Fundamental of Welding Science and Technology
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Lecture - 17
Physics of Welding

In last class, I was discussing about effect of different process parameter on metal transfer only. And, at the end of last lecture I was discussing categories of different welding efficiency, there I was discussing at the end of that lecture, I was discussing about heat source efficiency. And, I finished also heat source efficiency, there we also have that heat source efficiency generally varied from welding process to welding process.

It is observed that a that heat source efficiency depending upon the heat source type it efficiency can varying from 10 percent to around 99 percent, there we observed about heat source efficiency. And, at the and another efficiency also was there that is called melting efficiency, or that is also called heat transfer efficiency. Today, first of all I will discuss about melting efficiency, heat transfer efficiency in detail, after that actually I will discuss about effect of process parameter in weld quality; that means, last class I was discuss about effect of process parameter only one, but it is called metal transfer.

So, in today's lecture I will discuss about effect of different operating or process parameter on weld quality as well as deposition rate, and weld deposition rate weld bead geometry in details.

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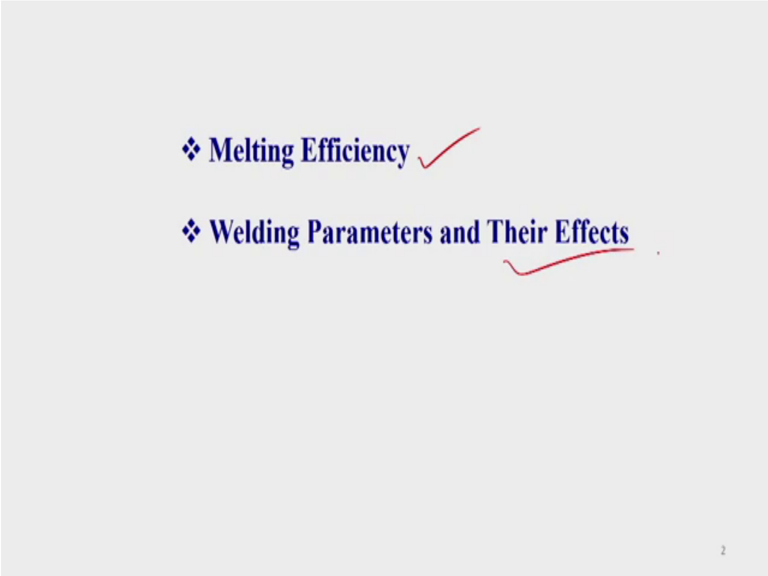

So, the this is the content of today's lecture; that means, first of all I will discuss about the melting efficiency, or this is also called heat transfer efficiency, and another one is welding parameters, and their effect on weld quality of welding.

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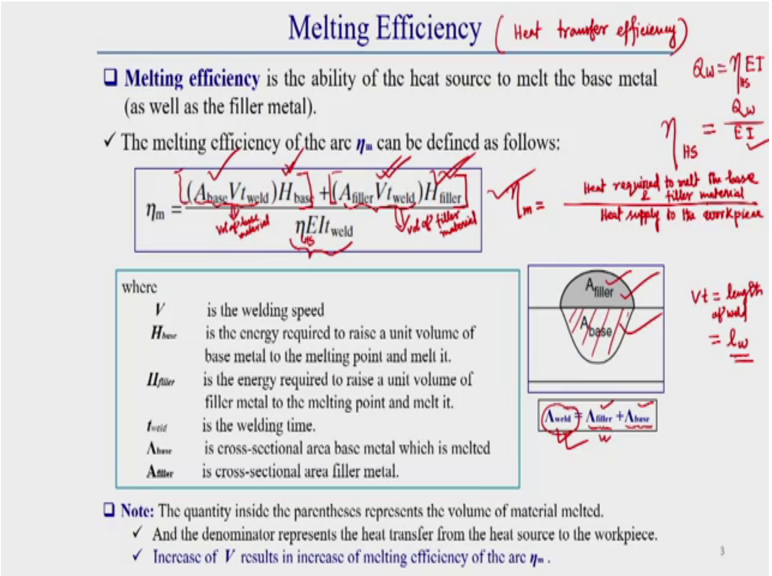

So, last class I have already discuss about heat source efficiency, there we observe that the rate source efficiency is the ratio between the heat in arc; that means, heat supplied to arc by heat by power source. That means, arc heat divided by; that means, heat transfer from arc to work piece; that means, work piece divided by work piece heat.

That means, this ratio generally was the heat generally we observe that all the heat is not transfer from arc to work piece, there is some losses occur that losses due to convection, conduction, radiation or some other losses can be there. Due to that things all the heat is not transfer from arc to arc the work piece material. So, that is why there is used sometime that is called heat source efficiency. Heat source efficiency means, that also we can heat source efficiency we are representing by; that means, eta HS that way we represent it.

Now, today we will discuss about the melting efficiency or heat transfer efficiency. This melting efficiency is the ability of the heat source to melt the base metal, as well as filler material. Actually, this is represent; that means, this melting efficiency actually whatever the heat is transferring from heat source to work piece, that all heat of work piece is not required to melt the base material filler material.

Here, generally there can be some excess of heat will be there; that means, here actually or rather. So, whatever the heat required to weld, rather the heat required to weld is generally we have to melt the these material and what happens as well as filler material. For that whatever the heat is required that is sufficient to generally do the welding.

But, what happens whatever the heat supplying from arc all the heat is not utilize for what is call melting the parent material or work piece or melting the and melting the electrode. So, here some excess of heat generally can be there. Based on this thing generally what happens, here generally we use melting efficiency, melting efficiency or we use generally heat transfer efficiency. This melting efficiency also it is called as heat transfer efficiency, heat transfer efficiency.

What does it means this heat transfer efficiency? Heat transfer efficiency means the that this we can write that this is the ratio of heat required to melt the base material, as well as what it is called filler material divided by heat supplied to work piece. That means, whatever the heat supply from arc to work piece that will be here in denominator. And, top of the ratio will be the heat required to melt the base material and as well the filler material.

So, what we can write actually this melting efficiency or we can say heat transfer efficiency, it is the generally what you what is the, what it what does it means? It is generally heat require this we can write heats required to melt the base and filler material divided by what we can write, heat supply heat supply to the work piece; that means, heat supply or we can say heat observe to the work, these 2 ratios generally is called generally melting ratio.

How we can represent this things this portion generally represent; that means, heat require to melt the base material; that means, heat required to raise the temperature of base material from room temperature to it is melting point and melt it, this generally this portion represent that thing. And, this second portion represent that heat require to melt the filler material heat require to raise the temperature from room temperature to melting point temperature of filler material and melt it just whatever the heat is required.

For; that means, to rise temperature from room temperature to melting point of base material as well as filler material require is generally used in top of that efficiency. And, below of this generally represented the; what it is called heat supplied from arc to work piece; that means, how much heat is coming to work piece.

So, this is generally this how much heat is coming to work piece that we can easily find out, that is generally that is represented in terms of Q divided by EI, that we have already we have discuss heat source efficiency is the is equal to the this heat observe to work piece divided by EI. So, from here generally Q w, we can represented as eta HS into EI that we can write.

