**Fundamental of Welding Science and Technology**
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**Lecture – 23**
**Submerged Arc Welding (SAW)**

Today, I am going to deliver a lecture on Submerged Arc Welding process. It is a fusion welding process and it is also heat source is electric arc. So, whatever the electric arc welding technique in last class I discussed that was GMAW arc welding process. GMAW means Gas Metal Arc Welding process. There what we observed they are generally used a consumable electrode which is continuously feed through a wire feeding mechanism and here in GMAW generally inert gas is used to shield the arc as well as weld pool.

But, in this case here it is called submerged arc welding because here the arc, weld pool, as well as some portion of electrode also submerged under the granulated flux which is not visible, but in GMAW it was visible, but here it is not visible actually. So, that is why it is called submerged arc welding process because here the entire arc is submerged under granulated flux which is not visible, but in GMAW process arc is well visible because it is generally surrounding by some gas inert gas.

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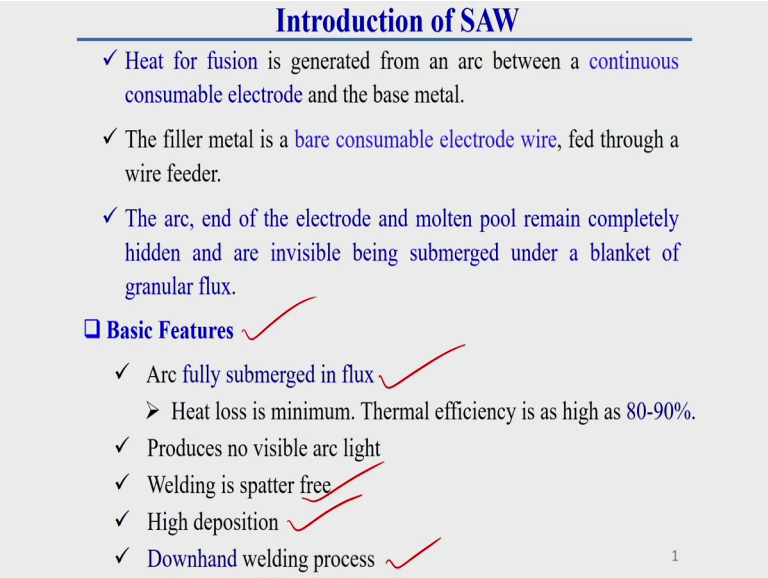


Here generally first thing whatever the sequence I discussed in previous welding process here also I followed the same sequence. Like here there will be introduction of welding,

then principle of welding, then welding setup then whatever the different process parameter in this welding process I will discuss in detail. Then, subsequently if there will be some different think then other welding process that also I will discuss here. Apart from this things I will discuss here what is the advantage disadvantage and application of this welding process.

First of all introduction in introduction generally in this welding process what I have already told you that it is a fusion welding process. Here generally heat for fusion is generated from an arc between a continuous consumable electrode and the base metal. So, whatever the things in previous GMAW welding process; that means, there was also a continuous feed electrode was there and there was a electric current, but here also similar thing is there, but here generally the this the whatever the filler material here used that filler material is also a bare consumable electrode wire which is generally fed by somewhere feeding mechanism, whatever the things we have used in previous case more or less similar thing.

But, the difference is here generally that the arc, end of the electrode and molten pool remain completely hidden and are invisible being submerged under a blanket of granulated flux. So, here generally there only one difference here we are observing that is the there generally used some inert gas to shielding the molten pool from atmospheric contamination, here generally used a granulated flux. There arc was visible in GMAW process, here arc is not visible because what happens here generally arc is and molten pool submerged or hidden inside the granulated flux.

Here the basic feature of this welding process are generally arc is here fully submerged in flux; first thing. So, as the arc is fully submerged inside the flux that is why here generally heat loss is minimum. As the heat loss is minimum in this welding process that is why it has very high thermal efficiency. This thermal efficiency can varying from 80 to 90 percent as this arc and weld pool fully submerged under the granulated flux that is why what happens here generally it is does not produce no visible arc light; that means, here generally digestion of electric arc light is negligible we can say.

Here welding is generally also as it is submerged under the granulated flux that is why here generally the spattering effect is also is not there ; that means, this welding process is a spatter free. And in this welding process due to it is high welding efficiency or

thermal efficiency we can say here generally it is a high deposition welding process compared to what it is called GMAW or TIG welding process.

And as here some granulated flux is used, that is why what happens this welding process mainly used in downhand welding process because what happens if we use this thing is in some positional welding like overhead or vertical types of welding process then what happens there is a chance of fall down that granulated flux. So, that is why this is mainly used in downhand welding process.

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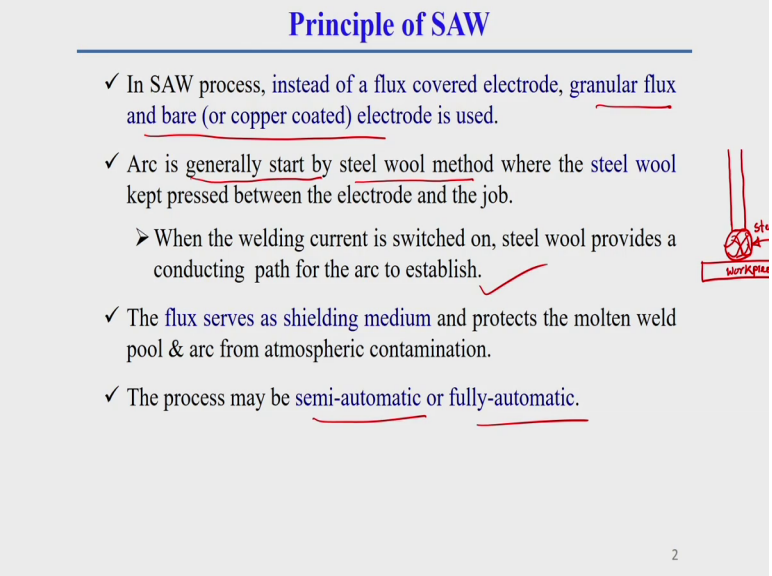


This is the principle of this submerged of this welding process. In this submerged arc welding process generally what I have already told instead of a flux covered electrode whatever used in SMAW process here generally granulated flux and a bare electrode is used then like in SMAW process there was used a flux cover and what happens flux covered electrode here generally a bare electrode with flux generally here is used.

So, what we can say this welding process is a combination of SMAW process and GMAW process. Here generally the idea of flux generally taken from SMAW process and idea of bare electrode is taken from what it is called GMAW process. That is why generally here by combining this two effect this welding process can be fully automatic or fully mechanized, that I will tell in subsequent slides.

Here generally arc is generally started by steel wool method. I have already discussed about this techniques in details during arc starting method. Here also a generally in this welding process arc is started by steel wool method. What does it means? Steel wool method means generally some sort of steel wool kept generally in between this; in between this electrode and workpiece. This is steel wool steel wool actually which generally kept placed in between this workpiece and electrode.

So, what happens if the current is switched on, then generally this is steel wool makes the conducting path to arc start actually. So, this steel wool once this current is switched on from the power source generally this steel wool provides a conducting path for the arc to establish. That way this arc is generally started in this welding process especially this welding process steel wool is a popular technique which is used to start the arc.

Apart from this things here also we can use tapping method whatever I have discussed; that means, by touching the electrode with the workpiece after that is just it is just removed, then suddenly generally there will start the arc, that way also here this tap method also can be used to generate the arc also here.

Whatever the flux here used it generally serves as a shielding medium whatever I have already told and it is generally protect the molten weld pool from atmospheric contamination. So, here generally this granulated flux act as a shielding medium which protect both molten wool arc from atmospheric contamination and this process may be semi automatic this process may be semi automatic or fully automatic.

