Welding Processes
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Part 02
Physics of welding arc

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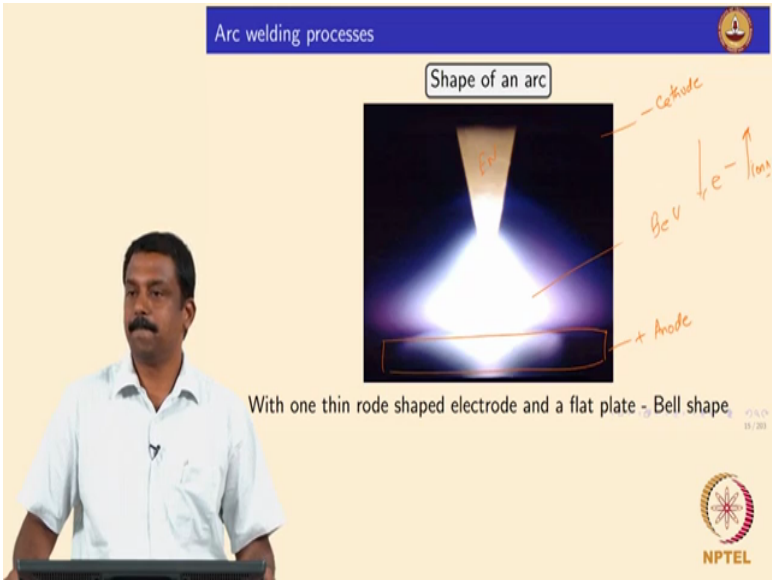

So whatever I have explain this discharge it is sustained inside the these guy the white bright regions, so the continuous discharge leading to collision of the energy carriers. What are the energy carriers in this case?

Student is answering: Electrons and ions.

Electrons and ions, right to the path of the electrons and ions is determined by ever polarity whether you want to keep the electrode positive or ever work piece positive, right. Based on your polarity of few electrode and base material the electrons would be traveling from the cathode to anode, negative to positive, so in the cathode your electrons generation cathode emits electrons, right.

So emitted electrons from the cathode would travel to anode, say for example in this case so I make this guy my the electrode is negative, ok and you have a this is positive terminal and this is negative terminal. Now what will happen now the cathode in this case is my tungsten, so this cathode what will do? The main function of cathode is to emit electrons, right. How it is going to emit the electrons? We will see, what are the mechanism? But now we can see that

the moment you make this the tungsten in this case, this is the electrode negative the obviously the electrons would be emitted from the electrode it will travel towards a base material which is positive anode, is not it

Similarly, the ions which are generated because of the discharge would travels towards the electrode, right. So your electrons would be traveling from the cathode to anode, the ions would be traveling anode to cathode and this is extremely important. Why? Because the energy generation or energy transfer is determined by the motion of the energy carriers. So generally the electrons because of it is mass and member of electrons, the density we always carry more energy more heat with electrons, right.

The ions there are very heavy, ok so even if it has one electron collides with one ion the electron may get heated up because of the mass, very tiny mass compare to ions, ions are all what? gas atoms is not it, the electrons are very tiny compare to the mass of the ions will be very high compare to the mass of the electron. So when the collision happens whether it is inelastic or elastic collision when the energy is transferred because of this collision, the electrons will be heated much more than the ions because of the mass.

So when the electrons travels they also carry lot of amount of heat than ion, so in this case that is extremely important welding case the polarity because wherever electrons go it is supported or temperature will be high, ok. So in this case so I have electron negative where would the temperature would be high?

Student is answering: work piece.

In the work piece, right it is clear right. Suppose if you are using in this case, like for example I used a non-consume volt electrode that means electrodes not melting. So it is always addressable to use when you are using an a non-consume volt electrode and that electrode as a negative, that means that the electrons will be emitted from the electrode will be sent to the work piece and work piece temperature can gone high, if you reverse the polarity what will happen the electrodes will reach the (electrodes) electrons will reach the electrodes.