So, this part will be this eta HS here we can write this is eta HS EI generally t weld represent generally heat require actually. Eta HS so, this eta HS with if we multiply with the these thing with welding time, then we generally get the heat that that eta EI is power once we multiply with this thing with time of weld, because then with it is generally converted to heat energy.

So, generally this welding time is multiplied with both top and bottom that is why this generally can be eliminated. So, this weld time because everywhere there is welding time, here is welding times, here is also welding time, and here is also below also. So, this can be cancelled out. And, how we calculate this second term of this of this heat energy, that we can calculate by checking the cross section view of weld bead. Generally, once we cut the cross section then they are we can get the overall cross section view of molten metal zone. So, then this molten metal zone let us this portion represent the cross sectional area represent top portion represent the cross sectional area filler material. And, let us this below portion represent the cross sectional area of the what it is called base material. So, let us this base material melting reason is this much portion and filler material deposition portion is this top portion.

So, here generally a filler; that means, area of filler material and a base means area of base material this, we can get easily from where from the what it is called from the cross sectional view of welded section. Because, from cross section view by cutting and polishing it this area we can easily visualize.

So, once we get this area then if with this area, if we just multiply with velocity and time, then area into velocity and time means length, this velocity and time represent v into t represent generally length of weld. So, what happens, if we know this cross sectional area of this base material this v and t represent this length of the weld. So, cross sectional area into length of weld represent what, that volume of weld. Actually these terms from this to this represent what represent the volume of what it is skill volume of generally base material melted base material. Similarly, from this parenthesis portion generally represent volume of volume of filler material melted, filler material melted. This, generally represent this that we can easily get from here.

Now, if we just with this volume, if we multiply this might multiply this H base, what is this H base? This, H base is the energy required per unit volume of base material to raise temperature from what it is called room temperature to melting point temperature of base material and melt it. Then, if we just multiplied this is generally per unit volume energy requirement. So, if we just multiplying this unit volume energy required with total volume of base material, then we will get total energy required for melting of base material from room temperature to um; that means, melting of base material.

Generally in second portion also we have this parentheses reason one; generally represent the volume of filler material. This volume of filler material once we multiply it with this H filler, here H filler represent the energy required per unit volume of filler material, to raise temperature, from room temperature to melting point temperature of filer material and just melt it.

Rest of the heat whatever the excesses heat is there that is not actually utilizing here. Only the energy required to raise temperature from room temperature to melting point temperature and just melt it. So, this generally represent so, this parentheses region a filler into v into t weld represent the volume of filler material deposited, during welding time..

Once, we multiply with this energy required per unit volume of filler material, then we get total energy required in case of filler material, to raise temperature from room temperature to melting point temperature. So, this we can easily find out. And, what is this thing this denominator this thing represent the, whatever the heat is supplied from arc to work piece. And, that we can easily calculate from heat source efficiency.

Now, here one thing you should remember; that means, we can easily get this total cross sectional area from micro structural observation. This total cross sectional area, but among this total cross sectional area what will be the filler material area and what will be the base material area? That is little bit difficult to distinguish. For that reason, but this total cross sectional area can be easily measured here total cross sectional area; that means, a weld area is the area of filler material and area of base material these total we can measure easily.

But, what happens this filler zone and base material zone this distinguishing is little bit difficult, that is why if we can get any one portion of this cross section. And, then rest of the portion of cross section we can subtract from this total cross sectional area that we can easily find out.

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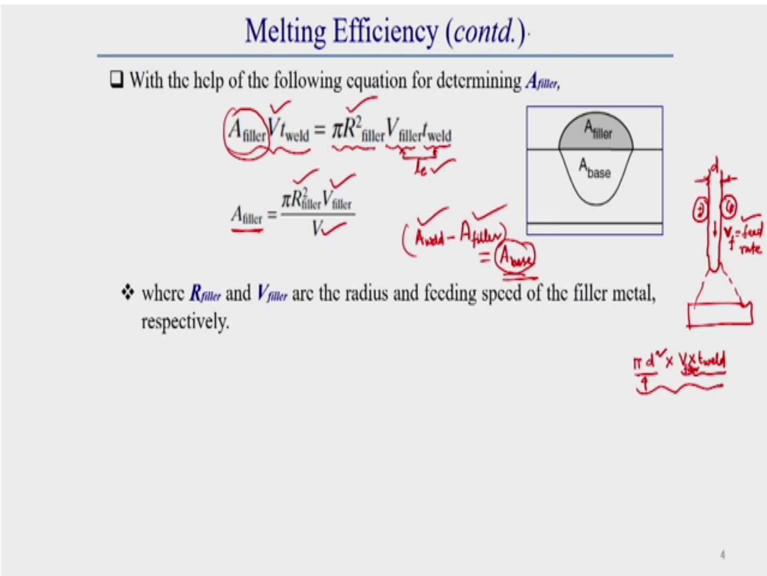

So, here generally area of this filler material cross sectional area, we can find out by using this following formula. What is this formulation? This is the volume of filler material, but we do not know exactly what is the cross sectional area of filler material, that we have to find out. How to find out this thing generally this filler material is supply by the means consumable electrode. Generally consumable electrode, generally consumable electrode is generally let this is the electrode, this is generally continuously feed, this is generally continuously feed by this feed roller mechanism, generally some feed roller or manually also it can be done.

So, what happens? Once, it is in a feed roller mechanism they are we now, what is the speed of this feel; that means, speed of these is consumable electrode. Because, what happens depending upon this so, speed of the consumable electrode means consumption of the filler material deposition, we can calculate by using this is speed of the filler material speed or feed rate. This speed actually call generally feed rate, feed rate of electrode, feed rate of consumable electrode. This generally can be automatically we can set it in welding operation, this is known to us; that means, speed of known to us and we know the diameter of the electrode also.

So, if we know this diameter of the electrode, then what happens if we know, if we know the what it is called feed rate; that means, speed of consumable electrode, then we can easily calculate, what is the volume of what is the volume of filler wire deposited that we can easily find out, that we can easily find out generally by pi d square 4, this cross sectional area of the these things into length of the filler wire. These velocity actually represent velocity of filler wire, or you can say v filler this we can represent as a v filler or feed rate speed or feed rate we can say.

So, this we can easily this we can easily measure. This is here representing generally in terms of pi R square cross sectional area of this consumable electrode, and v filler represent the feed rate or speed of the filler wire. And, during welding time if we multiple this represent the total length of total length of total length of electrode, total length of electrode, this we can represent early. So, this is known to us.

So, we know everything from here, R filler velocity; that means, feed rate of the filler wire and we also the know the welding speed. So, we know everything here. So, we can easily calculate what should be the cross sectional area of filler wire. So, if we can able to calculate this filler wire cross sectional area, then from this weld cross sectional area, if we just subtract this area of filler wire, then we can get how much area of base material what is the cross sectional area of base material are there that we can easily find out. Because, this is known to us and this is also known to us from micro structural study total cross sectional area. Thus, if we subtract this thing we can get easily this base material cross sectional.

