**Fundamental of Welding Science and Technology**
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**Lecture - 14**
**Physics of Welding -6 (Metal Transfer-2 )**

In last class, actually I was discussing about Metal Transfer. So, today also in Physics of Welding today's also I will discuss about metal transfer, whatever the rest of the metal transfer are there that I will discuss. So, before going to metal transfer in detail last class what we have also seen generally metal transfer occur in case of consumable types of electrode, there what we have observed? There we observe that in case of consumable electrode once the polarity is DCEP, that means Direct Current Electrode Positive that is reverse polarity that is called Reverse Polarity. That case around two third of the total heat is generated in electrode and rest of the one third is generated in work piece.

Why because this two third of the heat is generated in electrode due to the electron flow toward electrodes and bombardment taken place in electrode. Here why two third of heat is generated? Because electrode as the electron has very low mass; that is why what happens it generally gain a very high velocity or high acceleration and due to this high acceleration generally an high velocity it generate high impact or kinetic energy on the electrode consumable electrode. So, due to that thing very high intensity that means about two third of the total heat is generated in electrode and how this one third heat is generated is base material? This because as base material is negative terminal, so positive ion generally attracted towards work piece material or job material, there this ion goes and impact over the over the work piece.

So, due to this impact generally it is impact energy or you can say that it is velocity comparatively very less as compared to electron velocity, because ion has comparatively higher mass compared to electron. Due to this higher mass generally here its velocity is comparatively lower, due to that here less heat is generated in work piece last class actually I was discussing about this in details.

Today it is whatever the rest of the metal transfer, in case of consumable electrode are there that I will discuss first, after that I will discuss some extra what is the effect of different process parameter they are not process what are the defect of different types of condition and parameters on metal transfer that also I will discuss in details in at the end of this lecture. So, first of all last class what we have observed? We have observed there are three different types of metal transfer are there, especially these are Free flight metal transfer Contact and Slag protected transfer.

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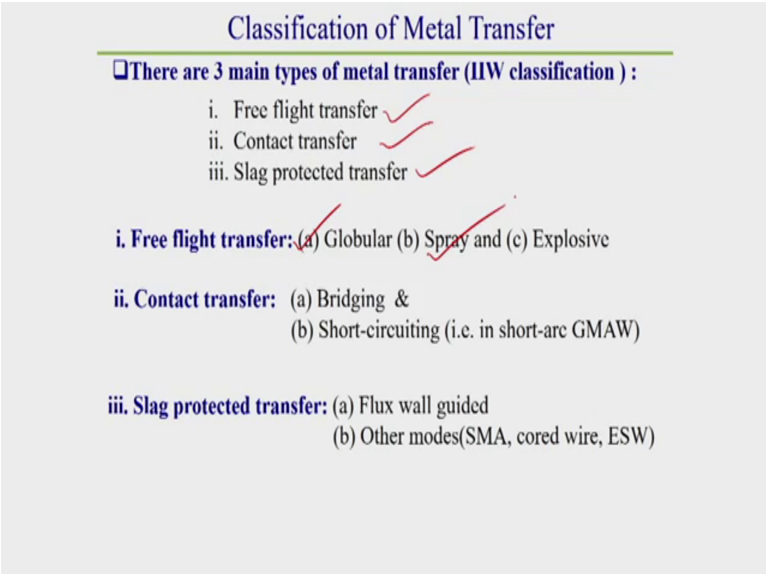


So, I was discussing so in free flight transfer generally I was starting to discuss about free flight metal transfer there I have started on globular metal transfer and I completed that globular metal transfer there what we have observed that in case of globular metal transfer. Generally drop diameter is approximately 2 times of the diameter of the electrode and what we observed this globular metal transfer generally observed in case of low current and high arc length that means higher the arc length higher the arc voltage. So, low current and higher arc length generally this free flight metal transfer occur. Today I will start to discuss about a spray transfer.

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So, generally a spray transfer in case of spray transfer here the drop diameter is approximately equal to or less than the electrode core diameter, whatever the electrode diameter there electrode. That means, this diameter of the droplet is approximately equal or less than generally the diameter of the electrode, here the drop transfer rate is much higher than the globular transfer.

What we observed in globular transfer? There we observed that the rate of drop transfer is approximately within 10 drop per second. But here we can get a drop transfer rate is around 100 or more than 100 drop per second. So, here is a continuous spray of drops are there general in case of a spray metal transfer there is a continuous spray of drop is there because, per second if there will be 100 or more than 100 droplets are there then there will be continuous spray of drop it is also a free flight categories metal transfer, that means here direct contact between electrode and work piece is not occur. Whatever the current use in case of globular types of metal trans here the current generally comparatively much higher than that globular metal transfer current. Why? Because what happens here drops should detach very frequently at frequently that because here droplet is faster.

So, to form drop generally whatever the pinching effect or pinch effect or neck formation force whatever the things is required, that should be higher then only a very quickly the droplet can form and detach from the electrode. That is why here current range should be higher, that is why here generally high arc current and low arc length is preferable because lower resistance or lower arc voltage is preferable lower arc voltage means lower arc length is preferable here.

Spray mode of metal transfer generally produce a stable arc compared to globular types of metal transfer, it generally produce good weld bead deep penetration and strong weld joint. That is why it is recommended for most of the different thickness of weld decorate especially this is also preferable in case of thicker plate also. Then another categories of free flight metal transfer or free flight metal transfer and that is under the category as a spray transfer is called Jet type, actual I was showing previous lecture. Another category jet types of metal transfer also are there, this jet type actually is a categories of free flight spray types of metal transfer here the drop diameter is further reduced and here the drop diameter become within a range of half of the electrode diameters.

So, due to that what happens here generally there is a continuous spray types jet is coming out from the electrode ands in deposited to the work piece, so that means further reduction of drop diameter is taken place in case of jet transfer. Now I will discuss the categories of different spray transfer what are the different categories of spray transfer are there.