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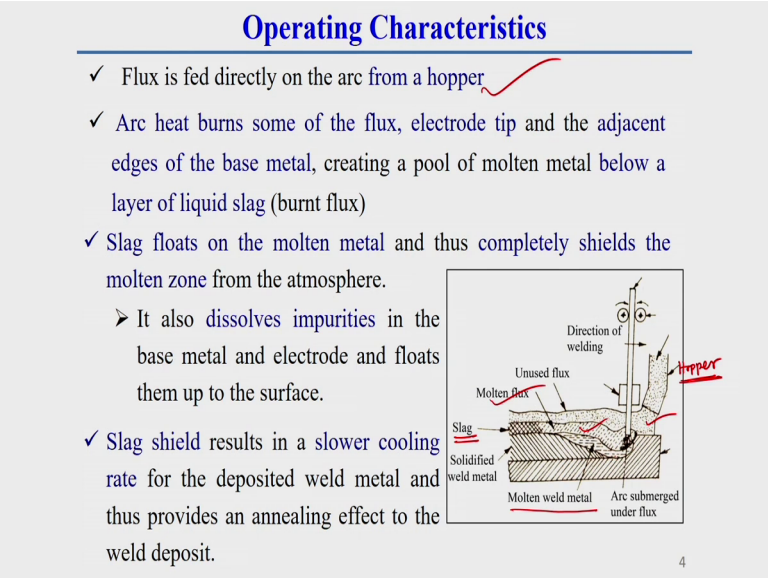


Now, the operating characteristic of this welding process how it is operated and howwhat is the characteristics of this operation that I will now explain in details here. Here generally flux is fed directly from a hopper. This is actually called hopper; that I will explain in next slide what are the different part of this welding process or welding setup. Generally, in a hopper generally it contain this granulated flux. So, this flux generally continuously fed over the arc. So, that it is cover the molten pool as well as arc and some portion of electrode.

So, it generally so, entire weld pool arc is under the flux which is supplied by a hopper. Now, next arc generally this arc heat whatever the arc is there that arc generally burn some sort of flux whatever the flux is coming from this hopper. So, it burn some sort of flux, it burn the electrode tip and adjacent edge of the base metal. So, by combination of all this three; that means, electrode tip adjacent edge of base metal and burning flux generally it is create a pool of molten metal.

This molten metal pool generally is created due to this melting of electrode and adjacent base metal. So, this molten pool generally surrounding by a molten slag actually molten slag means generally this whatever the flux are there, this flux generally due to this arc heating it is burned and it is what happens it is liquidify. So, after that liquification what happens it create a you see one things you can say it create a molten slag. This molten slag means this molten slag generally once this cooled down it is converted to slag.

So, actually we can say burned flux when it solidify then it is called slag. So, this weld pool you see here it is written molten weld pool generally is submerged under the molten flux. This molten flux generally once it solidify generally it is converted to slag. So, here one thing you should keep it in mind here generally this molten pool generally is lying below a layer of liquid slag. This slag float on the top of the molten metal and thus completely shield the molten zone from atmosphere. So, this slag generally it is cover this molten metal and it is generally protect the molten pool from atmospheric contamination.

So, it is this molten slag also cover this molten pool and flow toward the surface of the molten pool because generally this molten slags density is lesser than the weld metal. That is why, what happen; it is flow toward the surface of the molten weld pool. Apart from this thing, this molten flux dissolve the impurities in the base metal as well as the electrode. So, this molten flux generally also contain some sort of impurities of base metal as well as from electrode.

So, once this molten flux solidify then it is converted to slag. So, slag is a combination of burnt flux then impurities of what it is called a base material as well as impurities of electrode. Now, as the this slag shield this molten weld pool from atmospheric contamination that is why here generally it reduces the cooling rate of the molten pool. So, what happens here generally there is occur some annealing effect.

This generally makes the weld metal after solidification more ductile than other welding processes like GMAW welding process where generally expose the atmospheric contamination that is why what happen there generally comparatively cooling rate is higher in this case. In this case generally cooling rate is comparatively lower than GMAW process because here it is completely shield with this flux. So, less cooling rate is occur in this welding process, that is why here generally there is occur some annealing effect which makes the welded joint more ductile.

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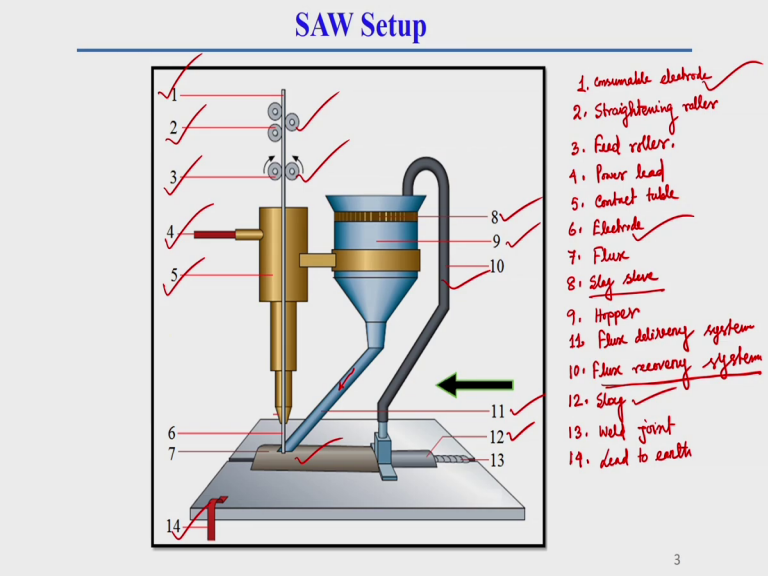


Now, this is the complete setup of this submerged arc welding process. Here one by one I will explain in detail this first one is called consumable electrode. It is called generally consumable electrode this one this one by one I will explain here what are the different part of submerged arc welding setup. The second one is called straightening roller.

Generally, this straightening roller the second one is called straightening roller because whatever the electrode or wire coming from the wheel that generally initially bent in nature. So, once it is go through this roller convert to state electrode, then electrode or bent filler material converted to state electrode.

Then, in third this is called feed roller. This feed roller; this feed roller means these generally feed the electrode to molten pool actually. These generally continuously this feed roller have some speed in this welding process generally constant speed feed roller is used. Constant speed feed roller is used means this feed roller is operated by constant speed motor. In case of submerged arc welding generally constant speed motor with self regulation characteristic what I have explained in last lecture in GMAW process, here generally this is more preferable technique that is used.

That means here generally self regulation of arc characteristics is used. Here generally the speed of the roller generally or feed roller is generally controlled by constant speed motor this 4 point is called power lead; power lead, this is called power lead. This power lead generally this 4 point this lead is connected to power source. Then this fifth point is

called contact tube; contact tube generally supply the current from this power lead to electrode. So, what happen this generally makes the electrode conducting actually, this 5th one.

Generally, the 6th point is called this electrode that I have already told you; that means, this one point this point one, whatever the things consumable electrode I told here also the similar thing. Why it is called electrode because it generally carry the current to generate the arc generate that what I have already discussed. So, here this electrode act as a consumable filler wire also because it generally melt and it is deposited. It is generally continuously feed by this feed roller.

Generally the seventh point is called flux or you can say granulated flux. This granulated flux cover the molten weld pool as well as arc as well as the electrode tip from atmospheric contamination you see this is generally called flux. Then this point 8 is called generally sieve, slag sieve, point 8 is called slag sieve. It generally recyclable; that means, this some portion of this flux which generally further and further it is used. So, what happens once we go for using this slag again and again. So, there can be a chance of some slag inside this flux, granulated flux. So, to remove this slag from this flux this sieve is used which generally remove that slag from this granulated flux.

Then 9 this is called the hopper. This hopper generally contain this granulated flux. This granulated flux generally supplied through this pipe or this has a name actually the that is flux delivery tube, we can say this slag general supplied by flux delivery; this is point 11 actually flux delivery system. This is called flux delivery system, this point 11. And this point 10 is generally is called some mechanism which is used to take the excess flux from this molten pool cover region by some shocking mechanism. So, here generally you can say we can write this point is called flux recovery system; flux recovery system.

