all about this metal transfer I will discuss in subsequent slide. First of all I will discuss in free flight metal transfer.

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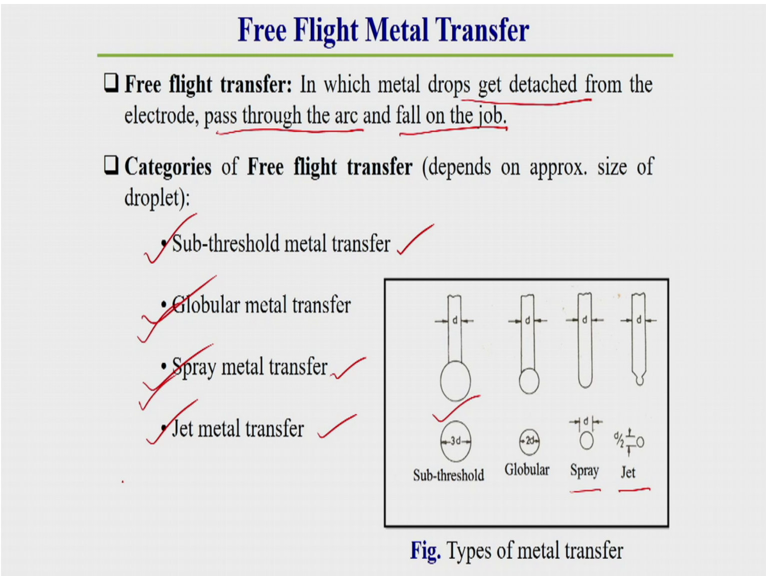

Generally free flight metal transfer what I have told you; that means, in which metal drops get detached from the electrode first, then is passed through the arc and fall on the job. So, what is happen here? Here generally drop get detached first, then pass through the arc and finally, fall on the gap. So, after detachment is freely fly in between gap that is why this welding this metal transfer is called free flight metal transfer.

Generally depending upon the size of the droplet this free flight metal transfer we can categorise into 4 different categories. This 4 different categories are one is called sub threshold metal transfer, which is look like this generally this is the sub threshold free flight metal transfer here the drop size is approximately 3 times of the diameter of the electrode.

Then, another categories is called globular metal transfer. So, here the drop diameter is approximately 2 times of the diameter of the electrode. So, then third categories of metal transfer is called spray metal transfer. Here the drop generally spray metal transfer and jet metal transfer, this is spray and jet metal transfer generally following this is spray metal transfer the drop diameter is approximately the diameter of the electrode. And in jet transfer generally here the diameter is approximately half of the diameter of the electrode.

Generally this a spray transfer and jet transfer comparatively this 2 categories also called as a spray transfer itself. So, this jet transfer also is lying in a spray transfer. A generally this sub threshold metal transfer the generally rarely we observe in case of metal transfer. Generally the sub threshold metal transfer generally it has rare application generally in traditional welding processes, that is why sub threshold metal transfer related things we will not discuss we will discuss about generally this globular metal transfer, a spray metal transfer in details. Now, first of all we will discuss globular metal transfer.

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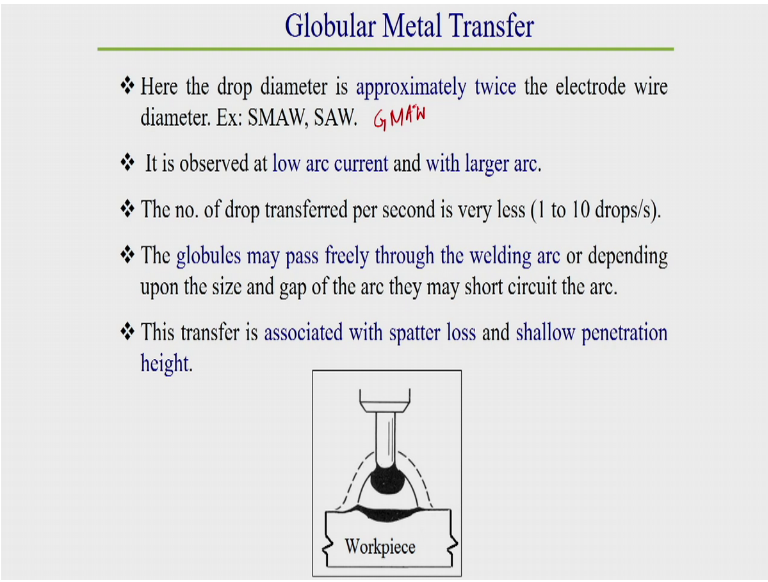

Generally globular metal transfer here the drop diameter is approximately twice the what I have already told you twice the electrode wire diameter. This generally we observed in case of submerged arc welding technique SMAW welding technique and GMAW also in GMAW welding process also; GMAW welding process also this types of drop transfer we observe.

This drop transfer generally form when the current is low generally comparatively low and this drop transfer occur when the arc length is high arc length high means arc voltage is high. So, generally this is observed for low current and high voltage.

The number of drop transfer generally this globular types of drop transfer is very small this drop transfer rate is varying from 1 to 10 drop per second; that means, its very small rate of drop transfer generally observed in globular metal transfer.

The globular may pass freely through the welding arc or depending upon the size and gap of the arc they may short circuit the arc also ok. So, it can depending upon the size and gap there is a chance of this globular metal transfer; that means, there is a chance of short circuiting the arc also. The this depends on if the means gap is a small and drop side is higher then there is a chance of this thing is there.

Here one things you keep it in mind this transfer is associated with spatter loss, because here the drop size is generally bigger. So, once its fall down to molten pool. So, there is generally splashing out of this molten metal can be there, there is a chances of a spatter loss. And as this drop is freely fall through the air gaps on the molten pool, here generally penetration is comparatively less than spray transfer or other metal transfers a spray types of metal or jet transfer metal.

So, why thus that also I will discuss in details in next class. So, next class I will discuss about spray metal transfer in details its categories lot are the different characteristics of different types of metal transfer in details.