Welding Processes
Prof. Murugaiyan Amirthalingan
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras
Dual gas GTAW and Plasma Welding processes

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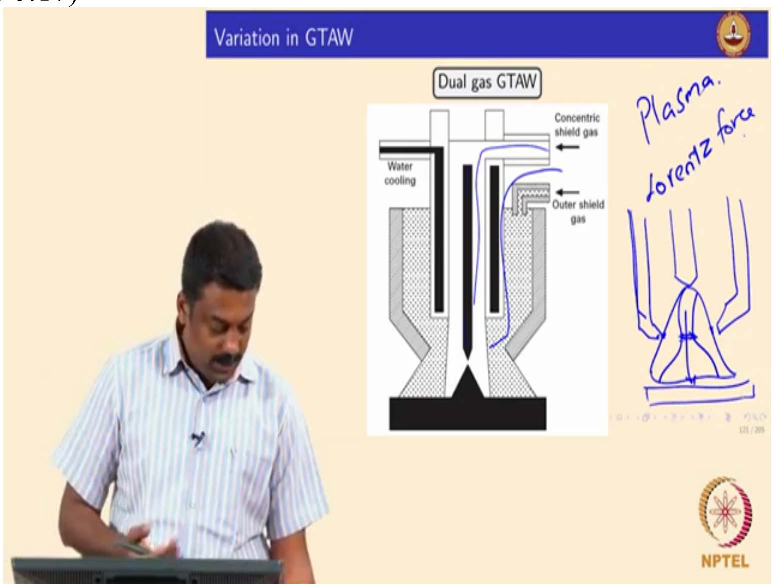

So we will move onto the another modification, we looked at pulsed, and square-wave DC. So we looked at the variable polarity DC and then we were looking at in the last case the cold and hot wire GTAW. So now we move onto the another interesting modification, we have done GTAW and which is commercially used extensively, is plasma. So recall, so why we are not calling plasma welding as arc welding or arc welding as plasma welding? Because they are two different entities. So when I taught you the physics of arc, the plasma is a state, is not it?

So it is said that arc becomes plasma when the arc becomes electrically neutral. So you need to achieve a condition such that the kinetic energy of all the energy carriers, be it an electron ion, must be the same. But in arc you do not reach that state. So you need to do some trick to make, to convert arc into plasma. So that means that we have to increase the charge carriers density in the arc in a such way that they become neutralized. Is it? Okay. So the one way of doing it is we need to increase the arc temperature tremendously.

We need to increase temperature tremendously so that we generate more ions and we generate in that more electrons and they collide to generate much more heat in such a way that you neutralize the arc column. So one way of doing it, no, again, so you can increase the current, keep on increasing it to maximum levels, so that is advantage because then you will also increase the heat input, the amount of heat goes in.

So other way of doing it is we carefully manipulate the heat transfer characteristic of the arc. So again heat transfer in arc is carried out by three ways, how? In what ways? The conduction and radiation. So conduction and radiation, we cannot do anything. So we cannot modify anything but we can manipulate the conductive heat transfer. So what are the two mechanism by which conductive heat transfer takes place?

Student is answering: Buoyancy.

Buoyancy and plasma jet formation. So what is buoyancy? How do you define buoyancy? Then same difference. So at the middle of the arc so we have high temperature whereas arc envelope you have low temperature and because of that we have a flow. And similarly in plasma jet formation, so what happens? The heat is transferred by plasma jet formation due to the generation of Lorentz force, is not it? So when the fundamental energy carrier, the particles, for example, electrons and ions, they are coming closer, they repel each other.

The closer they come, the more the force they generate in repelling action. That is Lorentz force fundamental, right? So we need to play around with these two phenomena so that we can increase the plasma jet velocities. So in that what you need to know? Now we need to bring these fundamental particles close to the center in such a way that, so we increase the plasma jet velocities. By doing so, we can increase the arc core. The moment you increase the arc core, obviously so you also increase the temperature significantly throughout the arc. And that lead to plasma state.

