Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology – Part- 1

Module- 47

by
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Hello and welcome to this manufacturing process technology in part 1 module 47.

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We left over at how we can you know try to solve it welding to a two different surfaces.

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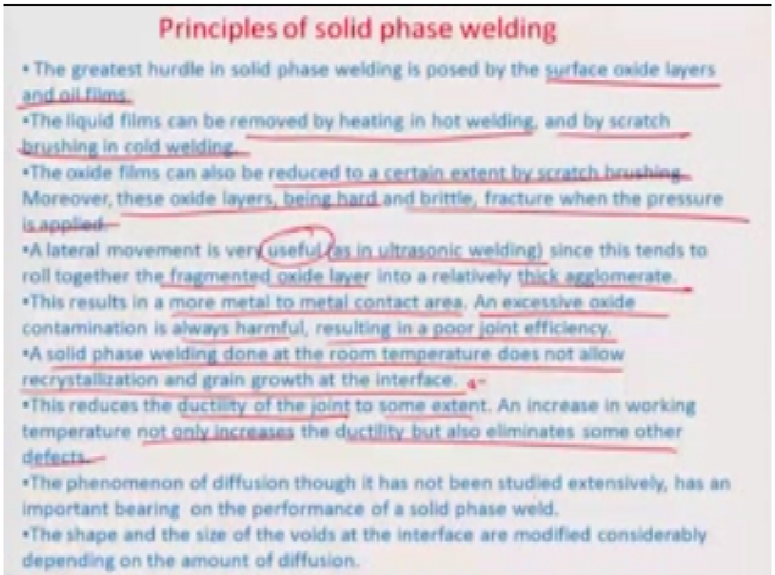

And I think we had just illustrated that the greatest hurdle in solid phase welding is most by the surface oxide layers and also by the films, the liquid films can be remove by heating in hot welding and by scratch brushing in cold welding the oxide films can be also be reduce through a certain extent by scratch brushing moreover this oxide layers being hard and brittle fracture when pressure is a applied and a lateral movement is very useful in particularly ultrasonic welding to do this removal of the oxide layers.

And basically the fragment that fragmented and get into a thick agglomerates at different regions of the particular surfaces, which is also we should also good and you know ensuring that there is close proximity in between the pattern metal surfaces together, so it basically results in more metal to metal contact area so an excessive oxide contaminations is always harmful resulting in poor joint efficiency and we also saw that solid phase welding in room temperature is not really allowed recrystalization and great grain growth at the interface.

To happen so this reduces ductility of the joint some to extent and in increase in working temperature and not only increases the ductility but also eliminates some other defects we also record that phenomena of the diffusion though it has not been very well studied is also a plays an important role on the performance of the sort of solid with joints and sometimes diffusion is used by creating a concentration gradient between the surfaces, so that there is some kind of you know migration of the atom surface to other.

Causing and we dispersing between the two crystal lattices together. so we will now try to understand some of the principles of liquid or fusion welding.

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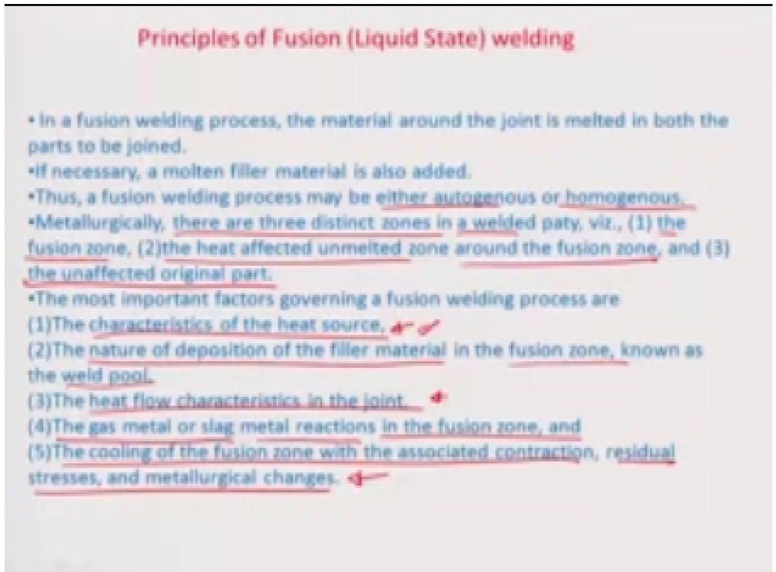