So, here we got this cross sectional area of base material as well as cross sectional area filer material. And rest of the thing is known to you; that means, speed of welding speed we know, we know welding time. So, we can easily calculate this melting efficiency easily, this melting efficiency easily. Now, here generally we have we will discuss about what is the effect of all this different welding parameters one weld quality; that means, weld quality means here weld quality means with geometry, welding a strength, deformation, deformation or distortion of welding, and what happens if penetrations. So, overall quality of the welding over this different welding parameter affects that I will discuss now.

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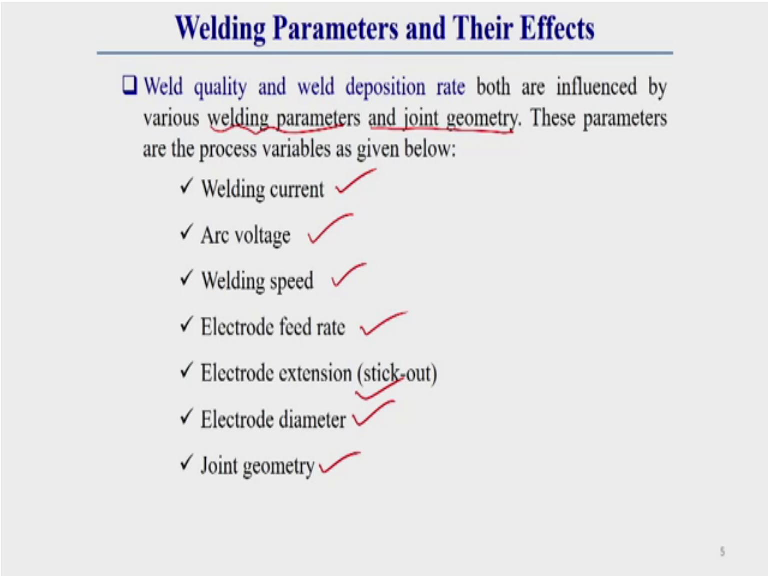

Generally, here one things you keep it in mind, weld quality and weld deposition rate, both are influenced by generally various welding parameters and joint geometry. This generally this weld quality and deposition rate is depends on different welding parameters and another things join geometry. About joint geometry generally I have already discussed in initial some lecture I was discuss about this joint geometry what are the different types of joint geometry are there, generally that I was already discussed.

Now, here I will discussed in details about different welding parameters effects on quality of welding as well as the deposition rate in details. What is this parameters? This welding parameter especially the measure welding parameters, which affect the weld quality, then weld bead geometry deposition rate, this measure welding parameters are generally as follows. Like, here it can be welding current, it is generally arc voltage, welding speed, electrode feed rate, length of stick out, or electrode extension, this is also call extension electrode diameter, and third then last parameter generally is called joint geometry.

So, each and every welding parameters details and joint geometry details I will discuss in the subsequent slide. There, we will see what is the effect of this different parameters in weld over all weld quality. First of all we will discuss about welding current.

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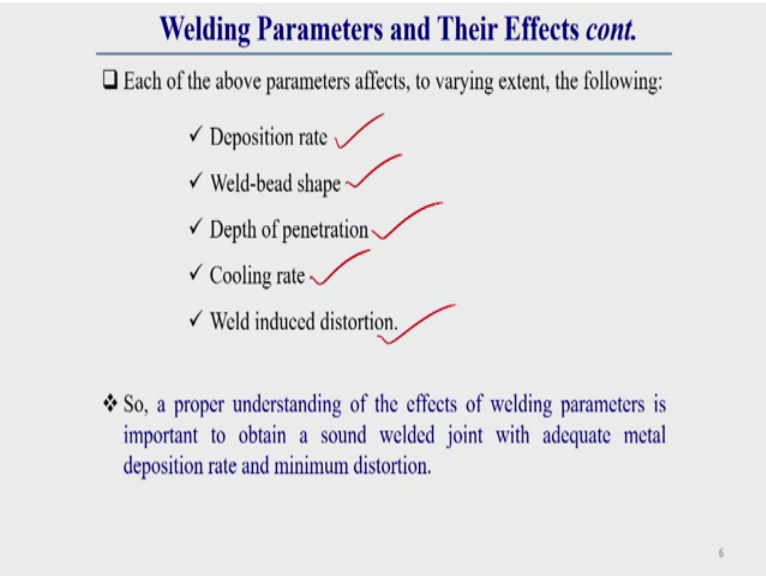

So, before going to welding current generally whatever the parameter I have shown above, this parameter generally affect the following generally, what is the effect of this parameters if it is varying. It is generally these parameters effects the deposition rate, it is effects on weld bead shape, it is effect on depth of penetration, it is effects on cooling rate, and it is effects on weld induced distortion.

That means, whatever the parameter I have told you previously that parameter have this effect, these are the following effect of that thing. So, what happens by controlling the above parameter we can get, less distortion, good penetration, good beat shape welding? So, we have to known in details about the above parameters effect; so, that I will discuss in subsequent slides one by one.

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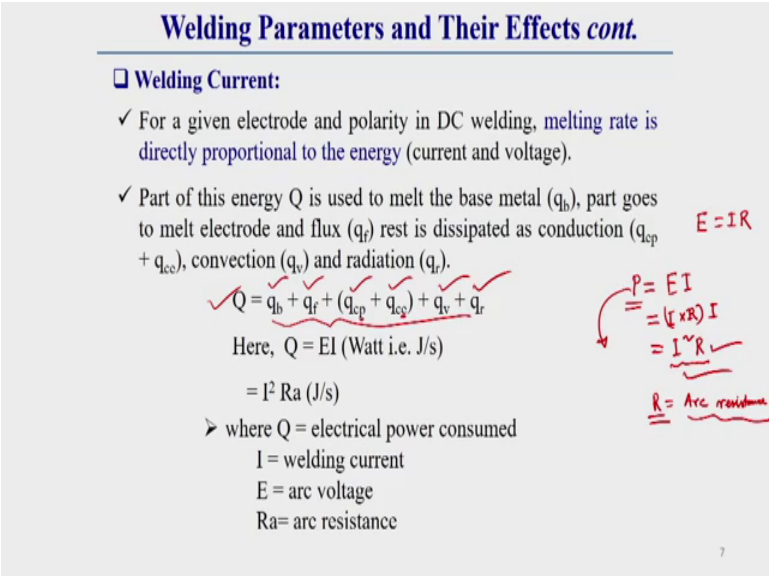

The, first of all welding current, yeah I have already discuss welding current means flow of electron, actual flow of electron through the gap of the arc. Generally, what happens due to this flow of electron generally what happens, that welding current directly proportional with heat energy that we know; that means, what is what heat energy or heat power. Generally, heat power we know that E into I, that we know. Generally, here generally this e means voltage this we can and represent, generally this E we can represent generally in terms of I into resistance of arc.

So, generally if we just put this E here I into R here and write then this power is actually represented as I square R. So, here generally what we observe this power is directly proportional to a square of the current here one things we can observe. So, welding power is directly proportional to around or heat energy generally heat energy rate generally directly proportional to the square of the welding current that we can observe from here.