So you can pump up lot of current but then it is not really practical. So simply what we can do is we can just cool the arc envelope at a given location. For example, if you have one the arc formed, bell shaped arc, so what we do is, the trick is here, so we will have one additional gas coming at the halfway between the electrode and waste material when the arc is struck. And then we cool a certain area at the envelope of the arc. So by doing so, what we are doing is we constructing the arc, is not it?

So the arc envelope diameter decreases significantly. So locally we change the diameter of the arc, is not it? That means that we create enormous amount of Lorentz force, because we are pushing the electrons and ions close to each other. So when they are pushed close to each other, what happens? They will repel with enormous amount of force, is not it? So obviously they are pushed along this direction. They would tend to travel in other direction. Because of increasing Lorentz force, by constructing the arc, we increase the core diameter.

And the electrons are compressed, that means that you increase the local electron density. Thereby, you also produce more ions, and they collide each other and they neutralize. And because the density is so narrowly placed, and you reach the electric neutrality. Is that clear? So by just doing a simple trick, by cooling an arc, by using an external shielding gas, we can constrict the movement of the electrons and ions. So if you are constricting the movement, obviously they collide each other, they generate more ions and more electrons.

So then you can reach a state at which the arc plus the plasma is generated. By doing so, you create so much of Lorentz force, the plasma jet velocity increases tremendously, is not it? Because you increase Lorentz force means that the plasma jet velocity is also increased. So that means that without changing anything, do not change any arc energy, do not change current and voltage, by just using a simple cooling mechanism, we can increase the plasma jet formation velocities, plasma jet formation and then velocities.

And by doing so, we can achieve a very high penetration, a very high arc energy. Yes, is that clear? So trick is very simple. So we have conventional TIG, electrode, tungsten electrode and you send shielding gas and then outer shielding gas and this is sent in such a way that we cool the arc envelope at a given location. And that can lead to the arc constriction. And the moment arc is constricted or shrunk, and we pack the fundamental energy carriers like electrons and ions in a very narrow region and they would collide and interact, generate much more heat for further ionization, energy for further ionization.

And then they can get neutralized. By doing this process, we also create much higher Lorentz force because now all the particles, what are generated fundamental particles, they are generated, they are all constricted to narrow envelope. Because of Lorentz force, you increase the plasma jet velocity and that can lead to the formation of plasma. Yes, is that clear? So that is the purpose of dual gas GTAW. And yeah, it is commonly used to constrict the arc.

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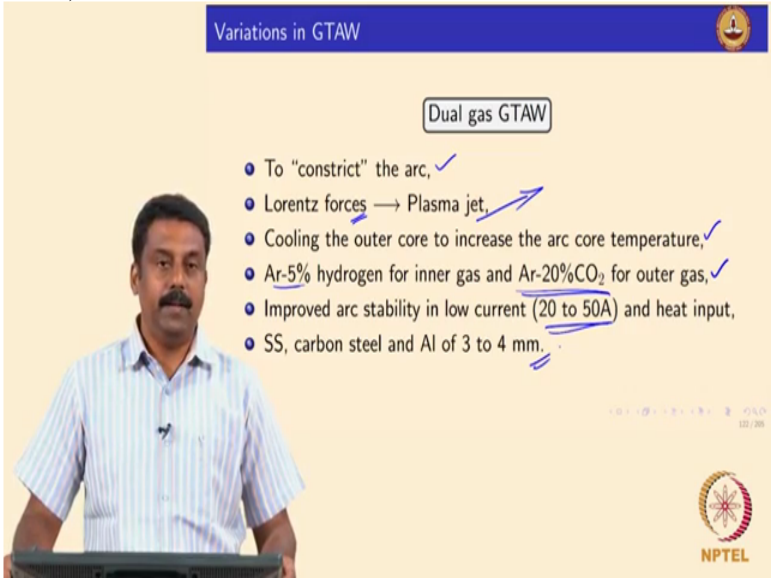

By constricting the arc, we create enormous amount of Lorentz force, leading to plasma jet velocity increase significantly. And due to that, we increase the arc core temperature and arc core becomes wider. Generally, argon is used as a plasma gas. So then we can also use somewhat cooler gas, again 20 percent CO2. Because we need to release the temperature, right? So when it ionizes, it does not release heat. So commonly used outer gas is argon 20 percent CO2. So in a gas we use argon 5 percent CO2, 5 percent hydrogen or pure argon. So argon plus 5 percent, again so it is also used to create more conative.