As the name suggest, basically technique where the joint is melted in both parts of the joint and either there is a filler material which is same as the parent material or different and it causes some kind of a weaker sensation again because of the tendency of the material to solidified and this solidification results in joining between the materials and so the fusion welding process may either be autogenous or homogenous. metallurgically if you look at the different zones there are three distinct zones which are which happens in such a welded part the first zone is a fusion zone of force.

The second is the heat affected unmelted zone around the fusion zone and the third is obviously the unaffected original path so there is an interplay of transfer of heat and cross the fusion zone the unmelted zone around the fusion zone and also the unaffected zone you know of weldment so that because of this heat flow there is the solidification just as we observed in the case of casting in earlier in great details and because of the solidification there is an aspect of strength which is involved in and joining the both materials.

So if we look at the different important factors which are used for governing fusion welding some this factors would definitely be the characteristics of the source, so whether we are using and dark or whether we using induction mold or may be a thermite material for creating enough amount of temperature so that melting happens would definitely determine as one of the governing factors, quality of the fusion welding process also the nature of depositions of the filler material in the fusion zone and known as weld pool would also be very critical factors.

The heat flow characteristics in the joint would be a very critical factor because to would be allow us to sort of estimate what is going to be the bigger size level what is going to be the grain sizing resizing level and ultimately its strength of the joint and the gas metal of slack metal reactions in the fusions zones are of critically importance.

Because such reactions that creates states which are highly brittle in nature and may result in some kind of joint failure etc. Because of chemical reactivity and then the cooling of the fusions zone with associated the contraction residual stresses and metallurgically changes associated with this poor cooling process could also determine what is going to be the quality of the belt going to be there, so the first characteristics here as you can see is the heat source and we are going to try and estimate or evaluate some of the different heat sources or heating process which are available in the.

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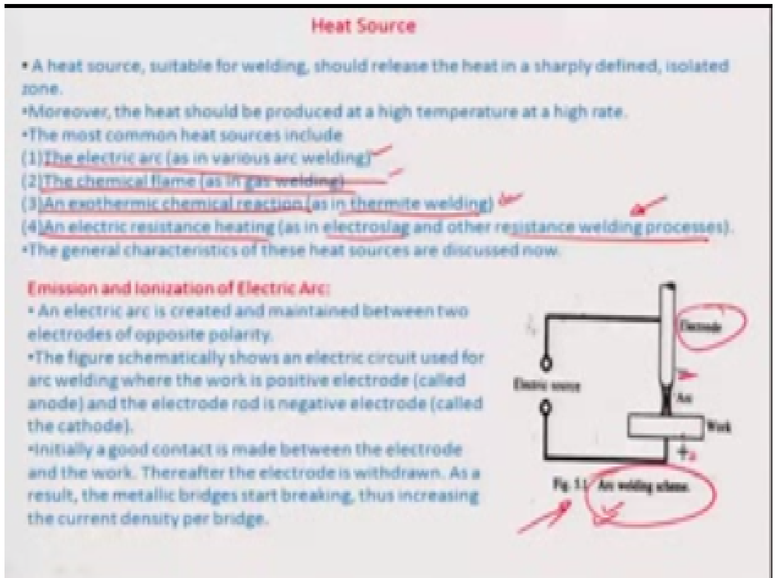

Welding so what are the difference kind of heat sources that are valuable for liquid state welding .so we have the electrical Arc which is one of the most common sources in various arc welding operations. we also have a chemical flame as in a gas welding were use some of the kind of an oxyacetylene gas and burn it so you can produce enough of energy or you also have an exothermic chemical reaction called the thermite welding methods where there is a typically and transition metal oxide.