Apart from this thing there is point 12 is there this point 12 is generally called the molten flux after solidification. It generally create a layer over the weld pool. So, what happen this point 12 is generally called slag this is called slag; that means, when this burnt flux solidify then it is converted to slag. So, point 2 is called slag and this point 13 is called weld joint actually weld joint, this is the welded portion. And this point 14 is actually lead to earth; earthing cable, lead to earth actually or you can say this is called earthing cable.

So, these are the different component of submerged arc welding process. So, many different part are there in this submerged arc welding process. So, this is the detailed submerged arc welding setup which is generally used in submerged arc welding process. Especially here one thing you should keep it in mind this flux delivery system and flux recovery system whatever it is used generally sometime this flux recovery system some welding machine it is available some welding machine it is not available. So, what happens this is generally used in some submerged arc welding process, somewhere it is not used actually.

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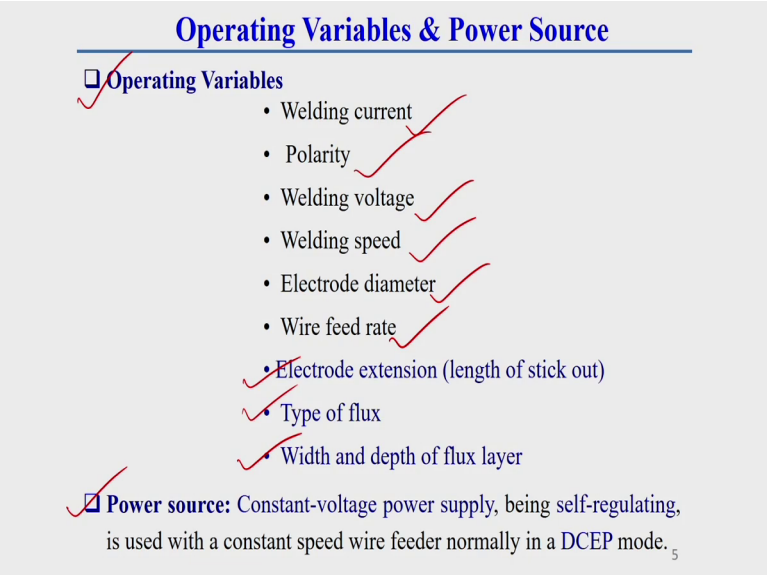


Now, this is the different operating variable and power source used in submerged arc welding process here you see this operating variable is almost more or less this operating variable is almost or more or less similar to arc welding process because there is some common operating variable which is available in every welding process like here is also used the operating variable is a welding current, polarity, welding voltage, welding speed, welding diameter, electrode diameter, wire feed rate. So, this operating variable is has similar effect or this operating variables have similar effect whatever the things I have discussed in previous welding techniques. So, I will not go in details about this operating variable.

I will discuss here whatever the extra different operating variable we can see or extra different parameters we can see in this welding process that I will discuss in details here.

Like here we will see there is used some type of flux. So, I will discuss in details what is the different types of flux used here what is it is effect on weld quality, then here also I will discuss width and depth of flux layer and also I will discuss briefly about electrode extension or you can say length of stick out, that what I have already discussed in previous GMAW process also. Here also briefly I will just discuss the extra part of that tig welding process. So, I will discuss here some extra part of length of stick out.

Now, here first of all what is the power source here generally used in this case generally constant voltage power supply is used and this power source characteristics is self regulating in nature. And here generally as it is a consumable types of electrode so, here DCEP polarity generally used why DCEP because generally electrode will be positive because we want electrode to melt because here generally electrode is consumable.

That is why whatever the electrode polarity we have used in previous welding techniques GMAW welding, here also same polarity is used because we want more heat to generate in electrode. That is why here DCEP once we will use as the electrode will be positive. So, bombardment of electron will be taken place on electrode. So, more heat will be generated over there that is why DCEP is preferable.

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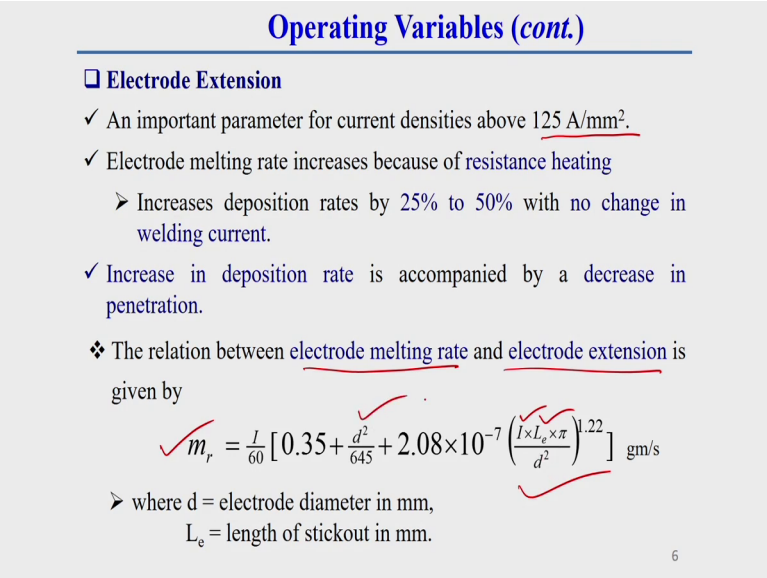


Now, first of all I will discuss about electrode extension. So, what I have this I have already discussed in last lecture also, but here I will discuss some extra part of that parameter. This is a very important parameter generally in case of submerged arc

welding process also because in case of submerged arc welding process generally high current is used compared to previous welding process like GMAW or TIG welding process whatever the current rate is used over there here the generally current rate is higher than that welding technique.

For that reason, here this electrode extension is very important parameter in submerged arc welding process because this electrode extension is a very important parameter once the current density goes above 125 ampere per millimeter square. So, here generally if the current density goes above this then it is a very important parameters and here one things we can observe here generally this electrode extension increase the melting rate because here this electrode due to this electrode extension there is occur some resistance heating.

So, it has observed that we can increase the deposition rate from 25 to 50 percent without change of any current. So, 25 to 50 percent deposition rate can increase by just changing the length of its stick out without changing any welding current it itself, but here one things you should keep it in mind as the here resistance heating is occurred. So, here the heat is some portion of power or heat power is taken by this resistance heating of electrode. So, here some sort of heat is generally come into electrode to heat this electrode portion; that means, preheating this electrode portion; that means length of stick out part.

Due to that reason here generally less heat is coming to arc. So, as less heat is coming to arc that is why here generally we will get comparatively lesser forceful arc. So, here generally lesser penetration also will be occurred. So, if the length of stick out increased then we can say the heat coming to preheating the electrode portion will be more. So, generally less forceful arc will be there. So, less penetration will be there.

So, generally here one things you should keep it in mind, higher the length of stick out lesser the forceful arc. So, lesser will be the penetration that you should keep it in mind. Here we can get a very interesting relationship between electrode melting rate electrode extension with as well as with current and diameter of the electrode. This thing from this is very widely used in case of submerged arc welding process generally in case of submerged arc welding process we can say that melting rate is a function of current length of stick out and diameter of the electrode.

So, here one things you can observe that higher the length of stick out higher the melting rate, but higher the length of a stick out another things you should keep it in mind lesser the depth of penetration. So, by this relation we can calculate the melting rate with the variation of welding current or length of stick out or diameter of the electrode.

