Welding Processes
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Modes of droplet transfer Part 02

Good, so we looked at in last class the force balance and the metal transfer kinetics. So we looked at various forces that aid the metal transfer and the forces which resist the transfer, so what are the forces that aid the metal transfer? Gravity if it is favourable, so if the angle between the arc access and the vertical okay so if it is parallel or zero then you get maximum, okay so that means that it down hand welding so you get the gravity influenced favourably for detaching the droplet, okay the droplet size also influenced by force balance.

If the gravity is the major force that controls the detachment then the globes, the droplets should gain enough mass to maximize the gravitational force and then we looked at the second force which is plasma drag force or aerodynamic force which is a function of a shielding gas as well as the process characteristics, okay so that you can play around by changing the velocity and you can also change by changing the shielding gas.

So the gas which gives the maximum arc core density or plasma jet velocity so you will also promote by detachment by making or by inducing the more plasma drag force. And then (()) (1:45) force, what is the (())(1:49) force? Lorentz force, so Lorentz force in most of the cases it aids the detachment, especially if the Lorentz force is diverging from the tip that aids the detachment and if it converges than it resist the detachment.

So the Lorentz force in most of the welding cases it aids and Lorentz force becomes rate controlling when the current is increased to beyond critical limit, especially so when the current is increased and you also see the change in droplet diameter from the globular to repelled globular and then it becomes spray. So in spray case in spray transfer case the Lorentz force is rate controlling and the droplet diameter becomes equal or less than the wire diameter when you achieve the spray transition.

And what are the two other forces which resist the detachment? Surface tension and then vapour pressure. So vapour pressure is created because of the vaporization of weld pool and (the pressure) the vapour which is generated it push towards droplet and this vapour force generated from this vapour always resist the detachment. And the vapour force is also the reason why you have a repelled transfer, so globular becomes repelled globular because the vapour push vapour pressure pushes the droplet leading to change in shape and due to that you also change the magnetic force that is inside the droplet and then the droplet becomes from globular to the shape of circus buffoon shoe.

So we looked at the video as well, so how the repelled transfer takes place, slightly higher current with high vapour jet force pushing the droplet. So these are the 5 major forces that control the droplet detachment and we also looked at an example using 1.2 mm carbon wire, so how the droplet transfer change as a function of current?

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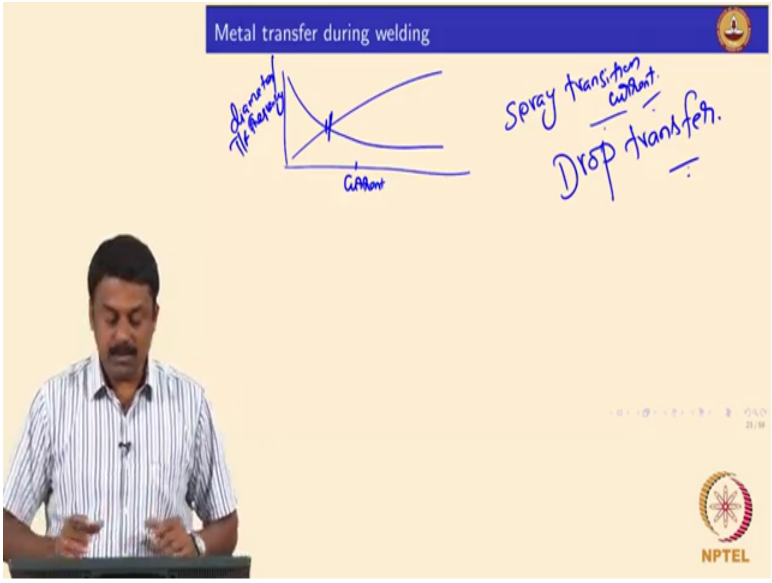

So we looked at the curve okay so diameter R transfer frequency has a function of current. Now how does the diameter change? So we have a larger diameter because at lower current gravity is the major rate controlling, so you need to generate enough mass so it decreases like that upon certain current from globular it becomes spray. So the transfer frequency increases as a function of current as well, so upon certain current the transition becomes from globular or repelled globular to spray and that current is known as spray transition current.