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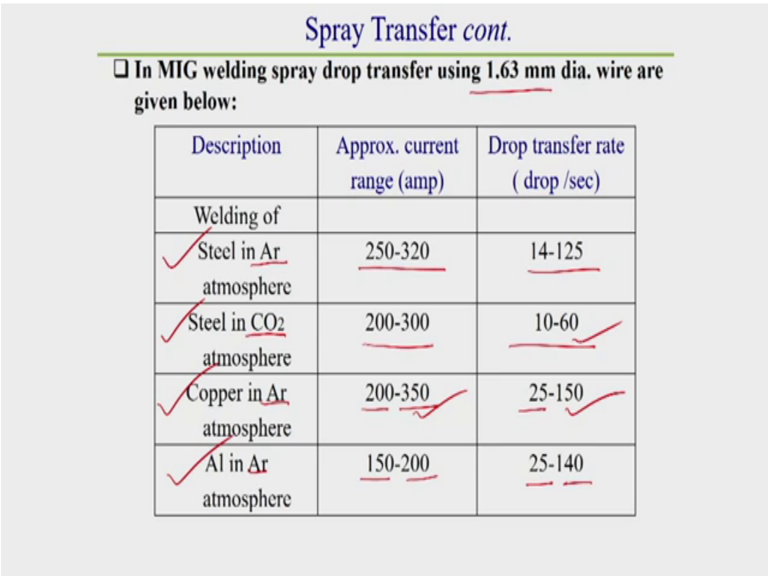


| Description | Approx. current range (amp) | Drop transfer rate ( drop /sec) |
|---|---|---|
| Welding of | | |
| Steel in Ar atmosphere | 250-320 | 14-125 |
| Steel in $CO_2$ atmosphere | 200-300 | 10-60 |
| Copper in Ar atmosphere | 200-350 | 25-150 |
| Al in Ar atmosphere | 150-200 | 25-140 |

Before going to different categories of spray metal transfer here I am giving you some feel, actually what is the rate of a spray transfer are there and how this is spray transfer dependent want actually how the spray transfer dependent on current then the shielding medium. Generally what happens drop transfer is highly depends on both the current and what it is called shielding medium also. It has observed that by changing the shielding medium by using same range of current we can improve the rate of drop transfer that I will show you a little bit after that I will go to actually different categories of spray metal transfer which is occur generally in case of consumable types of electrode.

So, generally in MIG welding here I am showing some experiment data in MIG welding generally spray drop transfer using a 1.6 millimeter diameter consumable electrode, that means whatever the electrode here we are using that is melted and it consumable types of electrode actually for this experiment the diameter was using 1.63 millimeter dia. So it was observed that once the welding is done by using argon gas, then for a range of current; that means, 250 to 320 ampere current it has observed that the drop transfer, that means a spray types of drop transfer ranging varying from 14 to 125.

That means here what we observe for argon atmosphere itself if the current is 250 then we are getting a drop transfer per second is around 14 and if it is 320 then the drop transfer rate we are getting within a range of 125 drop per second. Then why using same steel and if we use carbon dioxide as a shielding medium, that means carbon dioxide is active gas that I will discuss in details in subsequent lecture what is the effect of carbon dioxide on drop transfer and all the things. Now there generally in case of steel if this instead of argon if we use Co2 that means carbon dioxide as a shielding medium.

Then what we observe that here the drop transfer rate is comparatively very less than once we use argon as a shielding medium, here it has observed that the current range varying within a range of approximately 200 ampere to 300 ampere. Here generally what we observe? We observe a rate of drop transfer is 10 to 60 drop per second only, so which is approximately half of that once we use argon as a shielding medium.

Now, in case of copper also it has observed in case of argon atmosphere, that means once we use argon as a shielding medium in case of MIG welding. Then for a current range of 200 to 350 at lower range of current, what we observe that around 25 drop per second Drop transfer rate is 25 drop per second and in higher range current. That means at higher current that is 350 ampere current we observe a drop transfer rate is around 150 drop per second.

So, similarly for aluminium if we use argon as a shielding medium generally here the current range varying within a current range of 150 200, the drop transfer rate is varying from 25 to 140 drop per second. So, from here what we observe that drop transfer not only depends on current, it is also depends on shielding medium, it is also depends on material type that means, what types of material also we are using. So, with varying the shielding medium we can increase or decrease the rate of metal. So, from here we can observe from this table clearly; that means, by varying the current by varying the shielding medium we can increase or decrease the rate of metal transfer.

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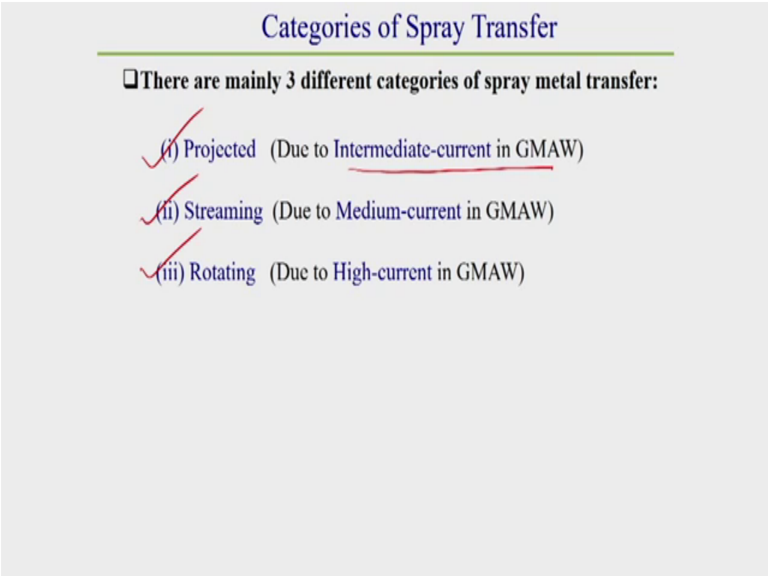


Now, we will go what are the different categories of spray metal transfer are there, there are different different types of spray metal transfer are there. First here generally this spray metal transfer mainly categorise into 3 different categories. What is this three different categories three different categories first categories is generally called a projected types of a spray metal transfer that is called Projected spray metal transfer , it is also sometimes called Axial spray metal transfer. Generally this projected spray metal transfer occur in case of intermediate current, this we observe in case of GMAW here for GMAW generally this projected metal transfer observed in Intermediate current.