But we are not allowing it to conduct freely. We are constricting that with cooler gas outside, so that now the plasma jet can be formed and then transferred. Clear? So how does it work? And you can use it in, because of this modification even a very small current we can generate good amount of plasma. So we will see in subsequent slides there are even in the micro amperage we can create a plasma. So that is commonly used for welding of very thin sheets.

And we can also get because of increased plasma deformation, what is known as key hole welding. So again we will see in the subsequent slides. If you have a very good penetration, and we can also use it as for key hole welding. So we will look at it in detail in plasma welding where we use two gases instead of one gas.

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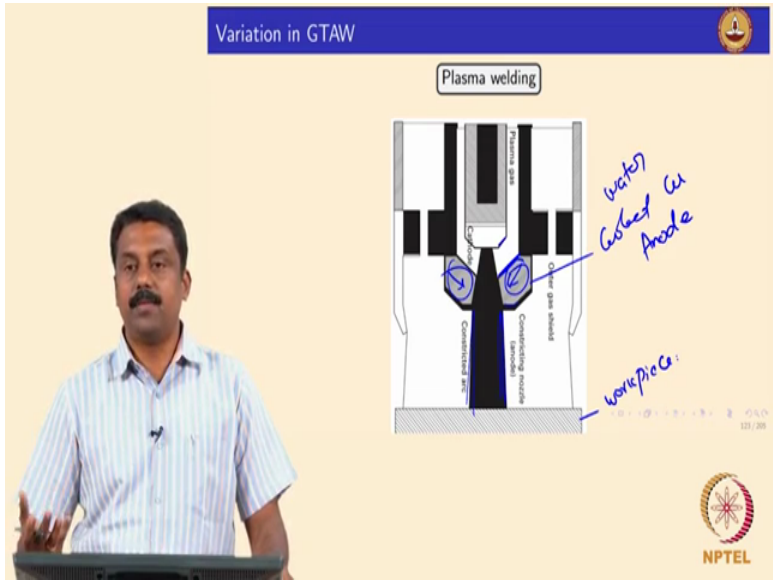

So one gas is the plasma gas, the other one is the cooling gas or outer gas. And typically what we do is here, so we have a plasma gas which is the gas used for striking an arc, in this case plasma. And then you use another additional arc piece, for example, in this case. And this arc piece passes the constricting gas. Generally this nozzle is cooled, otherwise this nozzle will heat up significantly. So generally we use water cooled copper nozzles to send the outer constricting gas so that we can form plasma jet upon constriction. So you form a plasma jet.

So plasma jet once it forms, it is considered a power beam like laser. So you can have like laser, so you can have a neutral beam with very high energy. And then we can also make advantage of this design. So we have another entity coming in in this schematic. For example, in this case water cooled copper. So in this water cooled copper, this also can be made into anode. So we can strike an arc between the cathode and then this guy and the work piece can be independent.

So it will be like an handheld beam. So we can also make use of another entity which is over here. If you make it in anode, we can strike an arc between this anode and the electrode TIG. Or we can also strike an arc between the tungsten cathode and the work piece and both are advantageous. Why? Because we can create two types of plasma. So in two mode, and then this two mode will be known as transferred arc mode or non-transferred arc mode.

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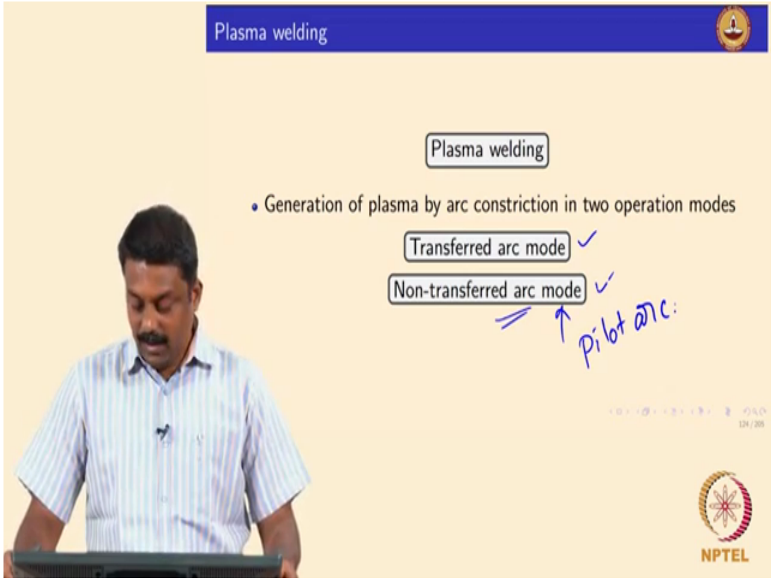