So most of the GMAW operations are carried out in an around spray transition, so that we promote spray transition and we also make sure that the transfer is stable. So if we increase the current further the spray transition becomes jetting spray. So then there is a possibility of creating spatter and the explosion when the droplet is detached because of tremendous increase in Lorentz force as well as the vapour pressure because when you increase the current the arc the current density also increases E, so the heat generated in the arc also increases tremendously so you end up generating more heat, the heat input increases or arc energy increases because (())(5:49) by speed is the arc energy.

So once the arc energy increases you also input more heat leading to vaporization and that can influence the detachment as well. So if you increase the current much beyond spray transition so jetting spray or even further rotating jetting spray or even exposure transfer can takes place. So for the most stable operations the GMAW welding is generally carried out in and around spray transition current.

So that is very important the window we operate, so when you design a welding procedure specification WPS so one of the factors which actually we consider is the spray transition and what current for wire diameter spray transition is observed and then we play around the other parameters. Say for example if you want to control the heat input so we can also play around with the shielding gas or you can also play around with the arc length, wire feed rate and so on so forth, is it clear?

So the ideal transfer is spray transition, so when the current is in and around spray transition you get an ideal transfer in spray mode where the droplet diameter is almost equal to the filler diameter okay so that transfer is known as drop transfer. So this drop transfer happens just above the spray transition where the droplet is transferred, the diameter equal to the filler wire and this is consider ideal transfer mode because and you also increase the productivity by achieving the spray and the droplet becomes very stable and it is not deflected and if you have repelled globular or jetting spray so your droplet transfer is deflected to the other directions that the arc centre.

So when you achieve a drop transfer you transfer a droplet precisely at the arc centre as well as the diameter equal to the filler wire with a very good transfer frequency.

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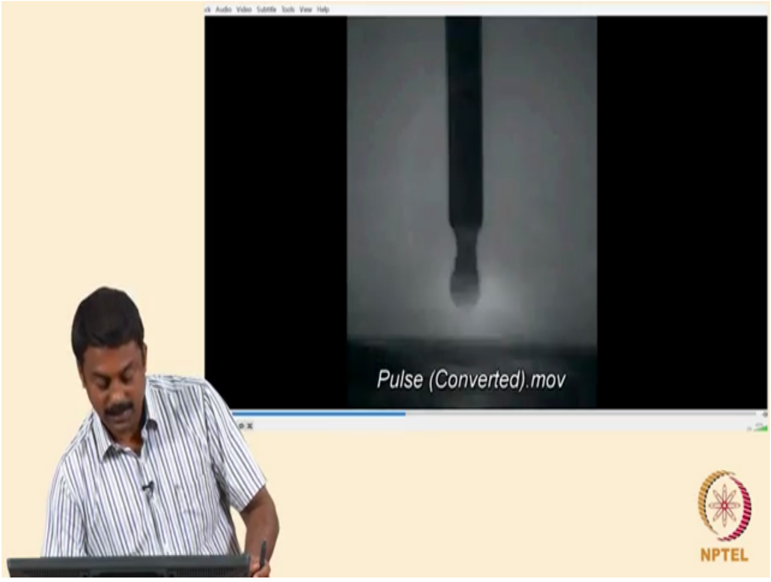