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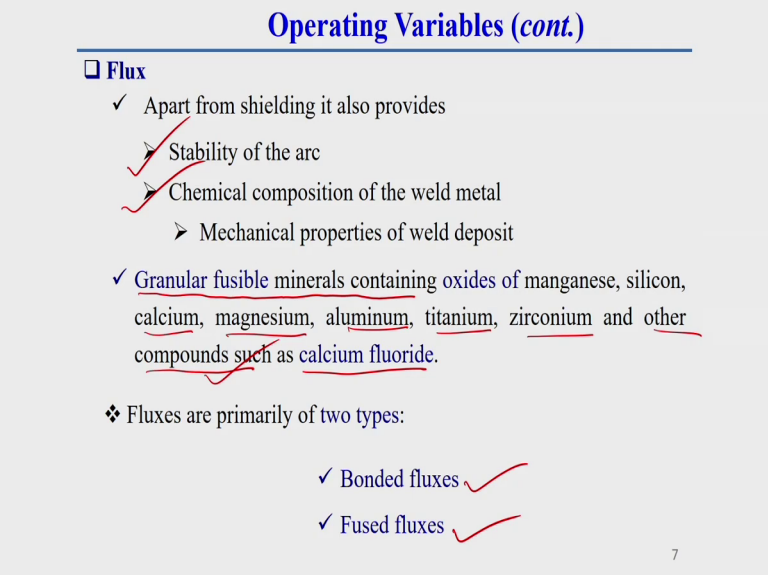


Now, flux this is a very important parameter in the submerged arc welding process. This flux is the main parameter in submerged arc welding process which generally important actually not main we can say that this is a very important parameter in submerged arc welding process. So, what we can say flux is a very important parameter in submerged arc welding process because this is not only shielding the molten pool from atmospheric contamination or shielding the arc from atmospheric contamination, it is also provides the following characteristic.

Generally it is also provide that means, it is stability is stabilize the arc; that means, for a stability of the arc it is helps a lot. It is also provide chemical composition of the weld metal; that means, it is generally whatever the flux we use here this flux also provide some chemical composition to the weld metal. So, due to this it provide the mechanical or strength or mechanical property of the weld deposit.

So, this flux have different different function it is not only provide the shielding of weld pool it is also stabilize the arc as well as provide the mechanical strength or mechanical property of welded joint. Actually this flux is a granulated this flux content whatever the

composition is in flux are there that also we should know. Generally, in flux there are generally granular fusible mineral are there. This granular fusible mineral, what is this mineral fusible means? That means, it can melt it. So, it is contains some very smallest of dust like granular particle which can melt due to resistance heating or heating of arc.

So, this granular fusible mineral generally contain the oxide of manganese, silicon, calcium, magnesium, aluminum, titanium, zirconium. So, these are the generally different metals oxide these different metal oxide generally used in case of in granular fusible flux. Apart from this thing there is some other compound also used that compound is called calcium fluoride. So, whatever the things here we can say? You can say that here generally manganese, silicon, calcium, magnesium, aluminum, titanium, zirconium oxide. So, oxide of all these different metals are there apart from this thing there are also calcium fluoride is also used which is a compound actually.

Generally in submerged arc welding there are two different types of flux are used one is called bonded flux another one is called fused flux. What is this bonded flux and fused plug that I will discuss in details in subsequent slide.

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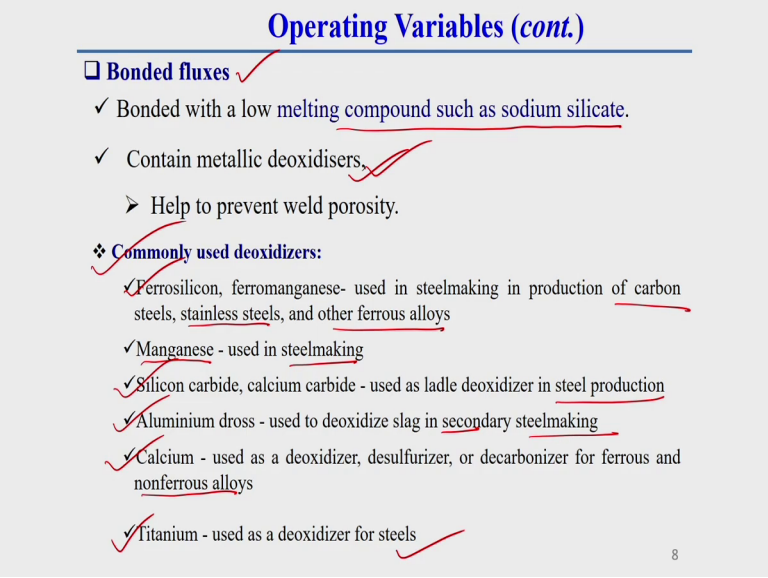


So, first of all bonded flux here it is called bonded flux because generally this granular fusible flux which contains some bonded element; that means, this granular fusible flux generally bonded with some low melting compound such as sodium silicate. So, whatever the flux composition I have told you in previous slide with this there is use

some bonded compound. This bonded compound have a low melting point actually. This low melting point bonded compound whose name is sodium silicate which is generally used in this bonded flux.

So, apart from this thing in bonded flux there is also used some metallic deoxidizer. So, here generally two different apart from this granular fusible flux whatever I have discussed in previous slide here is used some low melting compounds such as sodium silicate as well as there is used some metallic deoxidizer. These metallic deoxidizer generally helps to prevent porosity because if the oxidizer will be in flux then there is a chance of less porosity or you can say we can prevent the porosity in weld pool which is a very dangerous defects in case of welding defects.

Generally, here I am showing some sort of commonly used deoxidizer, that also you should know like ferrosilicon or ferromanganese. These are generally used in steel making in production of carbon steel, stainless steel and other ferrous alloy. Manganese is a commonly used deoxidizer which is used for steel making. Silicon carbide, calcium carbide is used generally deoxidizer in steel production. Aluminum dross also used as a deoxidizer in secondary steel making. Then calcium also is used as a deoxidizer or desulfurizer or decarbonizer for ferrous and nonferrous alloy. Then, titanium also is other types of deoxidizer which are generally used as a deoxidizer for steel making.

Here, just I am just showing what are the different types of deoxidizer generally available. So, among these generally some deoxidizer also used in case of bonded flux.

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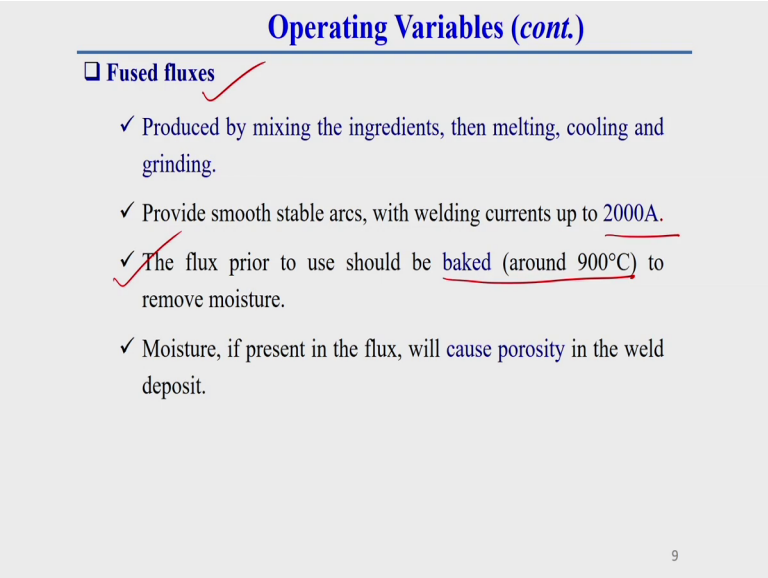


Now, fused flux this is a widely used flux in case of submerged arc welding process. This fused flux generally is a mixture generally how this fused flux is developed, how is this fused flux is generally making? Generally it is making first of all mixing of this granular fusible flux are there. Then this granular fusible flux this mix part of this granular fusible flux then melted. So, after melting it solidify by cooling and finally, it is grinding and converted to a small granular flux.

So, here what are the things are there first of all this individual different oxide is mixing together whatever the granular flux I told in previous slide then it is melted after melt it is generally cooling and solidify and finally, by grinding again this granular flux is made. So, as this flux is initially fused, then cooled and converted to granulated flux that is why this flux also called a fused flux. This fused flux generally can provide a very smooth stable arcs with welding current up to 2000 ampere; that means, up to 2000 ampere this fused flux can provide very stable arc.