What is intermediate current that also I will just discuss intermediate current is the current which is just above the transition current, just above the transition what is transition current then we should know. Generally transition current is a current above this current the metal transfer characteristics is a spray in nature, below this current range generally the metal transfer characteristics is globular in nature.

So, the current range at which that means globular transfer converted to a spray transfer that current range is called generally Transition current, that I will discuss in details on subsequent slides. Now second categories of a spray metal transfer is called a Streaming metal transfer, this is generally occurs in case of medium current in case of GMAW this is little bit higher range of current. Then projected a spray metal transfer a streaming spray metal transfer occur little bit higher current range then projected Spray metal transfer.

Then third categories is called a rotating a spray metal transfer, this rotating metal transfer generally occurs due to high current it is current range is comparatively higher very higher than the medium current range. That means, it is higher than this medium current range or higher than the streaming spray types of metal transfer case. So, this I will discuss one by one in details then it will be very clear to you, first of all I will discuss about projected metal transfer.

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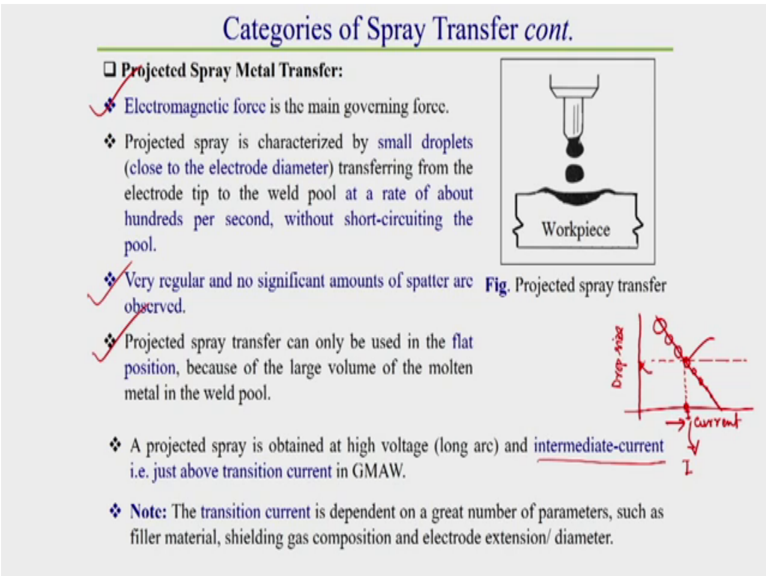


Here first of all generally in case of always keep it in mind that in case of metal transfer the main forces for detaching this molten droplet from electrode to work piece generally occurs due to electromagnetic force. So, here also in case of projected metal transfer first of all we will see what which force is main governing force here, here also the main governing force for this projected spray metal transfer generally electromagnetic force is the main governing force, because for a spray types of metal main governing forces electromagnetic force.

Generally projected spray is characterised by a small droplet which is approximately closer to the diameter of the electrode, that means core electrode generally it is characterised by a small droplet generally transferring from the electrode tip to the weld pool at a rate of about 100 per second without short circuiting the pool. So, it is characterised how it is characterised it is generally it is diameter is approximately closer to the diameter of electrode, it generally transferring at a rate around 100 per second and what happens during this transferring of material there is no short circuiting is taken place.

So, it is characterised projected spray is characterised like this as it is transferring through the line of axis of electrode that is why this is sometimes called Axial types of metal transfer. So, this projected spray metal transfer generally very regular and no significant amount of a spatter observed in this types of metal transfer.

So, due to this continuous spray of material generally here and droplet size has very less significant actually amount of a spatter are observe or we can say no significant amount of spatter are observed in this types of metal transfer. Then projected spray transfer can only be used in flat position, here one things we should keep it in mind generally this material transfer sometimes we are using generally the not this material transfer. Sometimes we have to do the welding one flat position, that means down hand position sometimes you have to Horizontal position, sometimes you have to do this thing Vertical position, sometimes we have to do this things on Override position also.

So, what happens all types of drop transfer we cannot use as Horizontal position Vertical position or Flat position. Generally this is what it is called projected types of spray transfer is preferable generally in case of down hand or flat position welding operation. Because what happens as here the drop rate is with within the range of 100 and its drop size is little bit higher, that means it drop diameter is also approximately the diameter of the; what it is called electrode that is why here the weld pool generally remains almost molten in nature.

Why because it is molten in nature? Because there is a continuous supply of molten droplet and here this volume of generally molten metal in the weld pool is comparatively higher side. So, due to this volume of molten material what happens once we go for doing this thing on horizontal position or vertical position or override position, then there is a chance of drop down that molten droplet from weld pool to down.

So, that is why this types of so here is a chance of that drop down or molten metal from work piece is there, that is why this types of welding operation instead of using in vertical or horizontal position this is preferable in case of down hand types of welding operation. So, what we observe here? Projected types of spray transfer where the drop diameter is closer to the diameter of the electrode, there we should use generally flat position welding not horizontal or vertical position welding.

So, a projected spray is obtained at high voltage and intermediate current comparatively high voltage means than other to a spray transfer, generally other to a spray transfer like have to streaming and rotating types of spray transfer is compared to that here voltage should higher and here generally current range is intermediate current which is lower than other 2 spray transfer types of.

That means, intermediate current is the current which is just above the; what it is called transition current, that means above the transition current. Now, what is transition current have what I have already told you, generally transition current general what we observe if we see current versus current versus drop side size let us or droplet size. If we draw the current versus droplet size it has observed that generally if the current increase generally this drop size drop size decrease actually.

Generally what we observe that means, the nature of this things we can say it is generally with increase of current drop size or volume of molten droplet is decrease. So, what happens at a range of current at a particular let us what happens this is the drop size, so let this is the drop size at which generally drop size become closer that size of the electrode at this let us let the drop size is closer to the size of the electrode.

So, if we increase the current so what we observe? That drop size gradually decreases. So, the current at which so what we observe the current at which let this is the current at which this drop of molten droplet size is this I current, at which that size of the droplet decrease from higher size to closer to the generally well the droplet size is coming closer to the diameter of the electrode. Then that current range at which this size is occur that current range is called transition or other words other way what we can say the current at which Globular transfer then the size of the molten droplet sizes are bigger size droplet converted to a smaller size we see generally the diameter is closer to the electrode diameter that current range is called Transition current.