So, for a given electrode and generally for a and polarity in case of DC welding, generally melting rates we know that melting rate is directly proportional to this energy; that means, this directly proportional to a square of this welding current. Because, this depending upon this power generally heat is generating. This power generally whatever the power coming from electrode; that means, from power source to base material, here generally this total power or you can say this total heat power we can represented in terms of these 6 different 6 different component. What is this 6 different component here you should know, little-little bit detail about this thing.

This actually what happens where q b generally whatever the heat is coming from, they coming from power source, this heat generally some heat is going to heat energy is going to R you can say heat power is going to base material, this is generally base material heat. This is generally some heat energy going to electrode; that means, some because some heat energy is required to melt the base material some heat energy required to melt the what happens or melt or heat the electrode. And, this qc p and q cc represent the heat conduction in plate, and heat conduction in electrode p if p represent for plate and heat E represent for electrode.

So, some heat is conducted to electrode, some heat is conducted to plate. And, what is this q v and q v represent the convection heat transfer rate, and q r represent the rate of radiation heat transfer. So, this is actually energy balance equation or what you can say on case welding for a particular types of welding, how the energy balance equation is coming?

So, this energy generally all the heat energy; how it is dissipating over the welding reason that it is representing. Here, generally one things you can observe this whatever the heat energy you are getting this is generally, proportional to a square of the current and this R represent the Arc resistance. Whatever the resistance you are getting resistance, whatever the resistance in arc is there this R represent the resistance of the Arc. So, from here generally we got the idea, how the heat energy connected with what it is connected with the current?

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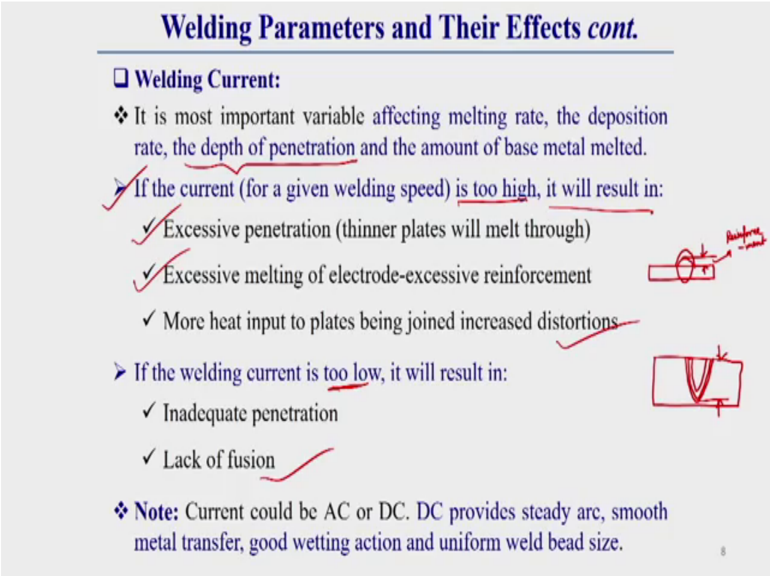

So, from here itself you get the idea; that means, current has is the most important variable generally here. The V generally affecting the melting rate, the deposition rate, the depth of penetration, and the base material melted. So, the amount of base metal melted. So, here one things you keep it in mind this current is the most important variable here.

Who is affects most of the important part? Generally, how it is what is this important part, it is affect is main effect if effect is on melting rate, second effect is in depth of penetration. How the depth of penetration and all the things it is affect that I will discuss in sub sequential. The welding currents main effect is melting rate and depth of penetration. Depth of penetration means generally if the welding current is high, welding current high means what does it means? Welding current high means flow of electron is more over there.

So, if the flow of electron more over there in case of DCEN, electrode negative in case of DCEN generally if the flow of electron more is there or if in case of DCEP, if the flow of electron more is there, then what happens, flow of current; that means, flow of current more means flow of electron more. Flow of electron more means what happens, bombardment force; that means, more current means, more bombardment force will be there. How this more bombardment force will be there, that I have already discussed in force different forces in welding arc. There we discuss there is generally one force is equal radial force, another one force is equal radial force, another force I actually I was discuss that another force is called axial force.

In case of axial force generally which generally create generally what happens, in case of axial force which generally create a turbulence effects in whirlpool region. So, higher the they are also I was discussing, higher this forces generally is almost directly proportional to a square of the current, that also I was discuss. So, there the we observe this is also proportional to a square. So, if the current is high this turbulence effect and all the things is increased.

Due to this turbulence effect or axial force affect, generally what happens more penetration is taken place. And, as I have already discussed this heat energy is also directly proportional to what it is called, directly proportional to a square of the current. So, if the current is more than heat energy also will be more.

So, heat energy more means more material will be melted; that means, deposition rate also will be increased.. This thing only represented here; that means, if the current is too high, then what will be the result. The result will be here generally if the current is too high, then there will be excessive penetration what I have already told you. Why excessive penetration will be there, because there is more forceful arc will be generated; that means, there will be more turbulence effect in when the whirlpool.

So, more penetration will be there in case of high current. So, what happens that is why high current generally in case of high current, there is a chance to melt through in case of thinner material. So, high current generally is not preferable in thinner types of plate. So, second point is if the current is too high, there will be expressive melting of electrode.

So, there will be excessive reinforcement. This, reinforce what is excessive reinforcement you should know what is reinforcement. Reinforcement means generally if you do the welding, you can say that which shape generally become like this. So, above the surface of the base material generally some portion of the generally some portion of the material generally deposited to work the surface of the base material. So, these portion generally call reinforcement reinforce.

So, this reinforcement generally what happens if the melting rate will be more of the electrode, then this enforcement this enforcement height generally will be more; that means, more material will be deposited over the surface of the electrode. And, here one things you keep it in mind as the higher current result in higher penetration, as well as higher melting rate, that is why and higher current represents generally higher heat input. So, if the heat input will be higher than generally due to this high heat input there will there will be more distortion or more deformation of the welded blade.

So, more heat input to plates being joined increase distortion of the welded plate. Now, if the current is too low; that means, if the current is too low it will it is will result will be opposite; that means, here generally will be inadequate penetration here; that means, whatever the penetration required, that part of penetration will we will not get. So, here generally less as an analyst penetration we will get. So, that is called inadequate penetration. Apart from this thing there can be lack of fusion. So, this 2 effect it can create if the current is less.

Now, here one thing you should keep it in mind, generally compare that that this current can be ac current alternating current or DC direct current, but always keep it in mind direct current is generally more preferable. Because, generally it is provide a study arc a smooth metal transfer good wetting action and uniform weld bead size generally DC current provide say. So, DC current is more preferable.

So, from effect of current what we observe this currents main effect is to increase the depth of penetration as well as generally what is call melting rate of the material. So, main effect is generally depth of penetration current effect. So, higher the generally let us for thicker section, for thicker section depth of penetration what does it means, depth of penetration means the higher the current higher will be generally, higher will be the depth of penetration.