Here one things you should keep it in mind this flux generally prior to use we should baked it. So, baking operation is required this baking operation means dry this flux by some heating. So, this baking temperature also should be around 900 degree centigrade otherwise generally there is a chance of moisture content in this flux. So, if in this flux there is moisture content then there is a chance of porosity types of weld effects.

So, to prevent this porosity types of weld effect generally this flux when you go for using for welding operation before welding just we have to baked it by some baker over a temperature or dry it over a temperature is around 900 degree centigrade and simultaneously we can we should use for doing the welding operation.

Once we baked it around 900 degree centigrade temperature then the moisture if there will be present that will remove. So, there is a less chance of porosity in welded joint. So, that we should keep it in mind; that means, this fused flux when you go for use we should baked it around 900 degree centigrade temperature.

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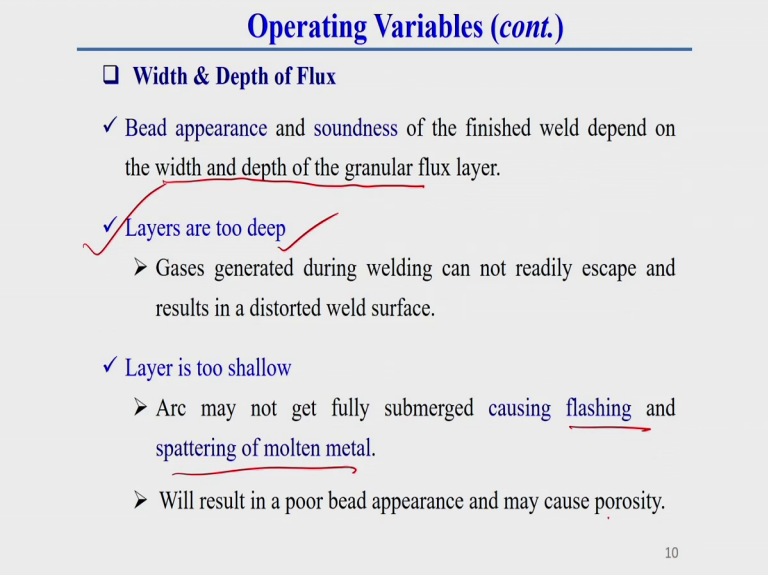


Now, width and depth of flux. This is a very essential or important parameter in case of this submerged arc welding process generally bead appearance and soundness of finished weld they depends on the width and depth of the granular flux layer. So, width and depth of granular flux layer provide the bead appearance as well as soundness of the welded joint.

Here one things you should keep it in mind; if the layer are too deep, what will happen? If the layer is too small, what will happen? Too deep, this flux layer is not good as well as too less flux layer also is not good. Like if the layer of this flux is more deep; that means, more thicker layer are there; that means, more flux over the weld pool will be there then what happens whatever the gas generated during welding operation that gas cannot easily escape from this weld pool region.

So, this gas generally entrapped inside this weld pool region. Due to this gas entrapped inside the weld pool region there is generally occur distorted types of shape of weld bead. So, here generally gas entrapment as well as distorted shape of weld surface is occur if the layer of flux is too high. And if the layer is too small that is also not good because if the layer of this flux over the molten pool is too less then what happens arc may not get fully submerged which can cause flashing and spattering of the molten metal. So, if the flux layer is too less. So, that arc there is a chance of arc visibility as well as which can cause some flashing effect as well as this spattering effect.

Apart from this thing there is a chance of porosity and distorted weld bead appearance. So, less so, too less thick layer also or shallow layer is also not preferable in case of submerged arc welding. So, there is some optimum layer thickness is there that we should choose and use in case of submerged arc welding process.

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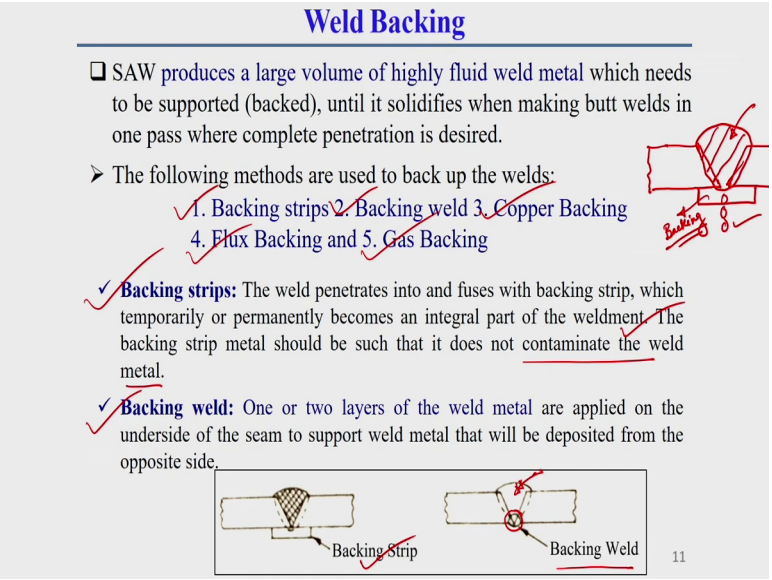


Now, as the submerged arc welding process is a high deposition what I have already told you high deposition welding process and what happens in this welding process generally we can get a large volume of highly fluid weld metal. So, what happens once we go for using this welding process for single pass butt welding process then to support this high fluid molten weld metal to drop out from backside of the welding welded joint generally there is used some baking to support that molten weld metal.

So, to support the molten weld metal in case of single pass submerged arc welding process single pass submerged arc welding process means let since one pass there will be the welding which will completely melt and join the workpiece; that means, by single run itself there will be joining of work piece will be there. So, what happens the as this volume of this molten material especially for single pass butt welding process as this volume of molten material is high in case of submerged arc welding as well as it is highly fluid in nature, if we use single pass submerged arc welding then there is a chance of dropdown of molten material from back side of this workpiece from the back side of this welded joint is there.

So, to prevent this molten droplet to come out from this back side there is use some backing system. So, this is actually backing system; backing system means to support this molten droplet not to come out form this joint there is use some support which generally prevent this molten droplet to come out and fall down from opposite side of this welded joint. This backing can be different types. There is generally 5 types of backing we can observe in case of submerged arc welding process. What are this 5 different types of method of backing techniques are there.

This backing can be done by backing strip; that means, this molten metal droplet we can support by backing strip, it can support by backing weld, it can support by some copper backing, it can support by flux backing, as well as it can support by gas backing. So, these are the different method which is generally used for submerged arc welding once we go for single pass butt welding process.

So, first of all one by one I will discuss in details about this different backing method first of all backing strip. Backing strip I have already discussed this is generally the weld penetrate into and fuse with the backing strip. So, in this backing strip generally it is become a temporary or permanent part of a weldment. So, here what happens the weld penetrate into and fuse with this backing strip which temporarily or permanently become an integral part of the weldment. These things we should keep it in mind.

This backing strip metal should be such that it does not contaminate the weld metal. So, this composition of this backing strips should be such we should not make any contaminant actually on the weld metal; that means, it should not provide any discontinuity or defect inside the weld metal. So, this backing strip it can be a permanent

part of this joint or it can be a temporary part of the joint. These backing strip you can see here this is generally a backing strip which is generally used back side of the welded joint which generally support the molten droplet not to fall.

Then there can be backing weld; backing weld means here in this case generally this underside of the welded joint here one you can see underside of the weld joint there can be one or two layer of the weld metal which are generally applied before doing the original single pass welding. So, what happens? So, first of all this backing welding is done by one or two layer after that generally the final welding run is done. Then what happens, this backing weld generally support that molten weld pool not to fall through this welded joint. This is called backing weld this is another technique which is used to support the molten weld pool.