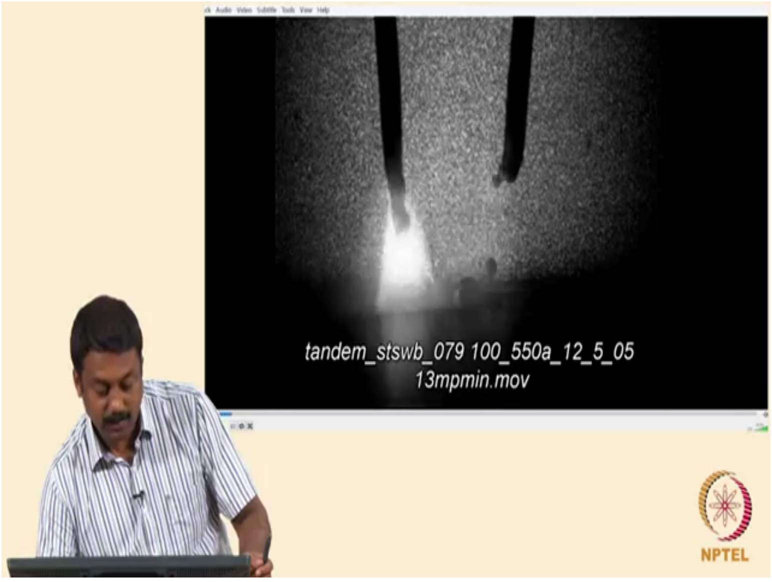

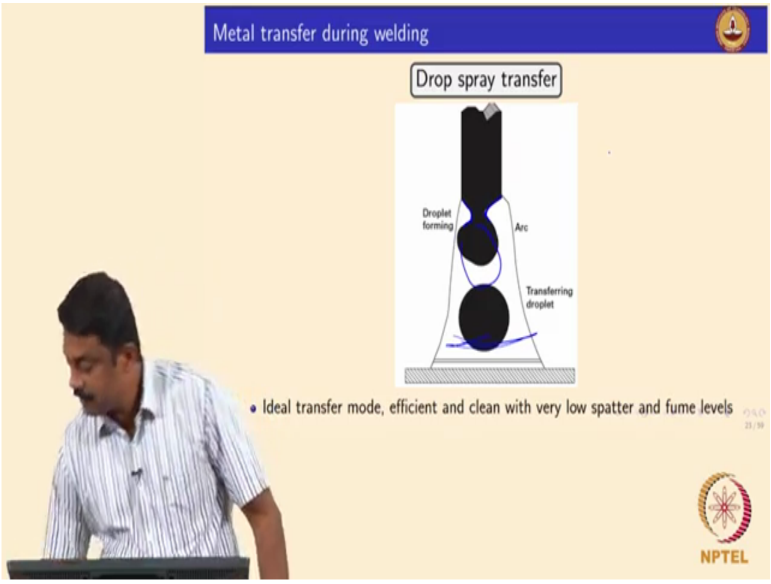

So this drop transfer we consider the best transfer mode this is spray because it is transferred continuously it generally happens just above the spray transition current so once you achieve such a transfer and this is the best transfer mode you can have, so this is known as (drop transfer spray) drop spray transfer where the droplet diameter is equal to the filler diameter.

So it happens in such a way that so you have a droplet molten and then you form a neck so when the droplet the transfer forces succeed the detachment forces and droplet is getting detached by forming a neck because it is overcoming surface tension and the vapour (()) (9:15). So you form a neck and then droplet is detached as a free flight with the diameter equal to the filler diameter and this happens continuously in a spray mode.

If you have jetting spray then the droplet detached will be attached to the other droplet is coming out. So then you will have continuous (())(9:38) of a molten droplet transferred and if that is the case and you also create enormous the magnetic field inside the droplet and you would see the droplet once you achieve jetting spray the transfer the spray would be oscillating or sometimes even rotating because of the influence of the magnetic field in Lorentz force and that is not advisable.

Because then that will lead to spatter and the moment the liquid metal more surface area is exposed to arc you also vaporize and that would lead to the increased fume generation or the smoke generation and then you will also have a spatter so the moment you create enormous amount of Lorentz force vapour can also explode the droplet can also be exploded. So this is the ideal transfer you would get which is in spray mode where the droplet diameter is equal to the filler wire diameter and this can be achieved in most of the cases by using pulsing, so the pulsed current promotes drop transfer.