That means whatever the this penetration depth penetration, depth means this is generally fusion depth we can say how much material is melted inside the thickness of the plate actually, this is generally penetration. So, higher will be this forceful arc more penetration you can assume for that is why for thicker section generally, what it is called high current is preferable, because high penetration we can get.

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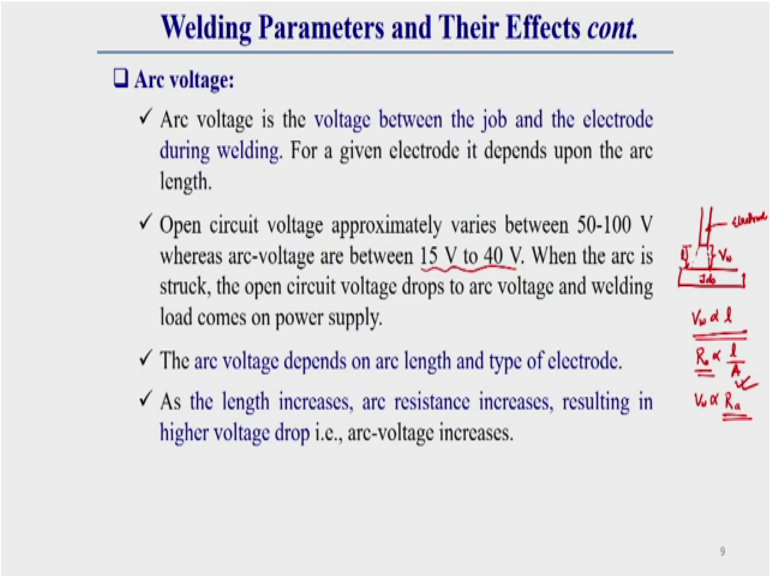

Now, let us go for other operating variables effect, that is call another operating variable this arc voltage. Arc voltage what I have already discussed arc voltage means the voltage difference between voltage difference or voltage between the electrode and work piece. Arc voltage means whatever the voltage we got in this gap in this gap. Generally whatever the voltage we got this is generally called arc voltage or whatever the voltage we get in arc that is we called as welding voltage or arc voltage. So, arc voltage is the voltage between this what it is called work piece or job and electrode that I have already discussed. So, whatever the voltage is there this is called arc voltage or welding voltage.

Here one things you keep it in mind, generally open circuit voltage generally to initiate this arc, once we switch on the power source, generally whatever the whatever the what it is called voltage generally supply from power source to electrode, that initially before starting the arc whatever the voltage is there that is called open circuit voltage. So, there generally no arc is there at that that time.

So, generally this open circuit voltage range generally to initiate the arc is generally it is higher than this arc voltage. Generally open circuit voltage varies between 50 to 100 volts that we have already discussed. And, generally this arc voltage varies arc voltage varies between 15 volt to 40 volt in case of this normal arc welding process.

When this arc is a struck then what happens, then the open circuit voltage drop to arc voltage and welding load come on power supply this you keep it in mind. So, generally when this open circuit voltage drop to arc voltage, then this welding loads come on supply. And, the welding voltage directly proportional to this directly proportional to arc length, this welding voltage generally directly proportional to arc length that we know, how it is directly proportional generally we know, generally resistance of arc.

Arc resistance generally is proportional to the we know resistance of arc generally directly proportional to length of the arc, and length of the and inversely proportional to corrosive, that is the general rule actually from ohms law that we know. So, generally this arc voltage we can represent l by A. So, from here itself we can get and V is generally proportional to resistance of arc. So, this so, here one things you keep it in mind that for welding voltage or arc voltage generally proportional to arc length. So, as the length increase arc resistance increase, so, resulting in higher voltage drop, that is higher arc voltage.

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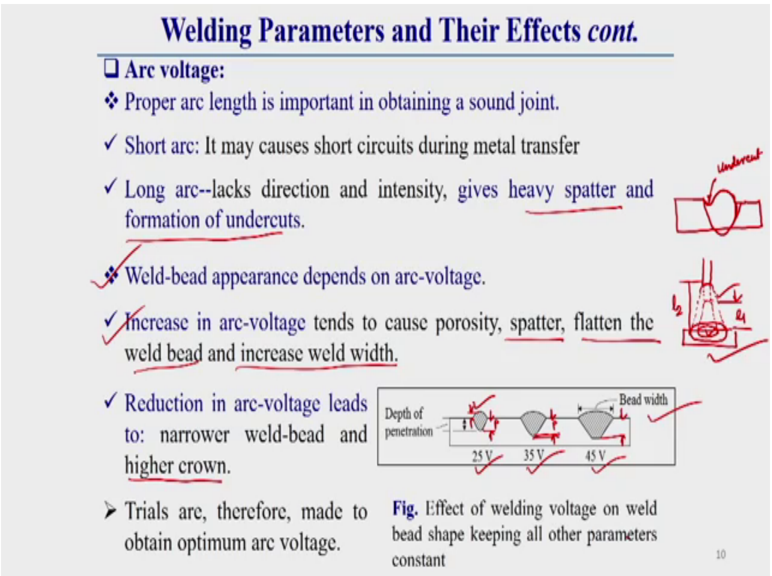

Now, we will see what is the effect of this arc voltage? Voltage related things you know actually. The main effect of arc voltage is on bead geometry generally, the arc voltage effects on bead geometry, arc voltage generally does not have significant effect on penetration like arc current or you can say welding current whatever the because current has effects on penetration, but arc voltages have effect on size; that means, generally width of the actual, width of the bead shape generally especially. How it is affect and that I will discuss 1 by 1. Generally proper arc length is important to obtain a sound weld joint, how generally one things you keep it in mind, if the arc is too short then what happens there is a chance short circuiting of electrode with base material, that types of chance can be there.

If, it is too high; that means, too long; that means, longer then this arc become unstable there can be arc can be unstable as well as there is generally too long arc lacks direction and intensity of the arc. So, what happens due to this lack direction and intensity, what happens it gives heaviest spatter and formation of undercut. This is the for long arc generally heaviest spatter is occur and there is occurs of undercut. What is this undercut? Undercut actually how it is looks like it is a welding defect actually.

So, undercut means undercut means that is let this is a this is the let this is a weld bead. So, undercut means some sort of depression, some sort of depression in weld bead, which is generally this definition lie beneath the surface of the work piece. So, this is actually a type of this is generally called undercut, this is a defect of weld, this is a generally defect of weld. So, this types of depression can come the arc is too long and this undercut can happen in case of long as well as, it generally have what happens there can be a spatter types of arc.

Why a spatter types of spatter types of molten material will be there, because generally this molten droplet us will fall from very high distance. So, once it fall down there is can be some splashing out of molten material outside this molten zone. So, that the that can create some spatter types of deposition. So, so short arc and long arc as we understand. So, now, here another main things of this arc voltage effect is what weld bead appearance, this bead appearance generally highly depends on what arc voltage. So, how it is generally higher the arc voltage means higher will be the length of the arc. Now, you see one things you keep it in mind you let us this is a so, here on things you keep it in mind.