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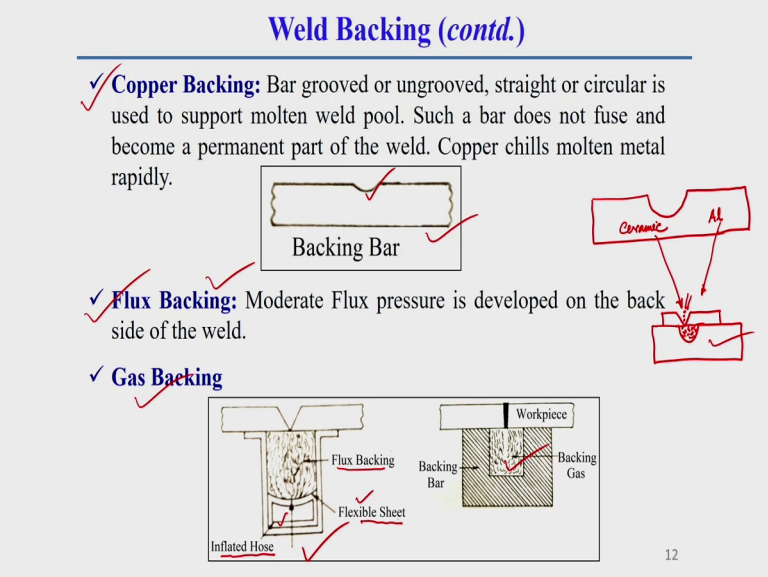


Then there can be used some other technique also that to another popular technique is called copper backing. If this is a copper backing means copper backing is a bar this copper backing actually is a you can say is a backing bar. So, it is generally this bar can be grooved type or it can be straight or ungrooved. This backing bar can be straight or circular. When it will be a straight? Once we use for flat butt welding there it will be a straight if we use for butt welding of pipe then it will be generally circular in nature.

So, one things you keep it in mind this bar does not fuse and it also does not become a permanent part of the weld. So, it generally recyclable; we can recycle this backing bar

we can remove it and reuse it for other welding purpose. Here one things you should keep it in mind this copper as we use as a backing bar it generally chills molten metal rapidly. So, nowadays also there is some other backing bar also used that is the ceramic backing bar.

Ceramic backing bar, then some sort of times also use some other backing bar that is called aluminum backing bar. So, aluminum backing bar also popularly nowadays used which is generally recyclable; that means, we can remove it and reuse it. This aluminum backing bar generally aluminum or ceramic backing bar also popularly used in submerged arc welding process.

Now, there can be other types of backing bar that is called flux backing. Flux backing generally this is a symmetric diagram of flux backing here this is generally below this joint there is a system which contain the flux, that is called flux backing. This flux generally provide some moderate pressure at the joint region, this moderate pressure is provide by some flexible sheet with inflated hose.

Here generally use a inflated hose and this is a flexible sheet. So, why this generally inflated sheet and flexible inflated hose and flexible sheet we can create some pressure in this flux region. So, there is create some moderate flux pressure below this welded joint which generally provide the support to not to drop down this molten drop droplet from the joint that is called flux backing system.

Now, another backing system is also used that is called gas backing. So, here instead of flux here is used some compressed gas. So, by this compressed gas also we can support the molten droplet not to fall back side from the welded joint. So, apart from this thing here generally flux backing also can be done by using ceramic backing bar or aluminum backing bar. Ceramic or aluminum backing bar also we can use with flux cover actually.

This also we can use; that means, this whatever the bar aluminum bar or ceramic bar are there this group initially filled with this flux after that it generally insert back side of the weld region. So, what happens if we do the welding here this molten droplet will not drop down through the back side of the welding joint. So, it will be supported. So, this is called generally flux filled ceramic backing bar or flux filled aluminum backing bar. This types of system is called flux filled aluminum backing bar or flux filled ceramic backing bar which is also widely used in industry.

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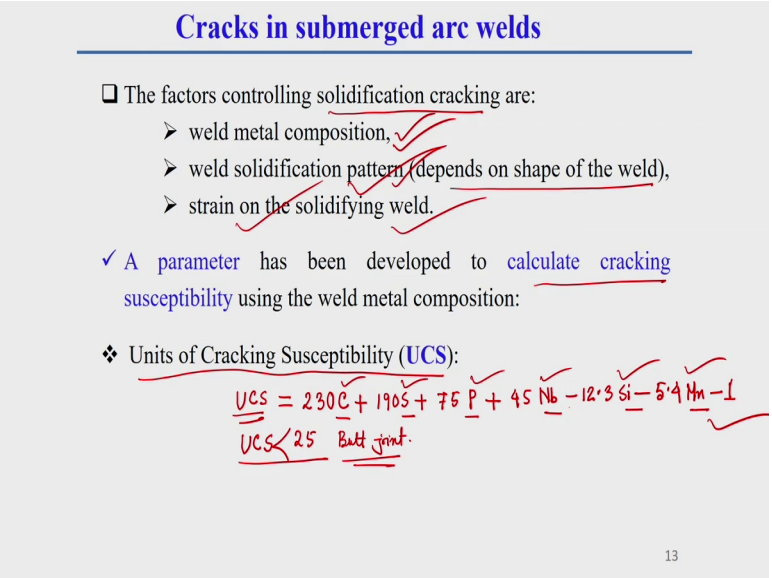


Now, here in this welding process in submerged arc welding process we can observe there is a chance of some cracking effect. So, that here I will discuss in details about the cracks in submerged arc welding what are the different reason. Actually this is the common reason of cracking in case of welding, but in case of submerged arc welding also this phenomena is observed. That is why here I am discussing about this cracking issue in case of welding that is called cracks in submerged arc welding process.

Here one things you can observe there is a different types of crack generated in welding that crack can be in different-different location. Generally this types of crack is a very dangerous defect in case of welding operation one of the very dangerous crack which is observed in case of welding process is called solidification crack. Solidification cracking is a very dangerous cracking in case of submerged arc welding process. The solidification crack which is controlled by different parameter or different aspects like this solidification crack is depends on weld metal composition, it is depends on weld solidification pattern; the solidification pattern is depend on shape of the weld and it is also depend on strain on the solidifying weld.

So, crack in welding process is a very dangerous phenomenon. So, in this cracking there is different types of cracking are there. So, one of the cracking techniques is called solidification cracking. This solidification cracking is controlled by different factor like it

is depends on weld metal composition, it is controlled by weld solidification pattern, it is also depends on strain on the solidifying weld.

First of all I will discuss about what is the effect of metal composition in solidification cracking that I will discuss in detail, then I will discuss what is the effect of solidification pattern in solidification cracking that I will discuss, then I will discuss what is the effect of strain on solidifying crack that also I will discuss in detail in subsequent slide.

For quantifying the effect of solidification cracking due to the weld metal composition here is used a parameter we can say. This parameter generally have been developed to calculate the cracking susceptibility generally using the weld metal composition. This cracking susceptibility we can calculate by a method that method we can say this is called generally Unit Crack Susceptibility or you can say Unit of Cracking Susceptibility which is represented generally by UCS. This UCS is depends on the weld metal composition it can be represented like this; that means, UCS is equal to 230 carbon percent, then 190 sulphur, then 75 phosphorus, then 45 niobium, then minus 12.3 silicon minus 5.4 manganese minus 1.

This is the unit of cracking susceptibility equation which is depends on different composition of weld metal like carbon, sulphur, phosphorus, niobium, silicon and manganese. Here one things you should keep it in mind if this unit crack susceptibility value is less than 25, then there is a less chance of solidify solidification cracking. So, in case of butt welding this is actually in case of butt welding butt joint, in case of butt joint if this USC value is less than 25, then what happens here we can get less chance of solidification cracking. So, lesser this UCS, lesser the chance of solidification cracking that you should keep it in mind.

So, as minimum as will be the this UCS value there will be less chance of solidifying cracking. So, if it is less than 25 then we can say there is no chance of solidifying cracking due to this metal composition and if the solidification pattern is within; that means, for a proper solidification pattern with this UCS value less than 25 there will not be any solidification cracking, then what should be the solidification pattern that also you should know. So, from here one things you should think that if the value of carbon sulphur, phosphorus, niobium if this value is in lesser amount then what happens there is a chance of less UCS value.