So we will come back to that later but we will look at the video how this transfer happens in real life, okay you see that so I am giving a pulse here and every pulse there is a droplet detached and this is recorded using high speed camera so what you see over here is it happened in within a second the entire video even less than a second. So you transfer as much droplet as possible so when you are recording with high speed with frames of 10000 frames per second so you would see number of droplet detached.

So you see that there is a neck formation so the neck formation is very critical here so the moment the droplet is formed it is pulled down by the Lorentz force plus the gravity and as well as the plasma jet force. So droplet once it forms the surface tension is trying to keep the droplet that is why you form the neck, the force so the aiding force should resist the surface tension.

So this neck formation is due to this surface tension which is trying to keep the droplet intact with the wire. So once the neck is formed obviously the increased Lorentz force would pull the droplet down. So this is the drop spray and this is the most preferred the metal transfer mode in GMAW where you have a spray mode so you are not compromising the productivity and also the droplet is extremely stable and it transfer to the work piece at the right angle which is actually beneficial because then you can also control the metal transfer such a way that you will have a less spatter, is it clear?

So compared to this and if you have a spray a jetting spray and the globular or globular repelled transfer and you have so material will be the droplet will be transferred to much larger area you see here this is sort of the diameter when it is transferred much smaller than the filler wire diameter and it is also continuous spray. So this is what known as jetting spray, you see that droplet is transferred to a varying angle, same here when you transfer in globular or repelled globular and you also form lot of spatter so because of huge mass it is exposed to the arc column pressure and you also create an magnetic field because of the Lorentz force that are contained in the droplet and you may expect the droplet to explode sometimes causing spatter, whereas in jetting spray you have a high productivity because the transfer rate is much higher but the stability of the process is effected because of the exceeding forces that aids the droplet transfer which are Lorentz force and then plasma jet force, is it clear?

So the most preferred the transfer mode is the drop spray mode, where you transfer the droplet the diameter similar to the filler wire and this happens just above spray transition.

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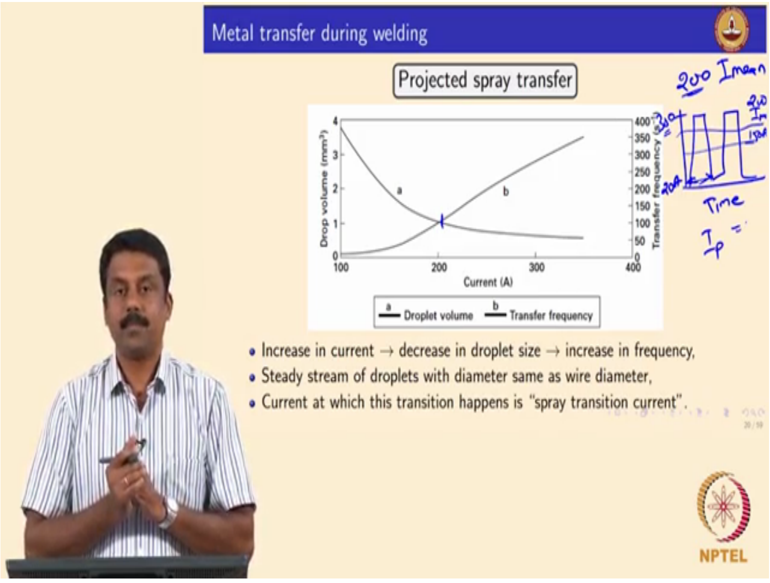

So in order to achieve the spray transition and you will have to have the current increased to certain amount, so you will have to increase the current to certain amount say about 200 amperes in this case and if you have a constant current so then you will have to give above 200 amperes, but when you are doing pulsing then you can also achieve this mean current by giving a pulsing where the I mean will be much lower.