Like that is a copper oxide or iron oxide being used with the aluminum which acts as a fuel particle and there is a transfer for oxygen between the transition metal oxide of the aluminum which results in an exothermic process, okay so typically these are also known as under water welding phenomena because it does not need any few oxygen in layer cannot do the burning and then we have a electric the resistance heating where typically the applications would be in electro slag or other resistance welding process.

The whole automotive to industry is geared around this electric resistance heating process where sheet metals are typically spot welded to each other. you know in order to pull together as an adjusting of the particular cast, so the general characteristics of this heat sources will try to nowe understand and discussing more so let us look at the first heat source which is the arc welding, so let us look at this particular scheme here, this is an arc welding scheme there is a electric source there is an arc which is created between electrodes.

This the cathode and then the work pieces the anode in this particular case as you made he call and I am sure most of you have seen the torque welding process is an initiated between and the electrode which is clamped on to a which is clamped on to welding clamp so typically electrode is clamped on to the electrode holder and you may also seen that the electrode is slightly broken from the surface and brought very close to the work piece and then suddenly you take it away and then it generates.

The high current flow at the instance you are touching the material the pattern material and then the moment you have to can out the electrode away and there is a arc which is struck between the electrode and the work piece, so what exactly is happening let us assume that the electrodes surface that we are considering somewhere here is little bit rough you know and there are many asperities which are there on the surface, and there is a can whole metal surface or work piece surface which is can having this asperities.

So as we take the electrode in the you know the holder clamp very close to this surface that are going to be asperity to asperity welding or locking which would happen you know something like this okay so there are many such areas, on the electrode which would actually have small asperity to asperity contact, with the parent materials so in this particular case it is more like a short circuit which would happen across of few asperities and there would be something called the short circuit current which is generated.

Which is a huge current by the by from the source or to the work piece surface. so typically the work pieces is also earthed because all the current that comes into the work piece, so typically flow so it is a ground at work piece in most the cases and so the all the electrons which would come of causing high current between the two surfaces would result in some kind of a local heating resistance heating across this particular surface and therefore in this condition If I try to disturb this small weldment.

Which have been made by pulling of the electrode back which normally happens there is going to be a shrinkage in that particular area of the bridge which has been formulated and slowly there would be a case where in the electrons, which are actually flowing now you know at a higher and higher density because obviously as the bridges trying to separate out the area between the two bridges becomes lesser and lesser okay, and so there is a state where the current density is so high that the electron normal starts boiling.

Of the material and such boiling would result in something which would ionize and layer of gas which is closed by and this we know as a arc okay, so there is a boiling of the electrons from these small asperity is the areas has reduced and as the trying to separate as you increasingly try to separate the electrode from the work piece, and because of the boiling the electron start coming of the metal into the surrounding gases starts ionizing the gases and so there are two different kind of electrons which are there typically in the you know state which results one is obviously in the primary electron which is been emitted by the electrode in a close facility.

Or in a close states and the other obviously is the gases which are in the medium which kept ionized because of this electrons, and anyhow some of the equal regions may be completely in elastic in nature and they may result in some kind of a additional electrons so you have ions and electrons which I formulated and so it is like plasma, it is like a hot plasma which is been formulated in some in a zone like this, so therefore there are many electrons which are coming out and there are many ions Which are there. and as we increase the distance of the electrode from the, the metal this arc kind of increases to an extent well you know to an extent that the VI relationship between the source which has a finite power and the requirement of the this kind of a arcs taken medium and would balance out each okay, so up to that extent the arc would stay and beyond that if you again increases a separation between the electrode and the work piece any further arc would cut off or distinguish.