Here, let us if this arc is a small, then the arc if the if the arc length is a small let this is l 1 l 1 and if this if this arc length become high let this is l 2. So, in this case in this case you will get more a spread more a spread arc then shorter arc. So, here you will get a bead width of this mass, if you increase the arc length, then here due to the spread of these arc. Generally, what happens here you will get wider bead shape, wider bead shape, because more arc area will be there due to this more arc area, there will be more flattening of the weld bead is there. Now, you can things are there, now it is the by increasing the arc length we can increase the weld bead area as we as much as we required, but it is not like that, if we increase more and more arc length then there what I have already told you.

There can be instability of the arc, as well as there can be lack direction as well as intensity can be there. Due to that things there is a limitation of arc gap, there can be extinguishing of arc also can be there. Because, due to this less intensity and all the things, there can be extinguishing of arc will also there. And, another things also you should know, that after certain length of arc generally this arc instead of a spray out it is generally constrict. Why this is constrict there can be occur some sub constriction of arc, because that radial force and other thing that electromagnetic force and other thing this effects generally can be there.

So, there can be constriction of arc also can be there. So, that is why generally higher and higher arc gap is not good. Now, why it is not good generally higher the arc gap though increased the arc voltage, but what happens there should be some limitation of arc gap should be there. That is why generally here one things you keep it in mind, generally trails are therefore, made to obtain optimum arc length. So, before generally actual welding lot of trails are required, there what should be the actual arc gap; that means, what should be the actual welding voltage, it was observed that increase in the voltage tends to cause porosity.

What I have told you already; that means, a spatter and flatten the weld bead and increase weld width. This, what is weld width, weld width means it is this bead width you can say. Generally, here itself from this diagram itself you can see, generally from for a for a 25 voltage for 35 voltage and 45 voltage how the weld bead shape vary, keeping all other parameter constant. If, we change the if we increase the arc voltage how the bead shape varying.

Here, one things you have seen generally here the change of penetration; that means, change of penetration means this thing, that with the depth of the penetration, depth of penetration is almost marginal. Do you see this depth of penetration, this depth of penetration generally one things you can see, it is marginal change, but what happens with increase of voltage, here generally this bead becomes flatter and it is beads wide become more and more, that we can observe from here. Why it is that, I have already discussed. Now, here one things also you should know that reduction in arc voltage; that means, in case of shorter arc length generally, there can be narrower weld bead which is like this narrower weld bead and higher crown, higher crown means this bead height.

This bead height can be higher side due to this reduction in arc voltage. So, narrower the bead shape become narrower as well as higher crown will be there, if the arc voltage is due to the reduction of the arc voltage. Now, we got the idea what is the effect of arc voltage. So, arc voltage effects on bead geometry especially bead width, generally higher the arc voltage higher will be the bead width, generally it is penetration effect is marginal that we observe from here.

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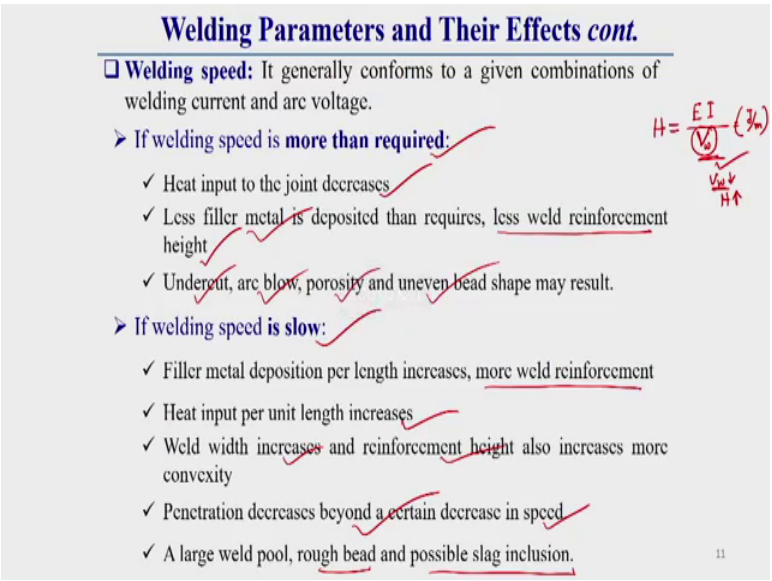

Now, we will go what is the effect of welding speed, this welding speed is the generally very interesting or important parameter, which generally represent; that means, how much heat will be supplied per unit length, that we can this idea we can get from welding speed. How you can you can represent this thing, that I have already discussed you that is the heat supply per unit length is equal to voltage into current divided by welding speed.

This is generally called welding a speed, welding a speed. This V w means welding a speed. Generally, here what you observed heat supply per unit length, this unit actually is the unit of this thing is joule per meter or joule per millimeter. So, from here we can see higher the welding speed, lower will be the heat supply per unit length. So, lower the welding speed higher will be the heat supply per unit length. So, once we get this idea then we will see what will be the it is effect.

Like, if the welding speed is more than what is required; that means, that means if the welding speed is high, here generally heat input to the joint per unit length will decrease definitely if it is high, if V w is high, then heat input will be decreased this will decreased, then due to this decrease of heat input there will be less filler material deposition. So, due to this less filler material, then if the less filler material will be there, then less reinforcement also less reinforcement height also, you will get apart from this thing due to more welding speed there can be undercut, arc blow, porosity, uneven bead shape these types of different different welding defect and this type different different effect can occur over the welding zone.

This actually undercut porosity uneven bead shape these are all different welding defect. And, arc blow I have already discussed about the higher the welding speed generally there is a chance of higher arc block can be also there, that I have already discussed in during arc blow discussion. Now, if the welding is speed is slow if this is; that means slow means if this is lower, this V w is less decrease, then these H will be increased. So, if H is will be increased then filler material deposition per length will increase. So, here you will get due to this more filler material deposition, more reinforcement you will get here.

Here, heat input per unit length also we will increase, due to this thing, because here H will increase due to lower this thing, then well width and reinforcement height also increase here well width as well as reinforcement height also increase. So, due to this here generally, here we will get more convexity types of shape of bead due to this low so, lower speed of welding, then here due to this lowest speed of welding generally penetration decrease we want certain decrease in a speed.

How it is that I will discuss? Here one things you keep it in mind, you never think are the higher the heat input means, higher the depth of penetration not like that, higher the because what happens, higher the heat input; that means, for slower speed.. Generally does not means that penetration will increase and increase it has a limit, after that limit generally penetration not increase, that is why this point here it is written that penetration decrease beyond a certain decrease in a speed.

After, further decrease of that, further decrease of the welding a speed that penetration does not affects, how it is that I will discuss in next slide. And, here another things you should keep it in mind due to this slow speed, a large weld pool rough bead possibility of slag inclusion also there, due to this slow speed. Now, we will see this penetration generally this penetration that is why generally we should decide our optimum welding speed also. Because, what happens for a particular welding for a particular welding speed generally we can get optimum penetration.

That a speed is generally intermediate speed, it is not either very high, or it is not it is very less, it is generally a some within some intermediate speed. We get generally what is called more high penetration.