So we generate plasma by arc constriction. And you can do it in two modes, in transferred arc mode and non-transferred arc mode. In non-transferred arc mode, we strike an arc between the tungsten cathode and then the water-cooled copper nozzles which is used to constrict the arc. That is also possible to make the copper nozzles and anode, so we can strike an arc. And then you can use that as a heating medium. I will tell, I will show the videos. Or you can also convert once you make a non-transferred arc into a transferred arc.

Then as long as you know, the moment you go next to the work piece, it becomes transferred arc when you strike between the cathode and the work piece. So this arc is also known as pilot arc. So there are lot of advantages having this. So why, what advantage we can have?

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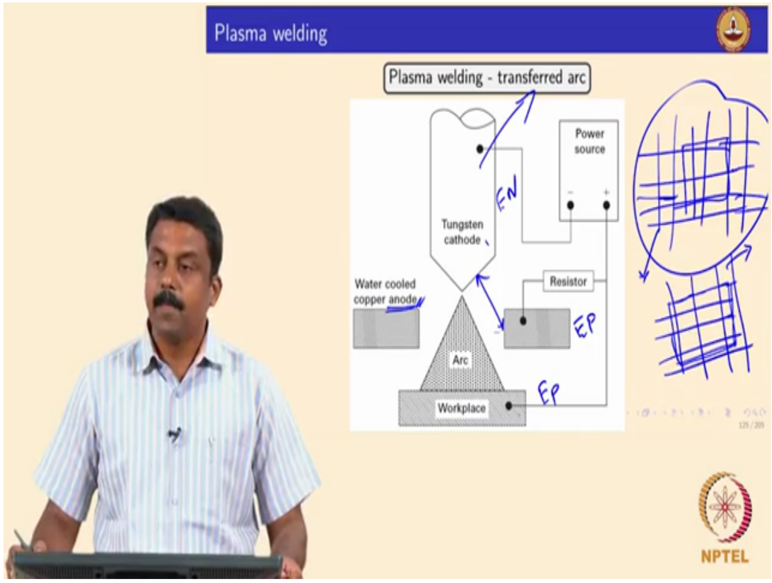

For example, in a transferred arc is like a conventional arc where you have a tungsten cathode and you have one the water-cooled copper anode which is used to constrict the arc so that the arc becomes plasma. So now you strike an arc between this workplace. So now what happens? If you remove the torch, arc goes away, is not it? So then there is not enough distance to strike an arc. That means that the workplace and the distance between the workplace and the cathode TIG should have a defined length. Otherwise, arc ignition is a problem.

So instead of doing this, we can also manipulate this configuration such a way that, so we do not strike an arc between the tungsten cathode and the workplace. We strike an arc between these two guys. So that means that we can independently move. So once you have a non-transferred arc, it is known as pilot arc, it is easy to do lot of work. For example, if you have one sort of mesh, now it is like an window mesh for example. And you need to cut and then do on welding. So if you want to cut this mesh, suppose you are using conventional torch and this is connected to the power source and your torch is connected to power source.

And this can be positive and the torch can be negative. And if you move along, the moment you go from here and you have one cut, and once you cross this wire, obviously there is no contact. The arc will extinguish. And again if you move over here, you may strike an arc. So in this case the efficiency goes down significantly. And every time we need to ignite and you need to extinguish the arc. So instead of doing that, you do not bring this into contact, in the picture. So you strike an arc between the cathode and the water-cooled copper anode.