Because now the power requirements of the arc would not be able get supplied by the power source that is giving power to this electrode work combination, so again in summary what is going on then the electrodes getting very closed generating small asperity, as there is a large current almost a short circuit level current which is flowing and then you trying to increase the electrode distance which is result in the some kind of again area minimization between these asperities of plastic well asperities.

Are going to get now and separate at the back and because of the area minimization the current density increases locally and starts giving raise to situation well there is electron boiling of these asperities, of this boiling basically ionizes the gas medium around and it starts building up the arc of high moving high fast moving case atoms and electrons in the space between the electrodes, okay so that you see as the, layering and region which comes between the electrode and the work in such welding process.

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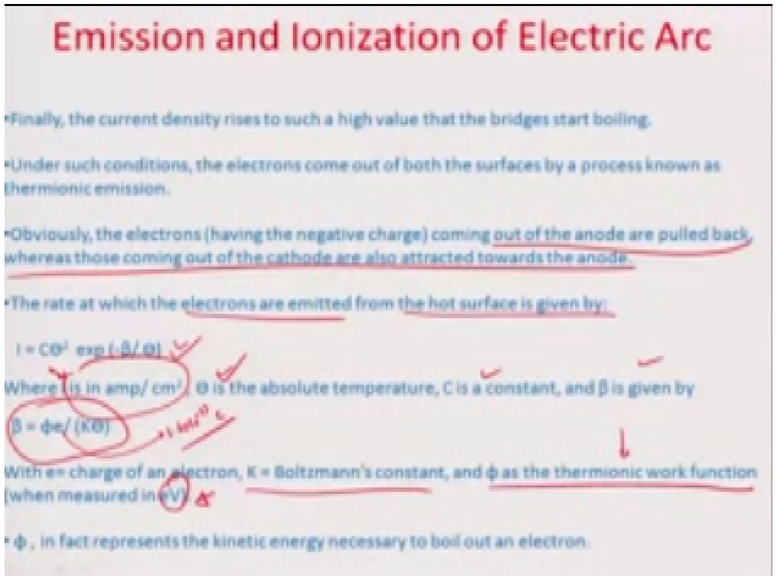

$$I = C\theta^2 \exp(-\beta/\theta)$$

$$\beta = \varnothing \frac{e}{k\theta}$$

So let us just look at some of the physical aspects or let say physical values feature formulated obviously the electrons having negative charge coming out of the anode would be pulled back whereas those coming out of the cathode would also be attracted towards the anode and the rate at which the electrons are emitted from the hot surface is given by this the characteristics equation I = Cθ^2 exponential – β / θ where I is an Ampere per centimeter square this is the current density.

Level of the particular potion of the surface θ is the absolute temperature to which obviously because of fast moving electrons the temperature will rise quite a bit which will result in the some kind of melting, of the weldment in which we want to really either melt the electrode and place or then when just melt the parent the region around arc. C is the constant and β is given by this expression here, ϕe / Kθ is that electronic charge 1.6* 10^{-19} columns and ϕ basically is also known as the thermionic work function.

And is measuring electrons volts and I give you a list of thermionic work function is for the different materials, and case molds from case cast in this particular case. so in fact the ϕ value these are thermionic work function value represents the kinetic energy that is really necessary into start boiling of an electron from a often from a surface, so the values of some of the ϕ is given here for common metal you know you have.