So, transition current what we observe? Transition current is the current at which globular transfer converted to a spray transfer, that means drop size reduce drastically from it is bigger size to a smaller size, that current range is called generally what is called transition current. Generally this transition current is a very important current, it generally depends on different different parameter like for. If the material type will be different then this transition current also will be different, so for a particular material generally this transition current also varies.

How this transition current varies? Generally for a particular material by changing the shielding medium is changing the electrode extension, by changing the electrode diameter also we can change the transition current. So, transition current not only depends on material used in electrode, it also depends on it is size size of the electrode; that means, diameter of the electrode it is length of extension of the electrode what is length of extension that also I will explain in detail in subsequent lecture. Then it also depends on shielding gas composition also, that means what we observed in previous slide itself that means if we change the shielding medium from argon to Co 2 gas then how the drop transfer rate varying, so it is depends on different process variable also.

Now, we will go to streaming types of metal transfer, what is streaming types of metal transfer? It is also a spray types of metal transfer here the drop diameter is comparatively much lesser than the electrode diameter how it is occur that I will explain in details here.

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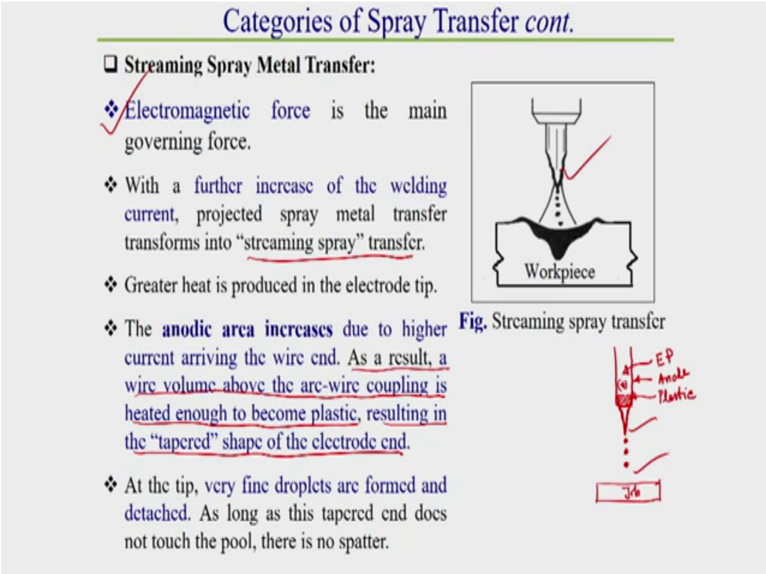


Here streaming a spray metal transfer state of material molten droplet generally coming out from the electrode tip, whose size is comparatively very smaller than very much smaller than what it is called projected types of spray metal transfer. Here again the main governing force is electromagnetic force, here whatever the current range we use for projected types of the spray metal transfer here generally current range we further increase. So, here a further increase of welding current projected a spray metal transfer generally, so with a further increase of welding current projected a spray transfer transfer into streaming spray metal transfer.

So, by further increase of current that means, once the intermediate current further increases then what happens? This projected spray transfer converted to streaming spray transfer how it is how this is streaming is occur? That also we should know due to this further increase of current the Anodic surface area increases, how this Anodic surface area increases that also I will explain due to the increase of this anodic surface area generally what happens they are due to this high current and anodic more anodic surface area they are generally generate high heat. Due to this high heat electrode become softer now due to this softening of this electrode what happens this electrode tapering occur because, that electrode softener become soften up and it become paste type or it become plastic type.

So, due to this paste or plastic type material heat generally converted to some tapering type shape, due to this tapering type shape the tip of the electrode diameter is decreases. So, due to this decreasing or we can say that tapering of the tip of the electrode is occur, due to this tapering whatever the droplet here is form that is generally mass lesser than the whatever the droplet form is in case of projected types of metal transfer.

So, what happens how this anodic surface area increase little bit I am explaining, what is here anodic surface area? Generally what happens here what we have already discussed we have already discussed generally in case of consumable types of electrode, electrode positive is preferable. So, direct current electrode positive so heat is generally positive. So, here generally and this is positive also called anode that we know positive terminal also called anode what happens here let us here this is the arc. So, what happens as a result a high wire volume above the arc wire coupling is heated enough to become plastic resulting in tapering shape of the electrode end.

What does it means; that means, here due to this high current, so here this tip of the tip of this anode generally here this tip of the anode area increases. So, here generally more electrode is melted at a time, that means more electrode is heated more electrode is more heated at a time due to this high current flow. So, what happens due to this portion of this electrode become plastic type, due to this high temperature and plastic or paste types material this portion converted to tapering types of shape this types of shape this portion generally converted to this tapering types of shape whatever the things I have shown here ok.

So, once it become tapering so electrode tip size generally become sharp enough, here generally electrode tip become sharp. Due to this whatever the drop size here it is forming this size also generally what we know that this size of this drop transfer depends on electrode diameter also here the size of the drop is comparatively lesser than the projected types of metal this due to this tapering effect.

Now, that is why generally at the tip very fine droplets are formed and it is detach and it drop down to work piece it generally drop down to work piece. So, this types of metal transfer is known as streaming types of metal transfer. Here also we observe that means as long as this tapered end does not touch the pool there is almost no spatter in this types of also metal transfer no spatter is observed as long as this taper electrode touches with the job. That means, short as long as it is not shorted the arc at that time generally what happens there is not occurs any types of a spattering types of effect in this types of metal transfer.

Now, this types of metal transfer generally we can use at flat position as well as in horizontal position also we can because, what happens here more force of as the smaller the smaller size of molten droplet is there, so molten pool volume of molten pool also less. So, what happens here generally there will be this types of streaming types of metal transfer we can use flat as well as horizontal position welding also.