So now your workplace is independent of the system. You always have a plasma in a pilot arc and then you can move it like any other gas welding. If your work using cylinder, you do not use power source, right? You have gas portal oxidized in bottle and then you have one torch igniter and then you cut it. Same thing can be achieved here as well because the plasma is generated by non-transferred arc by striking an arc between the cathode and copper nozzles.

So it is like any other gas cutting. And then you can also weld it. Simultaneously you cut it, I want to weld some other plate here, something like you have some shapes like this. And you need to weld in a flat panel and then cut it out. So you can weld it and then you can still keep the arc on and then you can go on and then again do it and simultaneously you can cut in this process because you always have arc on.

And whenever it goes through thicker sections, and if you connect the thicker section to power source, it becomes transferred arc, otherwise it becomes non-transferred arc. Is that clear? So in transferred arc we strike an arc between the cathode and the workplace. We still use an electronegative, electropositive. That is why it is known as anode. So you always keep this as positive and this as positive. And in non-transferred arc, workplace is independent.

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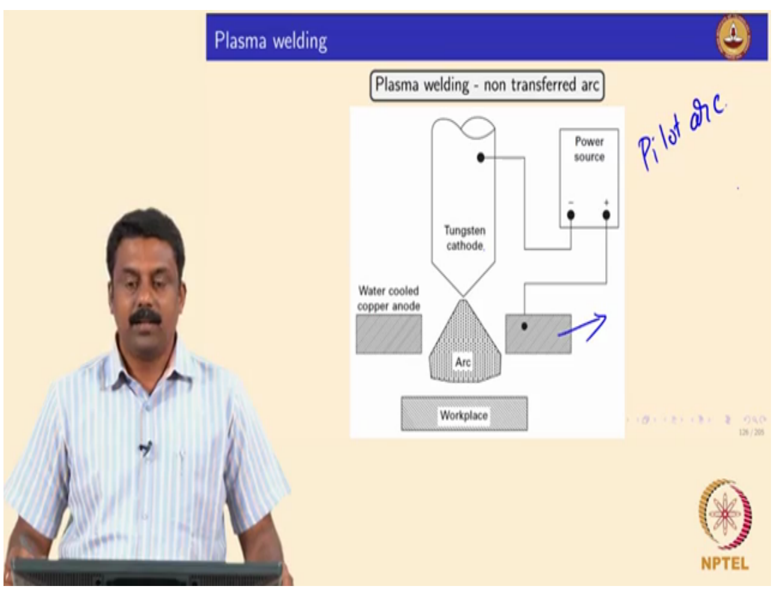

So workplace is not connected to power source at all. And the arc is struck between the cathode and then anode. Yes, is it clear? So this is very advantageous in various cases because the plasma source, that is why it is very commonly used for plasma cutting. So plasma cutting and welding, so if you have one single plasma source, we can use it for both cutting operations and welding operations because of the fact that you have arc always on whether it is transferred arc, non-transferred arc based on the need. Clear?

So the pilot arc, what is pilot arc? Pilot arc is struck between the tungsten cathode and then the copper anode. That is in your hand all the time when you are using it. When you are bringing it close to the workplace, the pilot arc can be converted into transferred arc. And you can still if you want to weld it in, the advantage is the pilot arc, the heat energy is much lower generally, so we can also use it for welding thin sections. It is like a melting that gas welding, oxidized welding because workplace is never in the contact in the circuit. Yes, is clear?

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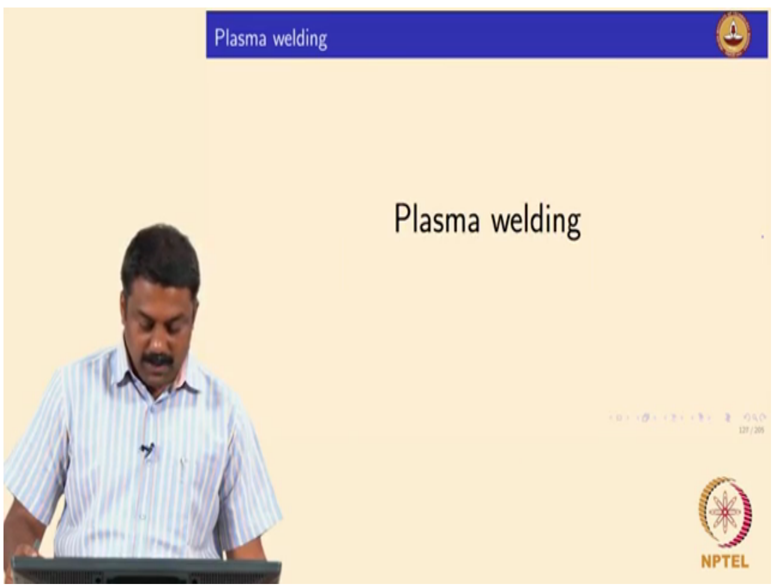