For example in a constant current mode if spray transfer happens at 200 I mean mean current and you can also achieve the spray transition when you are giving pulsing you can pulse between 350 amperes to say minimum say 20 amperes and this is time, whereas in this case the mean current will be much much lower than 200 amperes in pulsing, but still you may achieve the spray transition because so when you are giving one pulsing and during this pulsing the current goes 350 amperes I p the peak current.

So you would immediately melt the droplet and droplet can detach because of the increasing in Lorentz force, whereas in this case the current is constant, where in I mean in constant current is 200 amperes, whereas in here in 150 amperes in the pulsing case you can achieve a droplet transfer in drop spray mode that is why pulsing is always advantageous because you can achieve the spray transfer in much lower mean current.

Again we will see in detail when we are looking pulse GMAW, so right now what I want to say here is in order to promote the spray we will have to increase the current above spray transition current and the spray transition current for constant current GMAW whereas in pulse current GMAW the mean current will be different, in pulse GMAW the mean current will be much lower to achieve the spray transition, is it clear? Any question so far? Okay, good.

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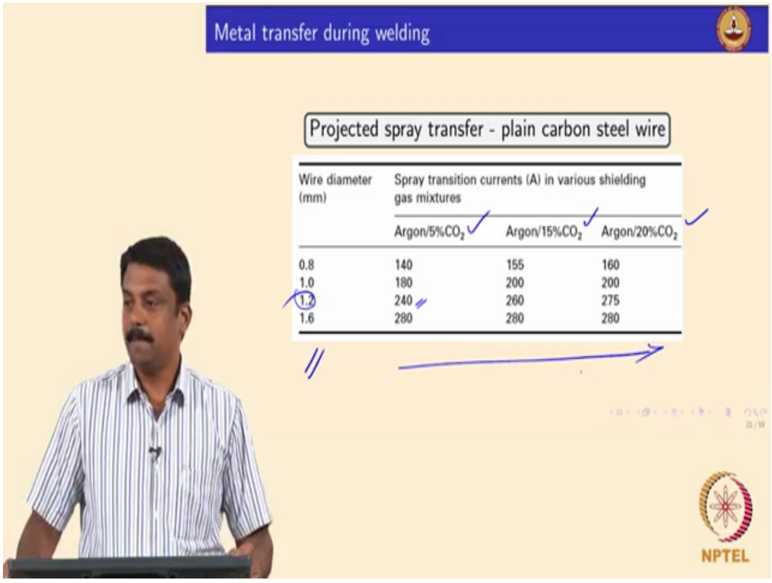

So the varying as a function of diameter the spray transition current also changes. Say for example for a given shielding gas for 1.2 mm filler wire that is the most commonly used filler wire diameter, so in this case plane carbon steel wire 240 is the spray transition current in a constant current configuration and if you are using pulsing it can happen 200 amperes much lower than what you have it in a constant current mode, alright.

And you also see increasing carbon di oxide what happens? Spray transition current increases, why? Because the arc energy, the heat in arc the heat energy in arc is decreasing because of increasing carbon di oxide so you need to increase the current to compensate the decreasing in heat distribution in the arc, again it comes from the physics of shielding, is it clear? Good.

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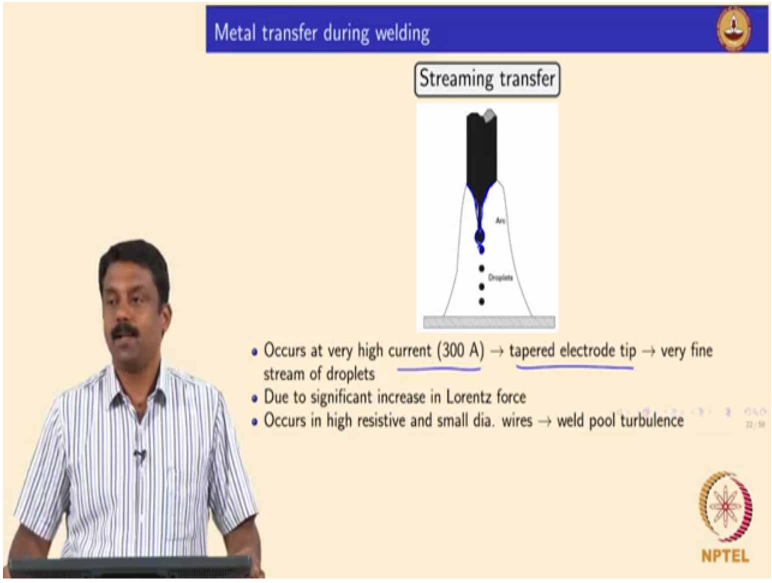