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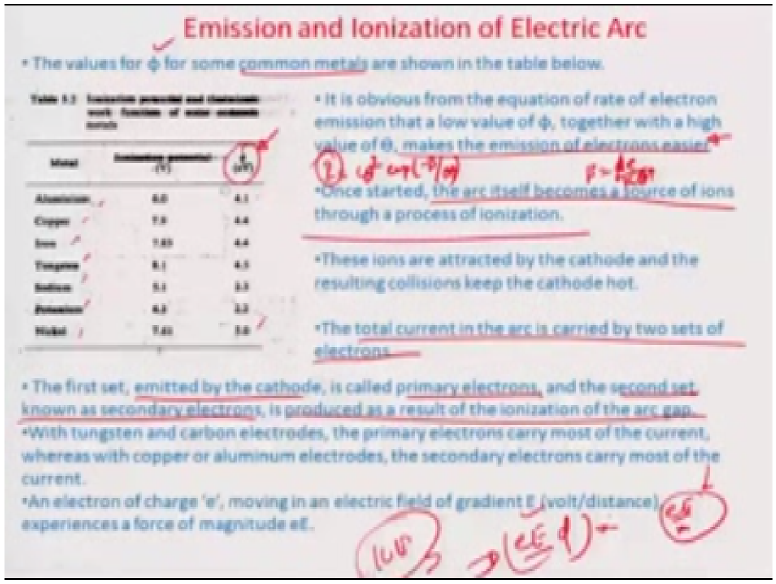

Aluminum, copper, iron, tungsten, sodium potassium nickel and the ionization potentials and this ϕ the work function values in we here we given is 4.1 to 5.0 as you can see for the various materials and obvious and that has the equation says $\beta = \phi e / K\theta$ and also the current density i equations says $C\theta^2$ exponential – β and θ increase in θ and would obviously and also a reduction and the ϕ may be would obviously result in a case where the current density is become huge okay, and it makes you can say the emission of the electrons much easier so with the lower work function value and higher absolute temperature the electrons would moves out more easily thus contributing to a higher level of the current density so the current permute area becomes more and more because of this simultaneously reduction of the thermionic work function, and the increasing the absolute temperature what started the arc itself becomes a source of ions through the process of ionizations so obviously there are going to be gas metals which gas irons which are or gas atoms.

Which are going to be there in the space heated up and then fast moving because of the turbulences created by some of the electron ions which are generated close to the that would anode and it results in again few more secondary of the electrons and secondary ions, generating in the process and so you know you have a conducting column of the arc which is created okay so the ions obviously are attracted in this case by the cathode and the resulting collusions keep the cathode filament by quite a bit hot. In fact there are many secondary electrons in rated because of the collusion of such.

Ions into the cathode similarly the anode side is more like an electrons sinks so it will observe all the electrons here but you know you have to understand that because of it anodic nature there is already a layer of electrons very close by an any electron which is coming to go to the anode should have to pass through this layer of electrons which are again close by so therefore there is a huge drop you know and the anode and at the cathode surfaces, whereas towards the if you look at we drop along the arc in a if we drop that sharp and as a result we can actually characterize.

The voltage versus length in case of the arcs to be very sharply drooping across the cathode and less drooping in nature across the arc, so we will actually do a sectional and we will try to introduce all things here, the total arc current is correct two sets of electrons that I earlier mentioned first set is emitted by the cathode directly it is called primary electrons and the second set is known as a secondary electrons and is produced as a result of the ionization of the arc gap, and so you know based on whatever material combinations.

You are using for example you may use primary electrons you may use that say tungsten and carbon electrodes or aluminum electrodes are copper electrodes. so with tungsten and carbon electrodes normally the primary electrons carry the majority of the current whereas with the aluminum of the copper electrodes, and may be secondary electrons which carrying majority of the current, so it really depends on what is going to be the work function value and the θ value of the arc where you are placing the arc.

Okay in terms of it is creation so and in electron of charging moving and electric field of let say capitally valued and we obviously expense a force e * E and it is moves with the distance d so the total amount of work which is done, which is also equal to the kinetic energy of the electron can be represented as eE/ d, it also moves with an accretion e / m whereas the mass of the electron, but obviously this kinetic energy is the reason why the temperature would privies up and cause many secondary ions and electrons to formulate in arc column.