So I will show in video, so it will be very clear for you guys.

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Suppose if you want to, as I explained you want to cut and then weld such a wire frames, so now we can bring, you can connect these also in electropositive to the power source. And then and so if you bring the non-transferred arc close to the mesh, now non-transferred, transferred, non-transferred, transferred. Non-transferred, transferred. Okay. So the arc is always there. The plasma is always there. So this kind of cutting applications is very handy. And similarly you can also play around with the heat input when you are welding subsequently.

Suppose you want to cut and then you need to attach another sheet simultaneously, so you cut it out and then use a pilot arc to weld and then use the transferred arc to cut and pilot arc to weld. And consequently you do it. So it gives lot of flexibility in terms of handling complex systems like this, mesh. Similarly you can also using a pilot arc you can reduce the heat input because pilot arc can strike it even with 20 amps, less than that.

Your micro-plasma can also be generated. So all this is possible by only one trick. What is the trick? By constricting the arc. So how would we arrive at this? By understanding the physics of arc. So we know that conductive heat transfer is extremely important. So you can manipulate the conductive heat transfer, you can increase the energy density. So how do you do that? We cool the arc envelope using a gas nozzle so that we restrict the movement of electrons and ions into the core and due to that Lorentz force increases significantly leading to formation of neutral plasma.

And during this process, Lorentz force generated and this Lorentz force, increase in Lorentz force because of increasing density of electrons constricted to a very narrow core, you increase the plasma jet velocity and leading to very high energy input to the material. Is clear? Good.

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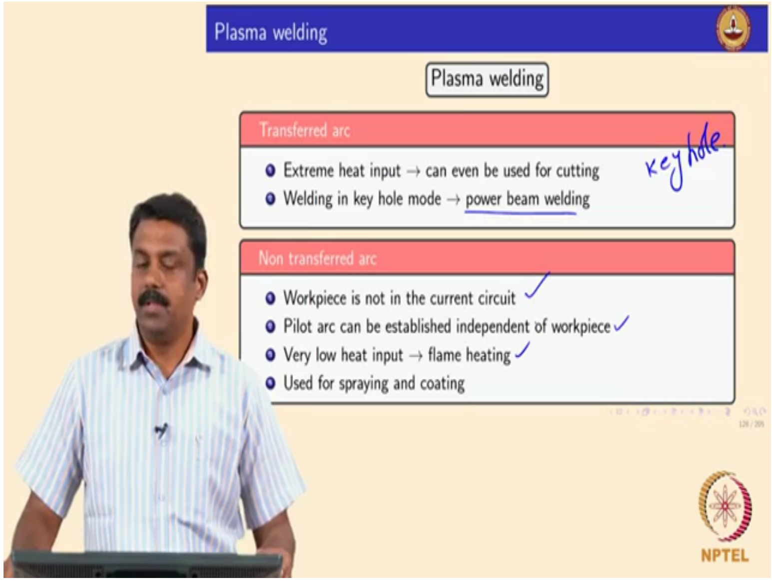

So what are the characteristics? As I said we have two modes, transferred arc mode and non-transferred arc mode. In transferred arc mode we can generate extremely high heat input. So because of the plasma jet what we form, by constricting the arc can have what you know as key hole welding. What is key hole welding? We will see in subsequent slides. So if you have complete full penetration, so we can achieve what is commonly used achieved in laser welding. So the power density of the beam can be as good as even higher than some of the lasers what we use. So similar to that is what you known as power beam welding in key hold mode.