So when you increase the current even further from drop spray, spray becomes streaming spray, so streaming spray is characterized by so much smaller in diameter of the filler which is transferring to the work piece and you have a continuous smaller diameter overlapping leading to a complete spray continuous spray going to the work piece, it happens in very high current generally in 1.2 mm plane carbon steel more than 300 amperes and then leading to a partial moulting of the tapering of the electrode tip and then you get a very fine droplet in transferring.

So this happens because of significance increasing Lorentz force because very high current. So generally it happens in high resistance and smaller diameter filler because then you also promote the (())(19:44) of Lorentz force and once you have the streaming transfer it will also cause weld pool turbulence. So obviously you have enormous amount of liquid going like open in a bucket open tap at high speed and another bucket you open a bucket in a drop which would have a maximum turbulence so obviously when you open a tap fully then you see the enormous turbulence in the bucket of water.

So because of that the weld pool stability is also decreasing, you also effect the fluid flow, your fluid flow is not controlled then you also have influence of this in the subsequent nucleation the microstructure development as well, is it clear?

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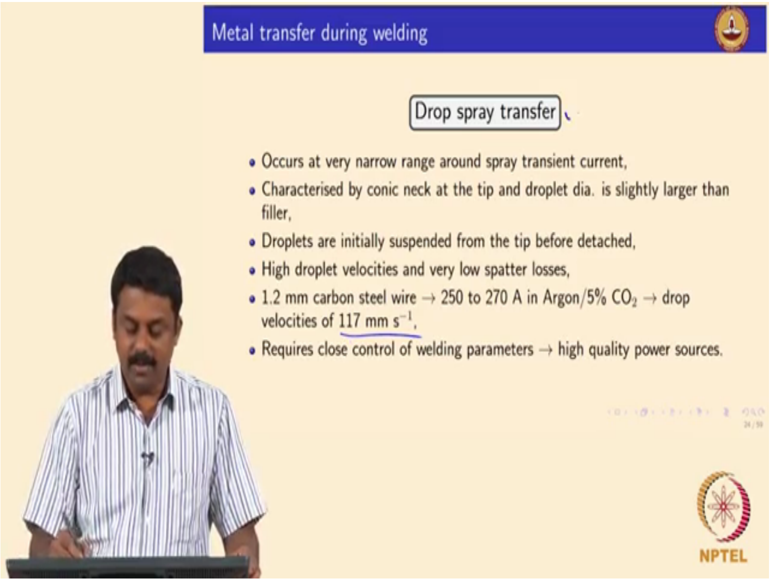

So we will look at drop transfer so main characteristic I have just listed down the drop transfer is which is the ideal transfer mode, it occurs very narrow range just above the spray transition. So from the video what do you saw? It is characterized by conic neck at the tip and diameter is equal to the filler wire diameter. So you see the droplet is suspended by the surface tension and then detached and this mode we can also achieve a high droplet transfer rate with very low spatter.

So if you look at 1.2 mm carbon steel wire it happens 250 to 270 amperage with argon 5 percent CO2 so you see the velocity drop velocity is of 117 mm per second you can achieve. So in order to achieve this transfer the parameter should be closely controlled 250 to 270 amperes so that is the range you need to operate in a constant current. In a pulsing it is promoted because we can play around each pulse we can make one droplet transferred like a video I showed you. So what is the ideal transfer? It is a drop spray transfer.