So, lesser the carbon percent, lesser the sulphur or phosphorus or niobium lesser will be the chance of solidifying cracking and another things also you should keep it in mind higher the value of silicon and manganese because here negative sign is there then there is a lesser chance of solidifying cracking, that you should know.

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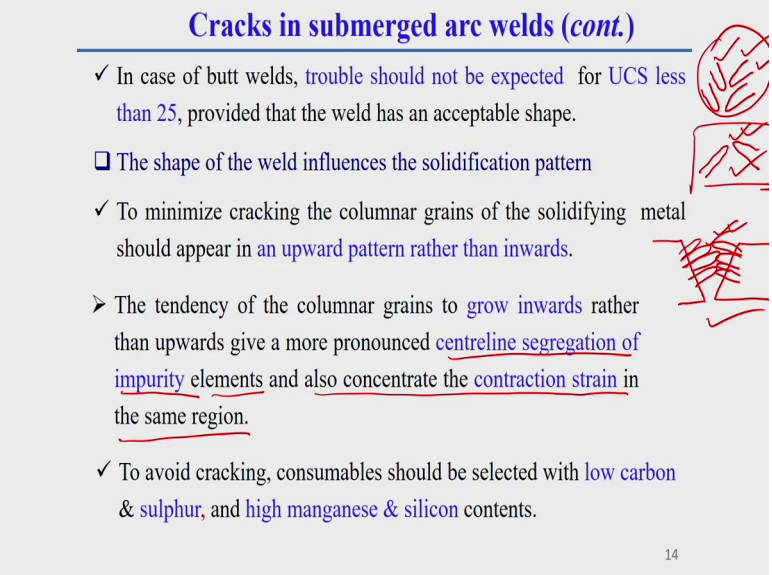


Now, we will discuss about weld solidification pattern. This is also affect a lot in this solidification cracking. Here one things you should keep it in mind if the solidification pattern during welding once it solidify in welding region you will observe there is generally once we will draw it then it will be more clear to you. You will observe there is generally these types of columnar grain are there these types of columnar grain you can observe in case of welding.

Now, this columnar grain generally whether it is in upward direction like this or it is in downward direction like this. So, solidification pattern generally it is generally in case of solidification pattern in welding region we can observe there is generally this columnar types of; that means, column shape grain are there. If this grain generally sometime it is form in upward direction like this it can forms downward direction also; that means, it can this columnar grain can form downward direction also like this.

So, what happens if the columnar grain formation is upward direction then what happens there is a less chance of solidifying cracking. So, to generally once our welding have upward this what is called columnar grain grains a grain structure then there is a less

chance of solidifying cracking. But, if it is if the columnar grain direction is downward direction there is generally more chance of solidifying cracking.

Why this is more because the tendency of the columnar grains to grow inward rather than upward give a more pronounced centerline segregation of the impurity element and also concentrate the contraction strain in the same region. Due to this generally if the grain direction is in downward direction then there is a more concentration of contraction strain in this region. Because there is a pronounced centerline segregation of impurity is there.

So, due to these things if the grain is downward direction like this then what happens there is a generally higher chance of solidifying cracking rather than if the grain direction is upward then what happens there is lesser central line segregation of impurity is observed. So, there is lesser contraction stain is observed, so, there is generally less chance of solidifying cracking is observed. So, always keep this taken in mind; that means, grain once it is form in upward direction this columnar grain once it form in upward direction then there you will get better weld quality then grain having low lower ward direction, that things you should keep it in mind.

So, to get this upward direction columnar grain, we should choose appropriate process parameter. It depends on generally appropriate process parameter. This process parameter generally here some term is used that is called from factor actually the ratio of width of the welding to depth of the weld zone. Generally higher this width to depth ratio lesser the chance of solidifying cracking or higher this width to depth ratio then greater is a chance to get upward grain structure. So, generally higher the form factor that generally I will discuss in detail in subsequent welding method there you will get the idea in details that about this form factor.

So, here one thing that you should keep it in mind higher to width to depth ratio of the welding region better is a chance to get what it is called upward columnar grain. So, we should choose the welding parameter in such a way so that we can get a upward columnar grain structure. So, if we get a upward columnar grain structure then there will be less chance of solidifying cracking. So, what we observe here in case of in welding process or solidifying cracking in welding process it is generally depends on composition of weld metal as well as it depends on pattern or shape of the weld zone.

Composition of weld metal we observe there is used some UCS or Unit of Cracking Susceptibility generally it is depends on composition material composition of weld zone. If this value is cross or more than 25 then there is a more chance of solidifying cracking, if it is less then there is less chance of solidifying cracking and apart from this thing if this weld shape which provide upward columnar types of grain structure that provides less chance of solidifying cracking.

So, these two things once we can get then what happens we can get a lesser chance of solidifying cracking tendency well joint. So, there is a less chance of cracking in case of welding joint.

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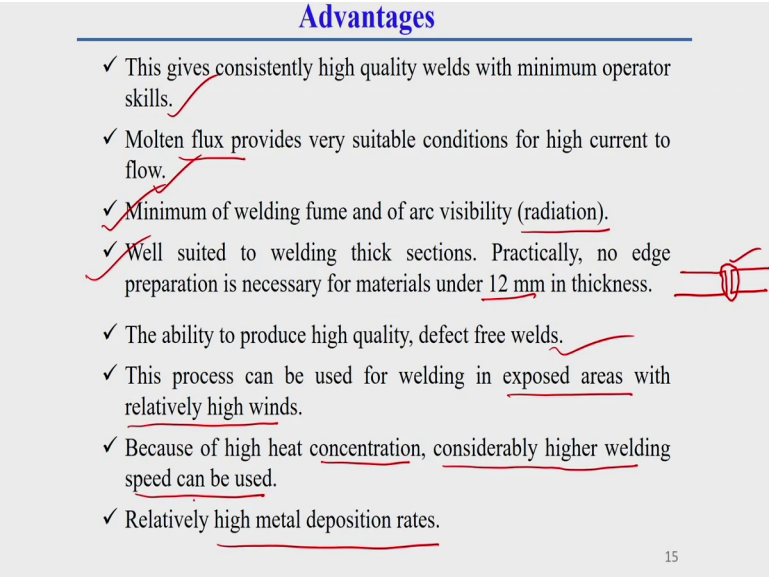


Now, we will discuss about what are the advantage drawbacks and application of this welding process. First of all we will discuss about the advantages of this welding process this gives consistently high quality welds with minimum operator skill because this welding process generally is fully mechanized or automatic types of process.

So, here generally operator a skill is not that much required. Here generally there is molten flux are there. This molten flux generally provides very suitable condition for high current to flow because this molten flux also provide some conducting medium which provide the suitable conducting path for high current.

Then minimum of welding fume and arc visibility are there because just the arc and other things is fully covered inside the flux, so, there is minimum of welding fume as well as minimum of arc visibility is there. So, radiation effect is also less in this welding process this welding is well suited to welding thick section because it is a generally very high deposition welding process and for generally here we can use very high current also. That is why it is well suited to very thick section also.

Practically it has observed that till 12 millimeter thick plate by using this welding process no edge preparation is required. A no edge preparation means without edge preparation without edge preparation means a square butt welding we can say without edge preparation a square butt welding we can do till 12 millimeter thick plate. Generally, in other welding process generally there is required some b group or bevel group, but without edge preparation we can join around 12 millimeter thick plate by using this welding process.

The ability to produce generally very high quality defect free weld, this welding. We can get a very high quality and defect free weld. This process can be used for welding in exposed area with relatively high winds that we should keep it in mind. Like in previous welding SMAW welding process in exposed area generally it is very difficult to use SMAW process because there is used some inert gas. So, that this gas cannot be proper if you use some windy weather or windy condition in exposed area there is a more chance of atmospheric contamination of weld pool is there in case of GMAW process or you can say TIG welding process.