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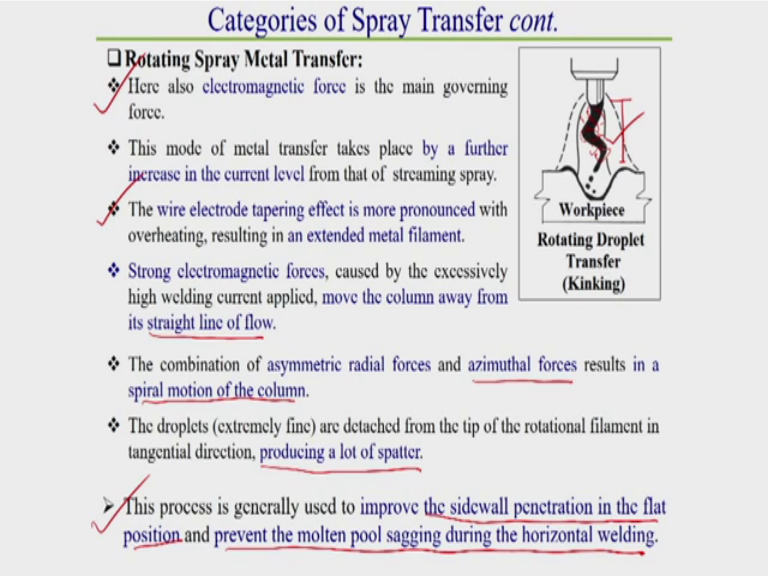


Now, now the another categories of spray metal transfer is called a Rotating Spray Metal Transfer, rotating a spray metal transfer here also the main forces is here also the main governing force is generally electromagnetic force. This mode of metal transfer takes place by further increase of current level from that of streaming a spray transfer. So, whatever the current we use in case of streaming a spray transfer, if we increase that current transfer further, then what happen then this types of metal. That means, rotating types of a spray metal transfer what happens in rotating spray metal transfer that I will discuss now.

So, what happens due to these the wire electrode tapering effect in this case is more pronounced with overheating resulting in an extended metal filament, what happens here in previous case what happens we have seen that due to this heating the tapering of the tip of the electrode taken place, that means molten consumable electrode taken place.

Here generally here instead of heating here generally overheating is taken place, due to this overheating this electrode tip become more and more soften. So, what happens here due to this overheating and more and more softening of the tip of the electrode here what happens some extended filament is created. Extended filament in the sense here more tapering and more material is extended from electrode tip extended out from the electrode and due to this more material extended out from the electrode tip and more current flow there develop more generally electromagnetic force. So, due to this high electromagnetic force generally this filament that means, the system electromagnetic force caused by the excessively high welding current applied move the column away from it is a straight line of flow.

Here generally due to this high electromagnetic force this metal filament cannot be able to contain its original shape and size. So, what happens here generally this metal filament move the column away, that means here this column moved away from it is a straight line of flow. So, here what happens this metal filament move away from it a straight line of flow, due to this here there is some curve or you say a spiral shaped types of metal filament is observed, due to this a spiral or curve types of metal filament. Generally what happens here that magnetic flux this magnetic flux line also will follow the shape of this metal filament, so due to this what happens in this region there is observe some asymmetric types of radial forces.

What we can observe from here itself how the radial force varying with the shape of the filament, so due to this asymmetric types of radial force and what happens here generally create some sort of transverse types of magnetic field or magnetic field and corresponding magnetic force also here it is observe. So, due to that that transverse types of magnetic field whatever the force is developed that that force is called azimuthal force that force generally called azimuthal force. So, azimuthal forces generally generated due to this transverse magnetic field distribution, due to this generally what happens so the result in a spiral motion of the column.

So, how this spiral motion of the columns is occur this spiral motion of the column is occur because, what happens due to this asymmetric types of magnetic electromagnetic flux line distribution and azimuthal force due to this asymmetric types of electromagnetic force distribution as well as due to this azimuthal types of force, what happens here generally spiral motion of column is occur. So, there is a motion of column is taken place in this types of metal transfer.

So, what happens for that reason the droplet are detached from the tip of the rotational filament, so here this filament is start rotating due to this asymmetric force or azimuthal force generally this filament rotated. So, the due to this tip of the filament generally rotated, due to this rotation generally what happens the drop detach from this tip of the electrode we see generally tangential to the filament direction definitely this will be tangential to the filament direction. That is why the droplet are detached from the tip of the rotational filament in tangential direction producing tangential direction producing a lot of a spatter because, as this asymmetric radial force as well as azimuthal force that filament start rotating or start a start rotation.

So, due to this rotation generally what happens whatever the droplet coming out from the tip of this rotational filament that is generally tangential to that filament axis. So, what happens due to this if the filament will rotate that molten droplet also will rotate, that is why here generally produce a lot of a spatter compared to other 2 different types of spray metal transfer. Else here the filament become more narrower that is why this types of metal transfer is preferable both flat position and as well as horizontal position, because here the droplet size also comparatively smaller than the projected types of a spray metal transfer and what happen due to this high current here generally more forceful droplets is coming out from the tip of the filament.

So, as this molten droplet flow in tangential to the filament direction that is why this types of metal transfer is good for side wall fusion, what happens it is generally side of as it that this molten metal droplet moving toward the tangential direction of the filament is that is why what happens for sidewall fusion in case of flat position welding it is its generally produce good quality welding. So, here this is return so this process is greatly used to improve the sidewall penetration what it is given sidewall penetration in case of flat position and prevent the molten pool sagging during horizontal welding. That means, whatever the generally here generally chances of molten pool sagging also less if we use horizontal position welding. So, this types of metal transfer generally there it is used.

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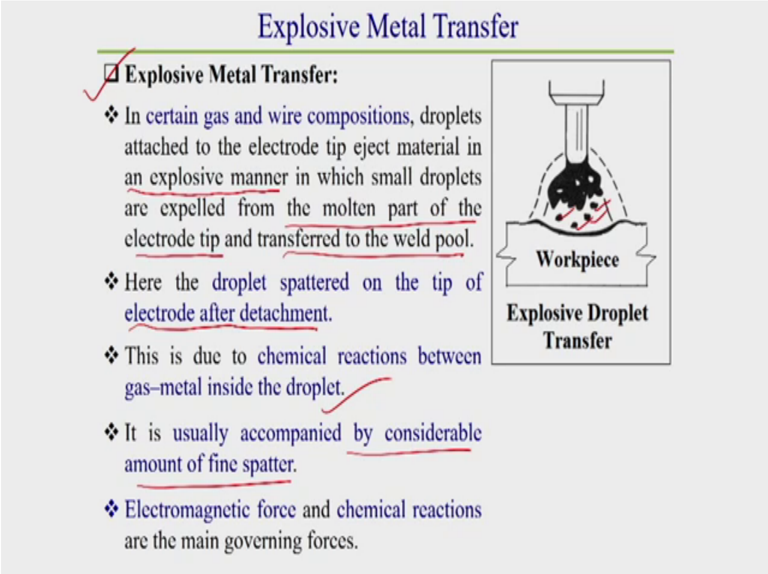


Then the another types of free flight metal transfer is called Explosive metal transfer, in certain gas and wire compositions droplets attached to the electrode tip is material in an explosive manner. Here the molten droplet which is ejecting from the electrode which explosive manner, in which a small droplets are expelled from the molten part of the electrode tip and transferred to the weld.