In non-transferred arc, it is always very handy because workplace is never in the current circuit. The arc is struck between the cathode and the copper anode. So it is established in workplace and it can be used for heating and spraying, coating. So if you want to do an electro, sorry, if you want to have cladding powered disposal, you can use simple powder. And you can modify the torch, conventional ET torch into plasma torch. So very simple.

Only thing is you need to have a constricting nozzle attached to that. And generally we use a slightly larger diameter of tungsten electrode because the energy density at the tip increases tremendously because of the arc constriction. So the diameter of the tungsten electrode we use for plasma is much higher than use it for GTAW. Good.

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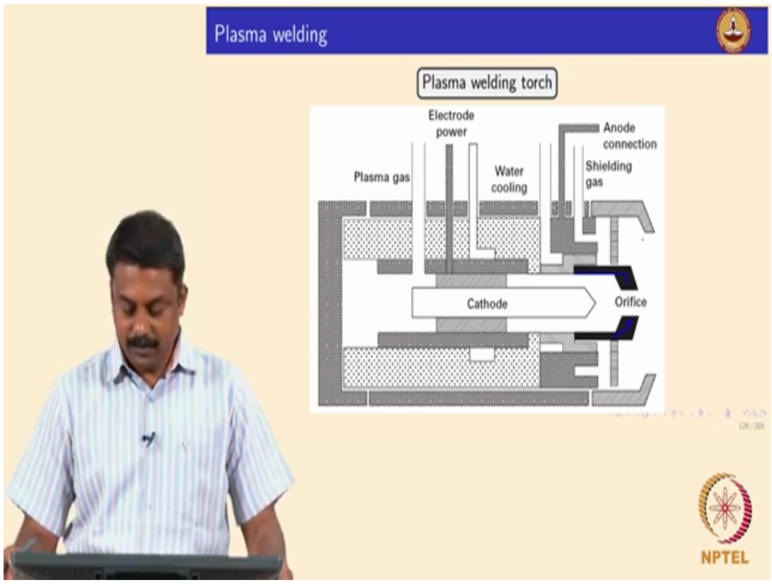

Yeah, so you need to modify, it is not that straightforward. So you need to have a proper cooling channels for the copper anode to made. So you have one cathode, you have one constricting gas coming in and you have plasma gas and you also have one additional shielding gas. So other advantage over here is because you use an extra shielding here, so the workplace is protected even better compared to the conventional GTAW. Yes, is clear? Good.

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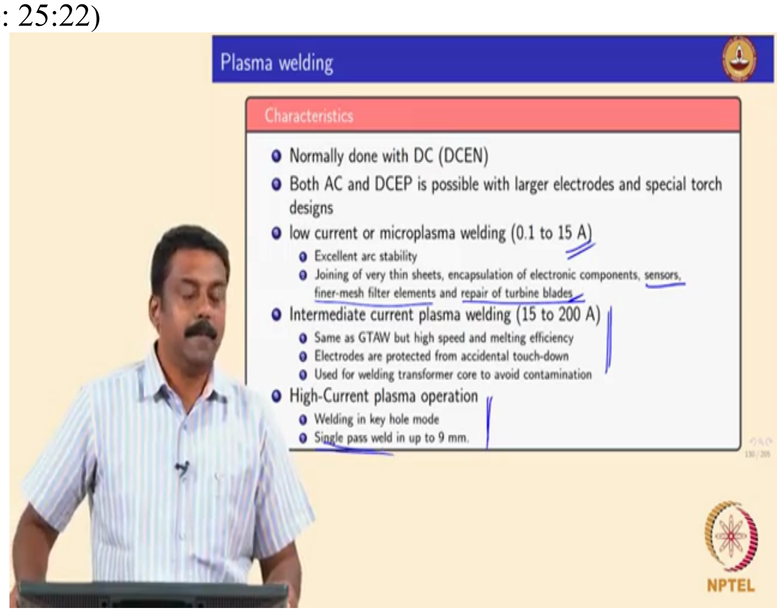

So some of the characteristics I said, now because we can generate with even very low current plasma, so we can do it in various amperage, with extremely low amperage, 15 amps, that is called micro-plasma. We can still get very good arc stability, it is used for welding very thin sheets, the electronic components for example, sensors, so filler elements. And sometimes we also use micro-plasma to repair the LED worn out parts like depositing with powder or with wire.