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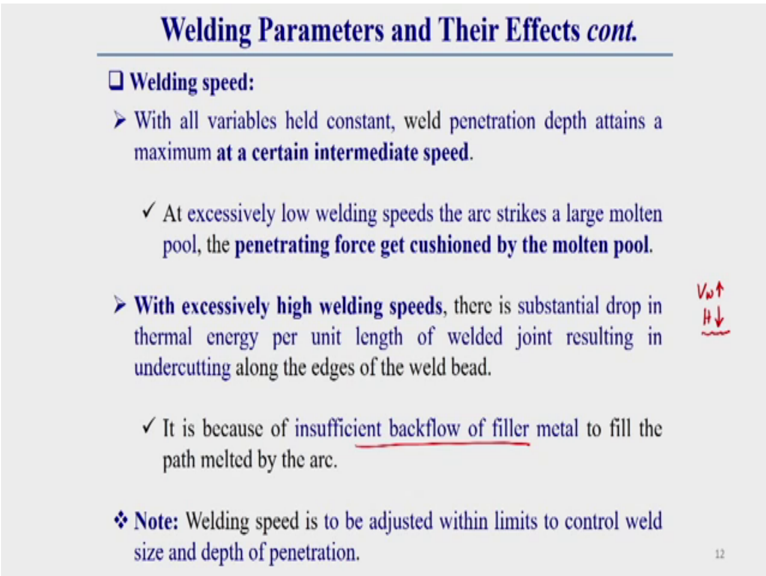

Now, why this is happened because at excessively, because if we decrease the speed again and again. So, at excessively low welding speed what happens, the arc a strike a large molten pool, definitely what happens if the welding speed will be low, then what happens volume of molten material will be high at a particular location.

Due to this volume of molten material generally the penetrating force get cushioned by this molten pool, because here whatever the penetrating force is coming over the molten pool, that molten pool generally cushion that forces. Now, due to that things what happens here generally further penetration cannot increase, that is why if this penetration; that means, after certain lowering of welding a speed generally penetration further does not increase. So, that is why here generally optimum penetration we got at some intermediate a speed.

Now, here another things we should remember with excessively high welding a speed generally, there is a substantial drop in thermal energy per unit length. Because, that you know, if the welding is speed is very high, then what we got this heat input per unit length will decrease tremendously. So, there is a substantial drop in thermal energy per unit length of the weld joint is there, it is a substantial reduction if welding heat input what happens, there is a chance of lack of weld material deposition can be there.

Due to that things what happens there can be undercutting along the edge of the weld bead, why this undercutting is there? This undercutting it is because of insufficient backflow of filler material to fill the path melted by the arc. This is due to insufficient backflow of filler material; that means whatever the material required to backflow to fill the path melted by arc, that sufficient filler material is not backflow if the speed is high. So, here one things you keep it in mind, welding speed is to be adjusted within limit to control weld size and depth of penetration.

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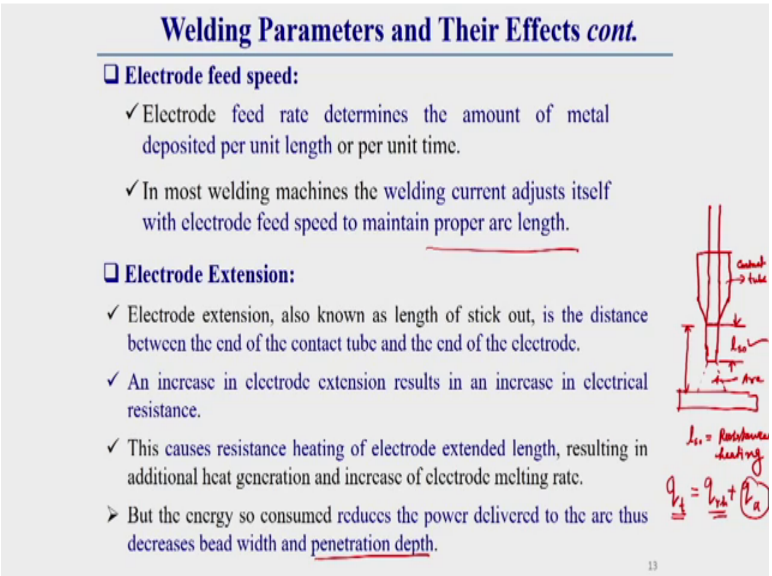

Now, we will see what is the effect of electrode feed a speed? Then, we will go for what is the effect of electrode extension and finally, we will discuss, what is the effect of electrode diameter effect?

So, first of all we will see what is the effect of electrode feed rate? What I have already discussed? Electrode feed rate means, if the electrode feed rate will be more, then what happens, then deposition rate will be more, because feed rate more means more material will supply to the work piece. So, here generally that is why here electrode feed rate determines the amount of metal deposited per unit length, per unit time. Generally in most of the welding machine, generally depending upon this welding feed rate the current is adjusted.

So, what happens in most of the welding machine the welding current adjust itself with electrode feed speed to maintain generally proper arc length, that I have already discussed generally that is called self-regulation characteristics of arc in most welding machine generally that types of characteristic generally used. Now, we will discuss about electrode extension, what is the effect of electrode extension? This is a very important parameter, which have significant effect on deposition rate bead shape and all other things.

How it is that I will now discuss? Generally electrode extension this is also known as length of a stick out, that I have already discussed. This is generally what this is generally called contact tube, contact tube. And, generally I hope this contact tube, here generally this is called arc this is called arc; that means, electrode tube to work piece whatever the root gap is whatever the gap is there, that is called arc gap or here generally arc is created that is arc, that we know.

And, this contact tube tip to arc till arc, whatever the length of electrode extended out, that is called length of stick out, this is called length of stick out LSO, that we can write. So, length of a stick out generally is the extension of electrode coming out from electrode tip to a electrode, generally coming out from contact tube tip to arc position. So, here this is generally called length of a stick out. Here one things you keep it in mind generally if this length of a stick out increase, then what happens length of a stick out result in increase of electric electrical resistance.

Because, this length of a stick out if it is more then what happens here electrical resistance also will be more, because from this contactive like arc. If, the arc gap is more that generally there is arc resistance is more. Similarly, if this length of a stick out will be more resistance will be there. So, due to this more resistance this causes resistance heating of the electrode extended length. In this electrode extended length in this LSO here generally resistance heating will be there, resistance heating will be there, resistance heating will be there.

Due to this resistance heating here additional heat generation will be there and increase of electrode melting rate will be there. So, higher will be this length of a stick out higher will be the melting will be there. Now, for a particular power generally what happens due to this resistance heating of the resistance heating of this extended electrode, here generally power will be consumed by this resistance heating portion. So, for a particular power supply from this power source here some portion of heat is consumed by this resistance heating of electrode. So, rest of the heat generally supplied to work.

Due to this thing what happens the energy. So, consumed reduce the power delivered to the arc, thus decrease the bead width and penetration depth. So, what happens here this total. So, here total generally whatever the total power let total power is q t. This is generally representing to resistance heating of the electrode extension, and it is some portion is rest of the portion is going to arc here I am representing qa arc.