So then that is not good for non-consume volt electrode, right. So you will end up damaging the a rode in electrode much faster. So if use e p the electrode positive whereas that beneficial if you use consumable welding process, ok. See if in consumable welding process suppose if you have a filler wire should be molten, right. So then it is addressable to make your

consumable wire into positive, so electrons can reach, so you melt more the heat is transferred more, right it is clear.

The ions in some cases he also need to send more ions because ions are heavy so when the ions bambood he also cleaned the surface, ok ion bambood mud we used ion melting, so what do you do in ion melting? basically you generate ions and you send the ions to a rode the surface, right. Say suppose if you are a trying to weld a material which has strong oxide layer can you given example?

Student is answering: aluminum.

Aluminum, so in aluminum case you have a strong oxide layer so in that case you need to remove the oxide layer is not it, that means that if you bambood with ions is good for you because you are also cleaning the surface but then if you make that then you will also reduce the heat suppose if you make your work piece negative where you doing welding aluminum all the ions reach will reach the surface, so surface will be very clean but you are also sacrificing the penetration, is not it.

So then what we do not in case a efficiency we will use a A C current the alternating current that means the polarity is switched in cycle, so we get both advantages heating as well as cleaning, so that is why the welding of an aluminum in most of the case we use alternating current it is addressable because we need both actions, so we need to clean the surface as well as this will also transfer heat, right we need to melt, so you need to make a penetration, right.

So instead of choosing the polarity we have alternating current use an a c, so every time every cycle you also heat one cycle and other cycle you clean, right. Say suppose if you want to weld an steel you can use d c, if you use consumable welding process, ok so you can make the consumable negative sorry positive or negative does not matter based on your penetration. In non-consumable welding process it is always addressable to high electrode negative so that you do not super heat, you do not a rode the electrode, yes it is clear.

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And before that I will show you an arc in real life, yes we will look at it, ok. So these videos I am going to show you they are all made with high speed camera because the phenomena are that is happening here extremely rapid, so we need to if you use an cellphone camera which always my students used to take some pictures which I really hate, so if you use proper high speed camera, so you can look at the action is in very clearly, right.

So I am going to show you one video, so where we use a non-consumable a tungsten electrode to strike an arc, so you can appreciate how arc work? How does arc work? Right. So what is we see here, so this is your electrode and we are melting an aluminum, so the arc is struck here, ok. So because of the heat is transferred from the arc by conduction convection radiation the locally melt the material and if you have joint here for example here the interface is molten by the action of arc and then when it is only fires then interface becomes 1, yes it is clear.

So again in this case the all the action the discharge, the collision the generation of electrons and ions they are all happening in a sustained rate continuously and because of that the arc temperature increases and then that heat is transferred by conduction convection radiation to the work piece and due to that ever the work piece interface is molten and when it is only fires the two interfaces becomes one interface.

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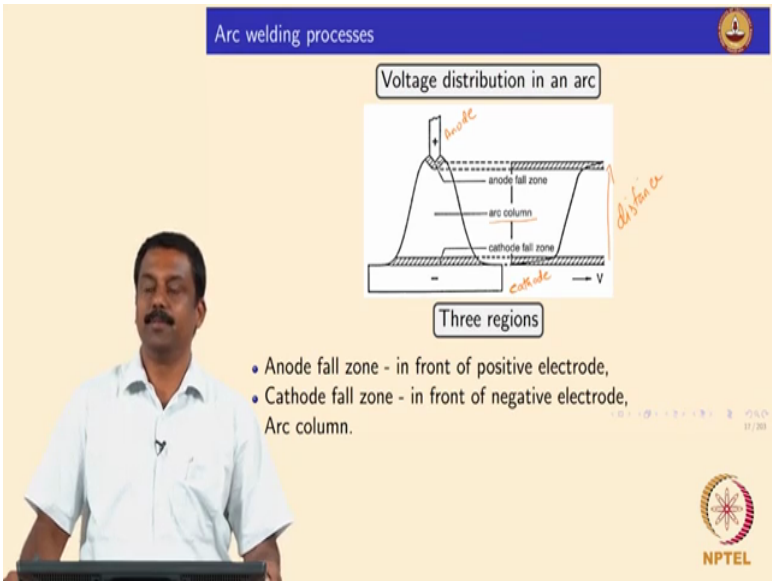