But, here as the arc can a molten pool is fully covered some granulated flux. So, we can use this things little bit more comparatively more wind area or more exposed area than GMAW or tig welding process because of high heat concentration here one things, another things high heat concentration here generally considerably high welding speed we can get because high heat input higher will be the melting rate. So, higher will be higher the speed we can get by this welding process and relatively high metal deposition rate what I have already told you due to this thing only this high speed we can shift.

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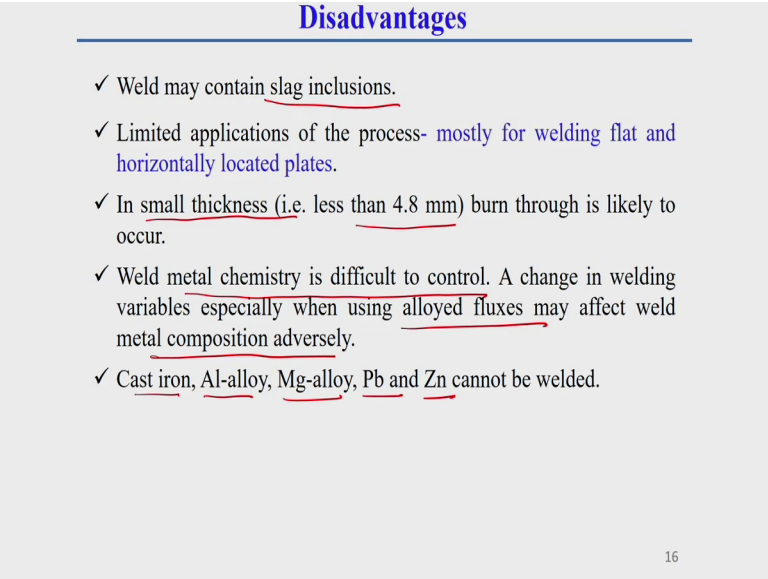


Now, as it has advantage similarly it has some drawbacks also. What are the drawbacks? This drawback can be this weld metal may contain some a slag inclusion that it may contain because here you we use generally this flux or slag. So, there is a chance of this slag inclusion in this welding process if the it is not proper. This welding process generally limited application in case of positional loyalty especially like we can use this welding process maximum in horizontal position welding. It is generally preferably used in downhand welding process, but this maximum we can use in horizontal position also by some proper system.

And another things in case of a small thickness plate this welding process is not suitable like less than 4.5 millimeter thick plate there is a chance of burn through occur in this welding process. So, in a small thickness was thickness is less than 4.8 millimeter that is still then there is a chance of burn through occur in this welding process. Here another things we should keep it in mind here weld metal chemistry is very difficult to control because generally this flux contains some oxide of different metal what I have already discussed.

So, what happens once we use this flux then it is melt and it is generally after melting there is a chance of mixing of this molten flux or molten flux composition with this weld metal also. That is why weld metal chemistry generally here is very difficult to control because a small change in welding variable especially when using alloyed flux may

affect the weld metal composition adversely. So, if there is a chance of change of welding parameter there will be change of chemistry of this alloyed flux composition. So, there will be chance of change of weld metal composition also.

Another things we should keep it in mind generally this welding process is not suitable for cast iron, alloy aluminium alloy, magnesium alloy, lead and zinc – this welding process is not suitable.

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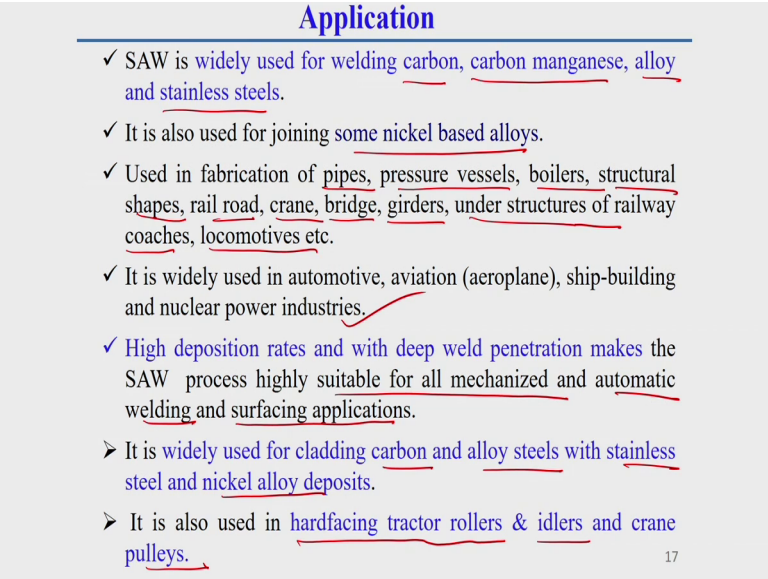


Then application of this welding process – submerged arc welding is widely used for welding of carbon steel, carbon manganese steel, alloy steel and stainless steel, it is widely applicable welding technique. It is also used for joining some nickel base alloy also it is used in fabrication of pipe, pressure vessel, boiler, structural shapes, railroads, crane, bridges, girders, under structure of railway coaches then locomotives etcetera, it has huge application.

It is also that means, it is used in shipbuilding industry, as well as automotive industry, as well as aeronautical industry, as aviation industry and it is also used in nuclear power industry also. As high deposition rate and deep penetration is observed in this welding process. So, this high deposition rate and with deep penetration make the SAW process highly suitable for mechanize and automatic welding and surfacing application.

Due to this high deposition rate and high penetration these welding also welding techniques also is used for some surfacing applications surfacing means it sometimes used for cladding purpose, sometimes it is used for hardfacing purpose. Like it is generally used as a cladding purpose over the surface of the carbon or alloy steel by using a stainless steel or nickel alloy.

Generally, this cladding operation is done to protect this carbon steel or alloy steel from atmospheric contamination; that means, from rusting of atmospheric contamination generally once we gives the a led cladding is a operation actually by which generally a surface layer is provided over the surface of some material which has generally less corrosion resistance. So, to protect this corrosion resistant of that material generally over the surface of the that material there we can provide some layer of other material which has high corrosion resistance, that is generally we can do by a operation that operation name is cladding operation.

This cladding operation is a very popular operation. By this techniques we can protect the corrosion as well as we can save the cost and other things. So, it is lot of advantage we can get. So, by submerged arc welding process generally this is widely used. Apart from this thing it is also used in hardfacing of tractor roller, idler and crane pulley. So, these welding process have very high application and it is widely used in industry.

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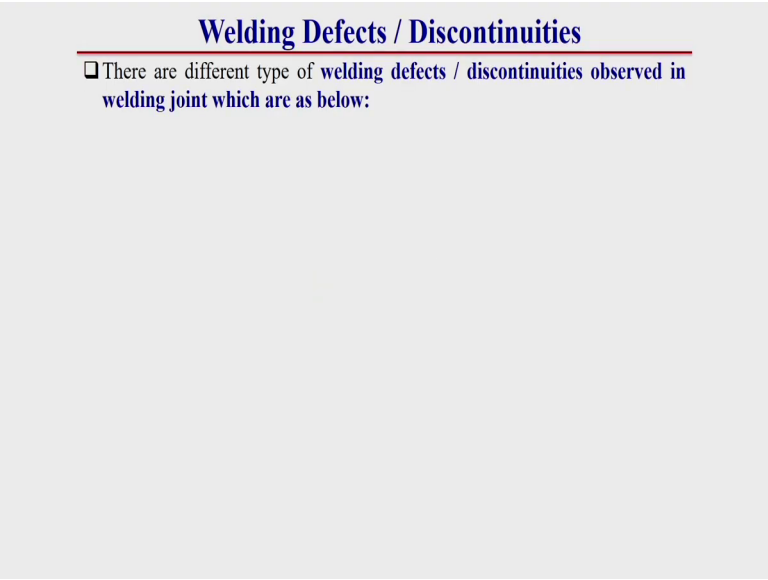

Now, in next lecture that is my last lecture I will discuss about welding defects and discontinuities. There I will discuss what are the different types of welding defects or discontinuities generally observed in case of welding joint or welding process, then I will discuss about what are the cause, what are the remedy, what are the prevention of that welding defects in details.