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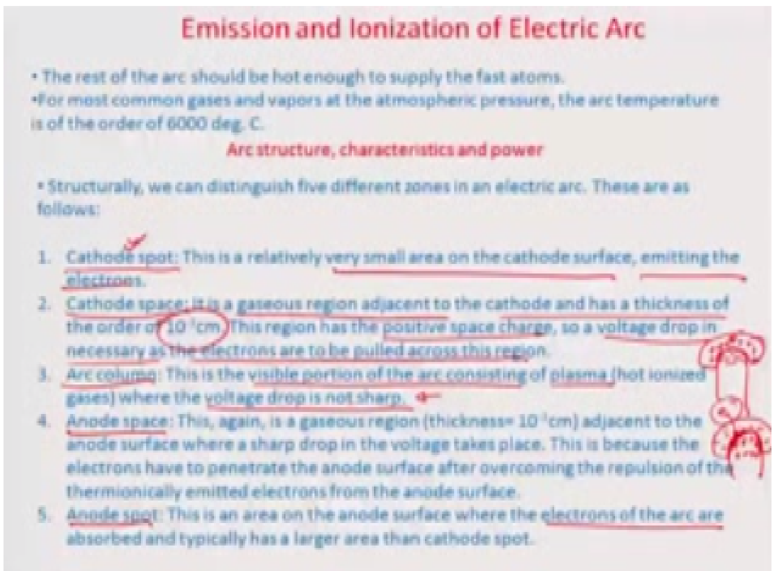

so let us talk about the arc structure and characteristics, so I already told you that on the cathode there is a spot from which this electron emission happens and this is relatively very small area on the cathode surface as a cathode spot and this is really the causative area of the region for emitting all the electrons okay, so that is what we know as the cathode spot. Similarly we have cathode space which is a gaseous region adjacent to the cathode has the thickness of the order about 10^{-3}cm close to 10^{-5}microns. So this region has the positive space charge, so obviously cathode which is highly charged, so it will attract all the positive ions near to it.

The region which would have been filled with it has been cathodes and voltage drop obviously in this region it is necessary for the electrons to pulled out across this region because you have positive ions, you know and once the electrons goes into this particular space, it will be hard to the electron into the negative cathode okay. So there is a drop in the suddenly energy of the electron, it goes into the positive space of the cathodes. So similarly that is following column which is visible portion of the are consisting of plasma, where the voltage drop is not very sharp and I will actually comment on how with the length the voltage will drop.

In just about the next section particular module and then obviously you have the anode space, the similar problem the anode being positively charged would attract negatively charged electrons rounded, so there is a space which would contain negatively charged electrons and it is very difficult for the electrons otherwise in the medium to penetrate through this negatively charged region to the anode side. The other reason why there is again a very sharp drop across this anode region.

And then obviously in the anode in around whatever region what gets formulated the no gas anodes spots. So this is really the section across which there is a electron flow and current flow on the anode.

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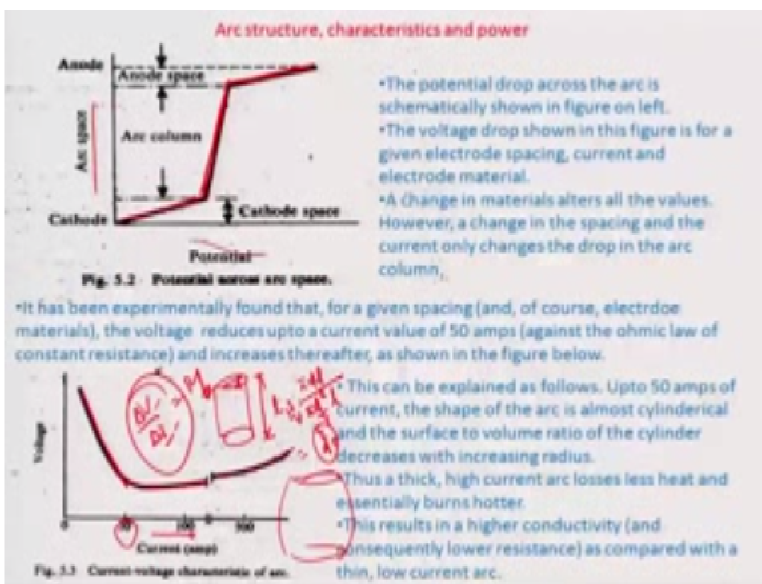