So, what happens here generally droplet is explosive in nature and due to this explosion this small droplet generally are expelled from the electrode tip and transferred to the weld pool it is this small droplet transferred to weld pool. Here the droplet spatter on the tip of the electrode after detachment here one things we should keep it in mind here generally spattering taken place, that means droplet is spattering taken place closer to the at the tip of the electrode itself.

Whereas, in other a spray transfer or other types of free flight transfer whatever the spattering is taken place that generally taken place over the surface of the work piece itself due to falling of this droplet on the molten pool. So, there is a chance of a spattering types of a flashing out the molten droplet is there.

But here due to this explosion what happens here the explosion of this droplet what happens here spattering is occur on the tip of the electrode itself. Why this is happen? This is happen due to gas metal reaction inside the droplet this is occur due to gas metal ratio inside the how it is occur that also I will discuss. It is usually accompanied by a considerable amount of a spattering what I have told you due to this explosion in nature of the droplet. Here also considerable amount of a spattering is occur here considerable amount of finest spatter actually because, due to explosion droplet converted to fine particle fine particle or fine droplet, due to that what happens here fine considerable amount of fine spattering is also occurs here.

Here which one is the governing force here? Here generally governing force is where generally 2 different governing force is acting here which one is electromagnetic force, second one as generally chemical reaction also. Another due to chemical reaction whatever the force are there that force responsible for this types of metal transfer. This types of metal transfer generally occurs case of some metal transfer there can be hydrogen gas oxygen gas inside the droplet.

This hydrogen gas oxygen gas this element generally can react with some molten metal element generally like Carbon. So, with carbon generally what happens if this oxygen reaction taken place, then this carbon with oxygen what happens it converted to carbon dioxide with time this size of this carbon dioxide generally increases.

So, what happens due to this increase of time its volume increases, so after certain after certain time, this volume becomes inside the volume that generally explosion occur due to this explosion droplet generally converted to converted to multiple number of a small particle of droplets. So, this is occurred due to that that means, due to this gas metal or gas material reaction gas material chemical reaction. So, this is one types of example of gas material reaction that is carbon with oxygen once it react generally what happen there is produced carbon dioxide gas, this carbon dioxide inside the droplet with time its volume increases.

So, what happens due to once it is volume goes higher and higher side then after some time there generally occurs some explosion. Due to this explosion this droplet generally burst out and what happens? Small particle of these droplet converted to a small particle ok, which is like this and it is this small particle generally drop down to work piece and it is deposited this is generally also a free flight transfer, here also there is no short circuiting of electrode and work piece is taken place.

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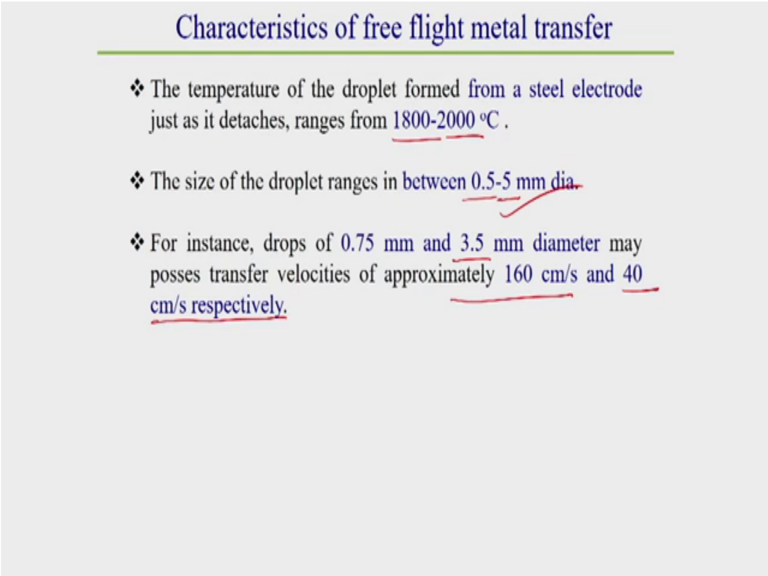


Now, this is all about explosive types of metal transfer what is the characteristics? So, we discuss about free flight metal transfer what we observe? Thar in case of free flight metal transfer, there is mainly three different categories of metal transfer observe one is globular another one is called spray and third one is called explosive.

Now, we will see what is the general characteristics of this free flight metal transfer I am discussing about metal transfer of in case of steel types of material. Here whatever the droplet generally transferred from the electrode tip to work piece, here this droplet temperature is within a range of in case of steel 1800 to 2000 degree centigrade this droplet size generally depending upon the electrode diameter. It is varying from electrode diameters and all it is this free flight metal transfer droplet size is varying from 0.5 to 5 millimeter diameter.

And this generally this drop transfer rate or drop velocity actually drop transfer velocity from electrode tip to work piece. What are the transfer velocity it is also depends on size of the droplet or we can say size of the electrode itself (Refer Time: 40:33) we observe that for a drop size of around 0.75 millimeter generally here one things we keep it in mind. That means, lower the drop size higher will be the transfer velocity definitely, smaller the size higher is the transfer velocity that that thing also here it is observed.

Generally for a size of droplet is around 0.75 millimeter dia it has a velocity is approximately 160 centimetre per second. Whereas, if the size is size of the droplet increase that means sizes size of the droplet more that is 3.5 meter millimetre, then what happens it has a velocity is around 40 centimetre per second. That means, what we observe that means it is almost proportional to the size of the droplet, that means inversely proportional to that means inversely proportional the size of the droplet. How it is? That means, higher the droplet size lesser the transfer velocity larger the droplet size a smaller the transfer velocity of droplet.