So what is important here if you want to understand how the heat is generated? We need to look at what are the component inside the arc, say I already explain you can make either the electrode positive or negative, ok does not matter whether you want to melt the electrode or you want to keep the electrode say for long time. Suppose assuming if we make the electrode positive and the work piece negative, so which is cathode here?

Student is answering: work piece.

Workplace is cathode and the electrode is anode, so in this case what will happens to electrodes electrons, electrons will be generated in the cathode and they will be traveling and if you look at in this condition inside the arc there are three distinctive regions, the three regions you can clearly see, ok. The regions which are just above the cathode which is characterized by the accumulation of ions, is not it.

The ions whatever is there generated would start accumulating and the surface of the cathode because they positively charge energy carriers would go and accumulate a negative cathode terminal, right. So the ions would tend to go and accumulate the surface of cathode whereas electrons would tend to go they accumulate the anode the positive terminal, is not it right. The regions are extremely it is small for example the region just above the anode surface is known as anode fall zone, ok.

The region just above the cathode which is cathode fall zone. Why the they are very important ? These regions are very important is because of these the accumulation of ions and electrons, the voltage cannot be constant because the charge is always accumulating, so we

define the voltage should be sustained, so in this regions if you look at so this is voltage as a distance the height, ok or you can say it is a distance in the cathode and anode fall zone because of the accumulation of ions and the electrons respectively, you will have a strip temperature gradient in this regions, ok whereas the third region which is known as arc column, in arc column you will have a more or less a constant voltage because the numbers density is more or less equal, number density between the ions and the electrons any more or less equal, ok.

So if that is equal obviously you have a steady are equal voltage as slight increase in the that is negligible, ok. So this very important understand before going in to detail this three regions how this three regions work? Because the heat generations say the arc determined by the physics are fundamental physical phenomena that are happen in this three regions, ok. So the stability of these three regions would determine your arc stability, so when you always say that in arc welding so the stability of arc is extremely important.

So the stability of arc how you change these voltages? Suppose if you have a very strip voltage gradient in the top of the anode then you have a problem, ok that will lead to the expansion, contraction an irregular expansion, contraction to the our old your arc will not be stable. The same goes with the cathode fall zone, ok. The arc column is generally neutral, ok we can assume that it is neutral but it is not really neutral because always the electron density will be higher, ok but it is negligible the because of that we have a steady voltage, constant voltage, ok.

So this important to understand before going in to detail in the arc inside when you look at the arc inside we have three distinctive regions, anode fall zone, the surface of the anode which is positive terminal and the anode fall zone would have accumulation of electrons, cathode fall zone which is and the surface of cathode which elastic accumulation of ions and then arc column, arc column is mostly elastically neutral because the energy density the number density is more or less equal, right.

And the due to this accumulation you have a voltage gradient, in the anode and cathode regions, right. We look at one by one, first look at the anode fall zone.

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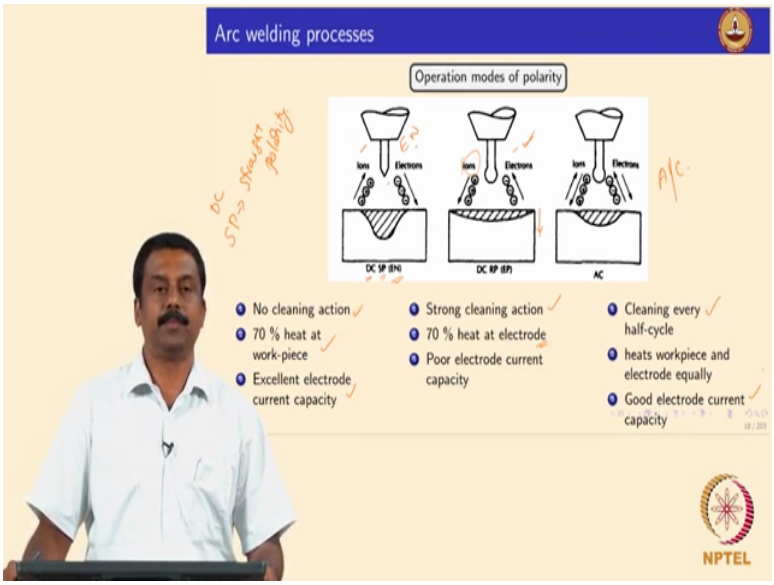