So if you look at the voltage characteristics and show in arc space the potential can value we have a huge drop and the cathode because obviously is in just earlier huge drop again or potential across the anode and then relatively smaller depth across the main column of the arc and that is how you would actually characterize the arc space, so now let us look at how the voltage would varying as a function of the current across the arc and if you look at the way that the arc builds up there are many a interesting thing associated with the buildup process so at the beginning up to the right say about 50 amperes of current the arc is more or less cylindrical in nature okay so if

I really looked at the surface area volume ratio of a cylinder let say we have a cylinder here okay and your length of the cylinder is L and the just diameter of the cylinder is b okay so the surface area is πdL and the volume is $\pi d^2 / 4L$.

So obviously the surface towards the volume ration and such a cylinder happens to be about close to 4 / d okay, so as the d increases obviously the surface to volume ratio would decrease so supposing now if I had a case where the these increasing of an arc, but the cylindrical constitution of the arc is carried forward and this happens only up to bound 50 amperes of arc current so were the current the arc formulated still is about close to cylindrical and shape, so the surface to volume ratio reduces within increase in diameter.

so if there is a thicker arc for example it will have lesser surface area and comparison to a thinner arc okay and in thinner a long there arc so because of all these is a reasons what typically would happen, is that because of the surface area also is a function or is like directly proportional to the rate of the heat transfer if the surface to volume reduces then of the volume, or the bulk of the arc which is containing all this gases and electrons and is also a cause of the temperature rise.

Would be able to raise the temperature to a quite reasonable value for these surface area of these smaller in comparison the volume, may not be able to despite that heat much so it is a hotter arc okay, so a thick arc is always hotter arc because it dissipation and valuable because of the decrease in the surface to volume ratio decrease so the heat transfer cross the arc may not be or from the arc into the environmental may not be so huge in compression to the heat addition to the arc because of these ionization of effect Which come in the space for the same.

so therefore below 50 amperes you can consider that as the diameter of the arc increases and that would happen this function of the voltage the conductivity of the arc which is also a function of the temperature of the arc, is got to actually increase and because of this the resistance will decrease and because of this you know the current value may decrease at a certain voltage so if the voltage reduction $\Delta v / \Delta I$ if we consider if the resistance is decreasing a function of thickness of the arc.

So obviously the $\Delta V / \Delta I$ will also be sort of decreasing meaning there by that is this part of the characteristic is showing that particular change so the is showing that particular change so the as you see this portion up to 50 amp is basically dropped in the resistance because of which you know even if the current increasing in voltage is not seeming to increasing. beyond 50 amps the curve the cylindrical characteristics of the curve is not maintained anymore.

And there is a gradual bulging of the arc length so the total length that the electron has to travel more increase because of such bulges so for of very significantly long time the both the effects of the resistance going down because of the hot arc and the fact that the arc is bulging and there is you know additional path length that the elections have to cover continues so that you can see that up to quite a bit of current value any more you are not having any significant change in the voltage they are kind of compensating for each other beyond that then what happens is that the bulge part of the arc.

That means you know the arc getting stricken like this would increase more path length in compassion to the heat transfer process the contribution of heat transfer process and there is a slow increase you know of the voltage with respect to the current beyond that so that is why this characteristics that in the first before 50 amps the increase of the cylinder size of the arc you know and the reduction surface area would result in an hotter arc and beyond that there is some kind of a balance between this heat retained vis a vis the path length increase because of bulging of arc.

And then there is predominant of the path length increase of the bulging part so that the again the V versus I becomes a linearly rising trend, so with this I would like to end this particular module but in the next module we will try to look at that how you can have this arc characteristics of voltage verse current as function of length to the inter spots with the voltage current characteristics of the power source so that we can talk about operating point so the welding system so with that I would like to close this particular module thank you so much.

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