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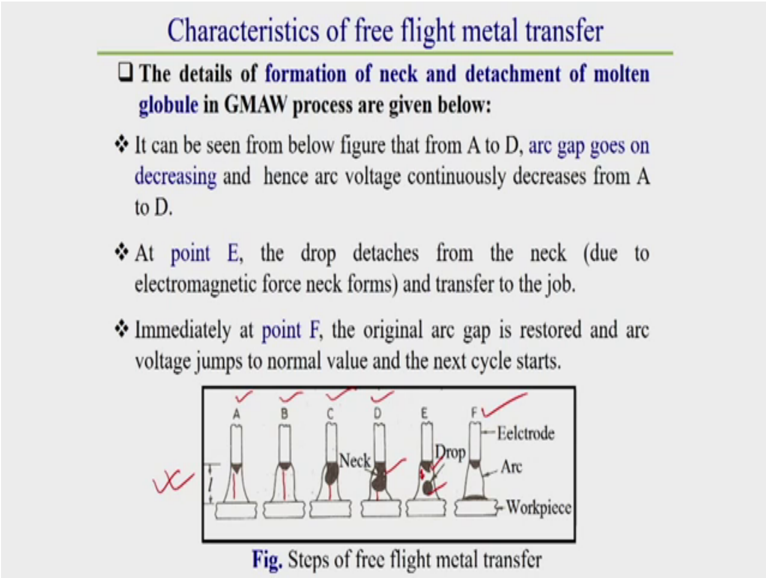

Fig. Steps of free flight metal transfer

Now, here we will see how the means drop transfer occurs and how it is current voltage characteristic in case of free flight metal transfer, that first we will observe after that we will go for other categories also how the characteristics is look like.

Now first of all here we will discuss the characteristics, that means the detail about formation of neck and detachment of molten globule in case of GMAW process which is here generally we are discussing. Here what happens from this figure you can observe all the things very clearly, it can be seen from the below figure that from A to D; that means, from here to here what we are observing here generally arc gap, generally here whatever the arc gap where there that arc gap generally gradually decreasing or so generally arc gap goes on decreasing from A to B.

So, here due to this decrease of arc gap what we will observe here voltage will drop down definitely voltage will be decreasing. So, from A to D this voltage drop continuously generally voltage continuously decreases from A to D, due to this decrease of arc gap. At E due to this high electromagnetic forces whatever the things I have discussed, generally due to this high electromagnetic forces at point D itself this neck formation start and at E generally drop detach from the electrode tip to work piece like here. Already detachment is taken place here one things you can see here already detachment is taken place.

So, once this arc detach from electrode to work piece then generally it is regain to it is original arc length that means what happens here arc length restored to it is original length. Due to that here arc voltage return back to it is original value. So, what happens again at fine tip generally next cycle of molten metal transfer start? How the things is occurring we understand, so from A to D generally due to decreasing the arc length, here the arc voltage gradually decreases. Once the droplet detach from the; what it is call electrode then what happens it regain to it is original arc length and the arch voltage return back to it is original position.

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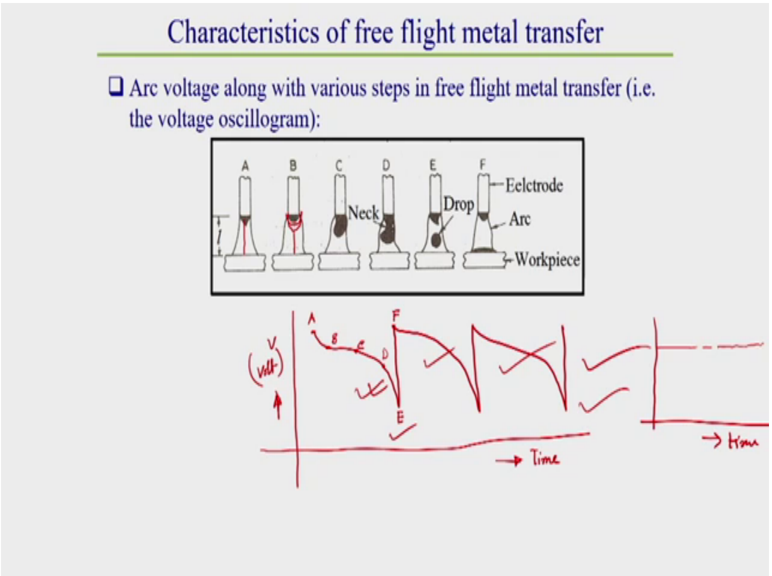


So, how the oscillogram of this arc voltage is look like that I am just discussing here, then you will get the very good idea from here how the oscillogram of this let this axis represent this axis represent time and this axis represent voltage voltage voltage. So, how the oscillogram of this thing will look like then it will be very clear to you, this oscillogram of this free flight metal transfer is look like this. So, what happens or here I am describing then it will be clear. So, this is let us point A; here generally original arc voltage is there. So, once this arc voltage is there that means arc gap is there arc gap is original arc gap without droplet.

So, what happens once this drop size increase then due to this increase of drop side you see generally the drop arc length decreases. So, due to this generally what happens? Here what we observe this let this is point B this is point C this is point D and what happens once this drop down taken place at point E, here generally suddenly this arc voltage regain to it is original value F.

That means, here generally time is negligible E to F generally what happens once the drop detach from the electrode immediately generally drop jump to it is original value. What we can say here immediately generally arc gap restore and arc voltage return back to its original value here A to F. So, how this A to D this arc voltage decreases arc voltage decreases because, due to this decrease of gap between electrode and work piece. So, this is generally called oscillogram in case of free flight types of metal transfer.

This time what happens how this voltage is varying in case drop transfer that we can observe here, this types of number of steps this types of number of sequence we observed within a microsecond. That means, if here the drop transfer rate is 100 per second, that means 1 by 100 second we will get this types of on curve on this types of one only oscillogram.