So, as this from this total heat supply some portion is consumed by this resistance heating. So, this q a arc heat energy generally are arc intensity of heat arc heat energy generally decrease.

So, q a decrease due to this q a decrease here generally less force full arc will be there. And, due to this less force full arc generally here generally penetration depth will be decrease. So, due to these things penetration depth will be decreased, why penetration depth will decrease, due to less power delivered to the arc due to resistance heating of the extended portion of the electrode.

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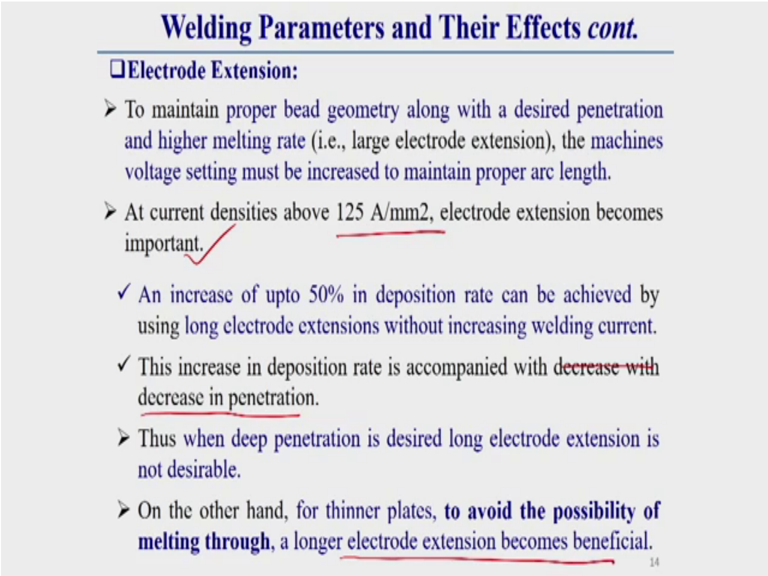

Now, that generally here one things you keep it in mind, generally at current level above 125 ampere per millimeter square, that is current density above 125 ampere per millimeter, this electrode extension become very important, this become generally very very important.

Because, if this current density is more than this, then this electrode extension will be beneficial, because what happens generally above this current density we can utilize for burn of or resistance heating of this electrode. Generally, why resistance heating of the electrode, generally we can increase the deposition rate around 50 percent, by without changing any current, generally without changing or without increasing the current value, generally an increase of 50 percent deposition can be achieved by using long electrode extension without increasing the welding current.

This increase in deposition rate, whatever the increase in deposition rate is there, this is generally accompanied with decrease with depth of penetration, because here some heat is consuming. So, less power is coming to arc. So, less penetration will be there, then another thing thus one things you keep in mind, when the deep penetration is desired long electrode extension is not preferable over there. So, there generally long length of a stick out is not desirable.

So, when depth of penetration required is more there should be shorter length of a stick out. And, another things you should keep it in mind for thinner plate generally to avoid possibility of melting through a long elected extension is more beneficial.

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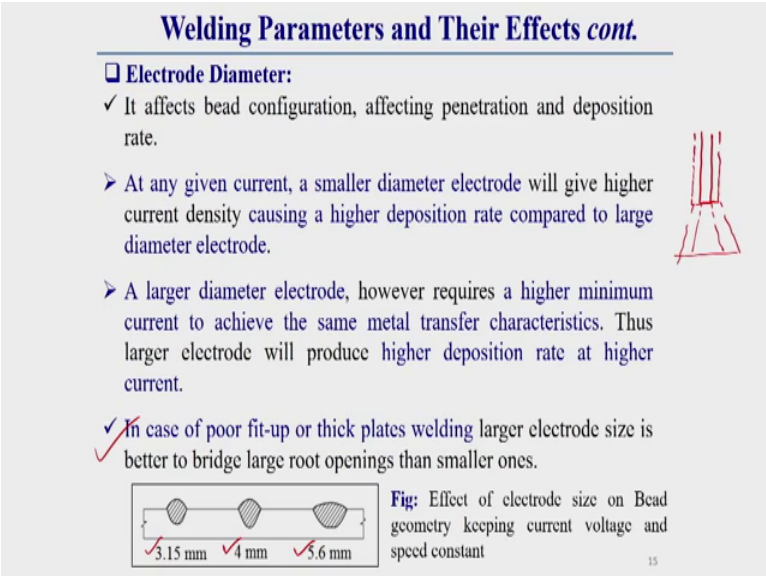

Now, the last parameter that is called electro diameter, which have also effect this electrode extension diameter also significant effect on bead configuration, penetration, and deposition rate. Why, we generally electrode diameter means; towards the electrolyte, this is one electrode, if the electrode diameter, this is this is another electrode diameter. So, here one things you should remember.

So, so electrode diameter, if the electrode diameter is increased generally what happens then current density will decrease, definitely current density will decrease. So, generally what happens if current density will decrease then less forceful arc will be generated, that is why here one things we should keep in mind for a particular current, for lower diameter electrode generally we can get more forceful arc than higher diameter electrode. That is why for lower diameter electrode generally for a particular current, we can get more penetration, this is one important point. Apart from these things for a particular current generally, due to this high intensity or high current density they are generally melting rate also will be more. So, for a particular current for lower diameter generally we can get more melting rate of filler material then higher diameter of electrode.

So, that is why a large and another things here you should keep it in mind, a large diameter electrode. However, require a higher minimum current to as if the same metal transfer characteristics; that means, for a particular metal transfer characteristics means for a less for a particular a spray types of metal transfer, whatever the current required for a lower diameter electrode. This current requirement will be higher for to get the similar types of a spray types of metal transfer for higher diameter electro, definitely that should be there. Thus larger electrode will produce higher deposition rate at higher current generally.

So, to get higher deposition by larger diameter electrode, here current level we should increase. Here one things you should keep it in mind in case of poor fit up or generally thick plate welding, larger electrode size is better to bridge large route opening than a smaller ones. Just that is why for poor fit up and thick plate generally larger weld electrode diameter is preferable. Here we are showing what is the effect of this is effect of this electrode diameter one bead geometry of the bead geometry of the welded sample. Here this is showing generally keeping all other parameter constant if we increase the electrode diameter.

Here one things you can see this depth of penetration and it is what it is called depth of penetration and it is bead geometry, how it is varying from this figure you can easily get; that means, lower diameter generally for same current and all we get generally comparatively more penetration, here generally for higher diameter for keeping same this things we get less penetration, but here we get wider bead geometry? Because, wider bead geometry why wider bead geometry, because what happens here less forceful arc, but what happens there can be due to this thing a less forceful arc.

There can be due to larger diameter this molten droplet deposition can be higher side this figure you can get this idea. So, these all about the effect of different operating parameter on weld quality that means, overall quality of welding in details. Next, lecture I will discuss about the different welding processes in first lecture, I will discuss about the oxy fuel gas welding techniques, then subsequently I will go to different arc welding techniques.