In these applications if you are repairing a large component, you cannot establish a good electrical circuit. So how can you make entire component electropositive? So if you want to repair a small area in the component, so you can use then non-transferred pilot arc and use a powder and locally deposit and repair. Or you can also do it in intermediate state, commonly used to weld thicker sections, to have a nice speed.

And in this process, the another advantage also is arc ignition when you are igniting the arc. Yeah, sometimes when you are doing (())(26:43) ignition unknowingly, if electrode touched down and you have a problem, because then the tungsten can have (())(26:54) leading to tungsten inclusions. In this case you always strike an arc in a non-transferred mode first, so arc is always on. And we can also do it in high current mode, then you generate enormous arc the energy density, the beam and we could get penetration as 9 mm in a steel. In the single pass we can weld. Right? Okay, good.

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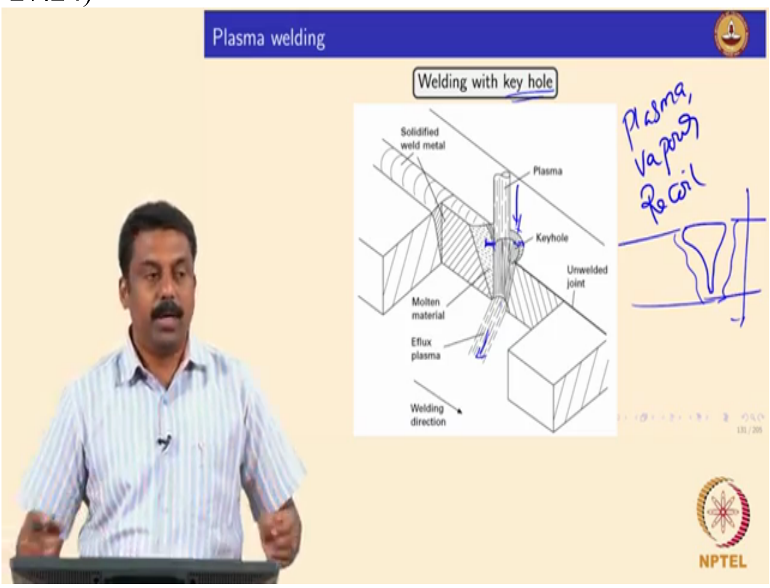

So I mentioned about key hole, right? So key hole is one characteristic you always see when you are doing a power beam welding. For example, laser, so when you are using laser or plasma, and you will have a complete penetration and once you have penetration made, liquid is formed, it is not vaporizing the liquid metal. And the liquid metal once it forms, you also generate vapor pressure. So the vapor pressure and the plasma jet velocity which you are actually sending towards the work pole, the pressure, and then you also have when the vapor start escaping from the molten pool, you also have one free coil pressure. It is like a rocket.

So when vapors are going up, it is also pushing. So you have all these three forces, the plasma jet which is coming from the plasma source and the vapor pressure which is pushing the molten pool and the recoil pressure which is actually going out from the vapor. Because when vapor goes out, it also pushes. See, all these pressures, the plasma, vapor, and then recoil would actually create a cavity. So you create a cavity surrounding the liquid pool. So this cavity generally it takes a shape of a key hole.

Sorry, it is not, what is key hole? It is like a door key hole, right? Something like that. So you will have one molten pool and you make sort of key hole, the door key, key hole. And this is created because of the plasma jet vapor and recoil pressures. And when you are looking at laser welding, we will see very detail the key hole formation mechanisms and the forces, force balances. Right now we can assume that these three forces can also be generated with a plasma and this sees sometimes beneficial. Because when you have, to have one thicker section, and you have a full penetration weld, so you need to form a key hole.

So the key hole, and then steady key hole would determine the weld characteristics. So that is why I want such key hole, I showed you in this picture. So you have a plasma and then yeah, so the vapor jet which is actually going out can create a recoil pressure. And vapor pressure will also push the boundaries of key hole to open up.