So, here one drop transfer from A to F 1 transfer drop transfer here another drop transfer here another drop transfer generally taken place, it depends on the time generally what should be the time value in between a drop transfer that within this time. Then that means, if it is 10 100 drop per second that means within 1 by 100 second we get a this types of pattern of or this types of variation of welding. Actually this types of welding voltage variation of welding voltage generally we observe in case what is called free flight types of metal transfer.

In this free flight types of material transfer generally one things you keep it in mind this current is almost a steady nature, that means current here does not varying with time, here almost negligible variation of current is observed in case of free flight types of metal transfer. So, this is generally voltage if we draw the current variation with time, so there generally we will get almost steadily varying. That means, is steady in nature that means welding current is almost constant over the entire welding time, so your current does not depends on this time here.

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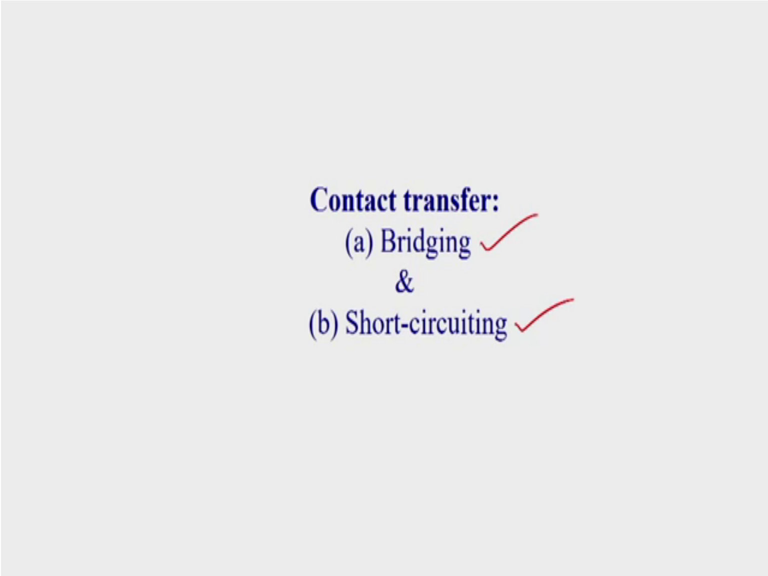


Now, we will go for the next categories of metal transfer that is called Contact transfer what. So, so in case of free flight metal transfer we got 3 different categories now in case of Contact metal transfer, here also we observe there are 2 different categories of metal transfer one is called Bridging types of metal transfer, another one is called Short circuiting types of metal transfer bridging means there is a linking of one droplet with another droplet.

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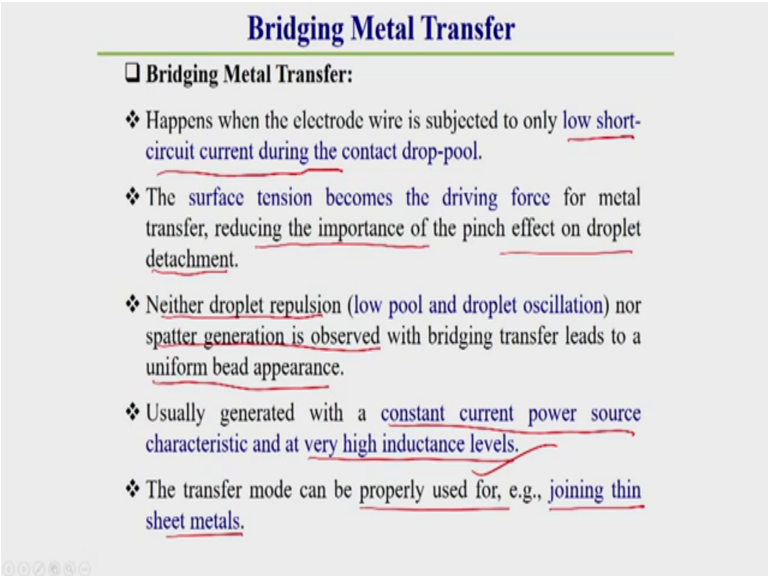

So, first of all we will discuss about bridging types of metal transfer, then we will go for short circuiting types of metal transfer. In case of this bridging types of metal transfer generally this metal transfer happens when the electrode wire is subjected to only very low short circuiting types of current during the contact drop pool. So, here generally one thing we keep it in mind here this is a bridging is a contact or short circuiting types of metal transfer.

So, here generally in case of this contact metal transfer means here the drop contact with work piece after that it detachment is occur. So, this contact or this shorting of molten droplet with work piece is occur once this occur within a very low short circuit current, then whatever the metal transfer is taken place that is generally bridging types of metal transfer. Here there is a linking of one droplet with other droplet are linking of molten droplet with work piece and electrode are there.

Here one things we should keep it in mind as here the cut circuiting current is low and here surface tension force is the main driving force in this size of metal transfer. Because once the drop contact with this work piece then what happens this drops detaching taken place due to surface tension force between work piece and molten droplet. Here as the surface tension force is the driving force that that is why here generally reducing the importance of pinch effect on drop detachment. So, here the importance of pinch effect is less pinch effect is not act as a driving force here, here another things we should keep it in mind neither droplet repulsion nor a spatter generation is observed with bridging transfer. Generally which leads to a uniform bead appearance generally, in case of bridging transfer generally we can get a very uniform weld bead shape because, here the droplet repulsion nor a spattering generation is observed here.

Why this droplet repulsion is less because here the current range short circuiting current is comparatively very less, due to that there is observe very low pool and droplet oscillation. Whatever the weld pool are there weld pool and whatever the droplet are there that oscillation is also very less here and in this case of metal transfer, this types of metal transfer we observe all the power source is constant current power source characteristics and at a very high inductance level generally this types of metal transfer we observe.

I have already discussed what is the function of inductance; inductance means higher the inductance generally slower the rise of current. That means, with rapid with quicker change of voltage there will be very slower change of current. So, change of current or rise of current is very slow with higher inductance level that is why this types of metal transfer used in case of constant current power source with a very high inductance level. This transfer more generally properly used for joining thin sheet metal, so this preferable for thin sheet metal and it is properly used also.

In next class I will discuss about the another categories of short circuiting metal transfer and I will also discuss about slag protected metal transfer in details, after that I will discuss what are the effect of different operating parameter in case of metal transfer also.