And before that I have already explain this, the polarity. The effect of polarity, you can either make your (consu) electrode positive or negative, so in first case we have electrode is negative, if electrode is negative what will happen? The ions would go and accumulate, ok. So if this is negative electrode negative, so the ions would travels towards electrodes and then electrons will travel towards.

Student is answering: base material.

Base material, so as I explain because of the mass the electrons carry more heat, so obviously you will have a larger penetration, right. Ions would reach the electrode which is also ok if use non-consumable electrode, right your strip would become stable and this is beneficial if you use a non-consumable welding process for example g t a w where your tungsten electrode should be there, you should not welding tungsten, so then you will allow your weld with tungsten, so then you will make exotic weld with tungsten.

So if you are a not be careful in polarity selection if you doing g t a w gas tungsten arc welding and you will also make exotic weld, it can change the properties of weld then you end up melting the electrodes, ok. So polarities are extremely important, the polarity of weld because that determined the path of the energy carriers whether you are transporting electrons and ions towards the electrode will be determine by the polarity, so if you want to make a deep intersection weld in an arc consumable welding process you use an electrode negative which is known as say for example if you use d c current straight polarity, so d c S P means straight, ok.

So what is dc? Direct current, right. So in this process no cleaning action because the surface is not cleaned, the ions are heavier, if ions have a bambood then you have a strong cleaning, electrons carry heat, ions carry momentum, ok. So if you bambood with ion you have a very cleaning good cleaning action. So if use electrode negative ions would reach the electrode, the electrons will reach the work piece.

That means that the cleaning action may not be there but you will have a deep penetration, ok. So the majority of heat is transferred by the electrons to the work piece, ok and so due to that you will also have a excellent electrode current capacity because the electrode shape does not change you are not heating the electrodes as good as in this case, so in this case if you use electrode positive than what will happen electrons will reach the electrode, so then you will end up super heating compare to this case and this case you will end up transfer in the electrons from the work piece to the consumable and due to that you will end up heating the electrodes much more than in this case and in this case we are also transferring ions towards the work piece that means that you will have a very good cleaning because of the ion bamboodment, ok.

So majority of heat is transferred to the electrode because of the electrons and due to that you will also super heat the electrodes and it is good if you use a consumable welding process because you also need to melt but it is not good if you want to use a deeper penetration weld, ok. So you are all sacrificing the penetration the depth of penetration, right. So you can choose judicially what polarity want to use, some cases this also beneficial suppose if you are applying if you are doing an just surface cladding, ok.

In surface cladding application you should minimize a damage you are doing to the microstructure, sorry I used a those microstructure but still you can visualize, so in surface cladding so you do not need to penetrate, you no need to melt whereas you just need to heat but you need to deposit more and more filler to the work piece that means this polarity can be very useful, right.

And if you are welding material with thick oxides for aluminum, so you also need have a reasonable penetration and you also need to do a cleaning, so then it is good to use alternating current, is not it. So there the path of electrons and ions are switched to because you changed the polarity in a every cycle, every current cycle, ok. So cleaning happen is in every half cycle and you also heat the work piece and electrode equally, right.

So that is what aluminum welding is always addressable to use a c because the efficiency is very high, right and you will also have reasonable current capacity, right it is clear, it is good.