Manufacturing Process - I

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Module - 3
Lecture - 8
Submerged Arc Welding

Welcome students. This is the sixth lecture in the lecture series on the welding, and this lecture is based on one very important welding process that is submerged arc welding process. In the previous lecture, I have covered the shielded metal arc welding process which is most commonly used for the general purpose welding and for the repair purpose; while, the submerged arc welding process is mainly used in heavy engineering industry where very thick sections are to be welded.

And a very unique feature of his welding process is the use of the granular fusible flux which is used to cover the arc and the molten weld pool to protect them from the atmospheric contamination of the weld pool, and this process uses very high current densities also, because of which it is able to offer high penetration and high deposition rates. So, this process mainly finds its applications in heavy engineering industry like in ship industries or in pressure vessel industries. So, we will start this lecture with the introduction of the submerged arc welding process.

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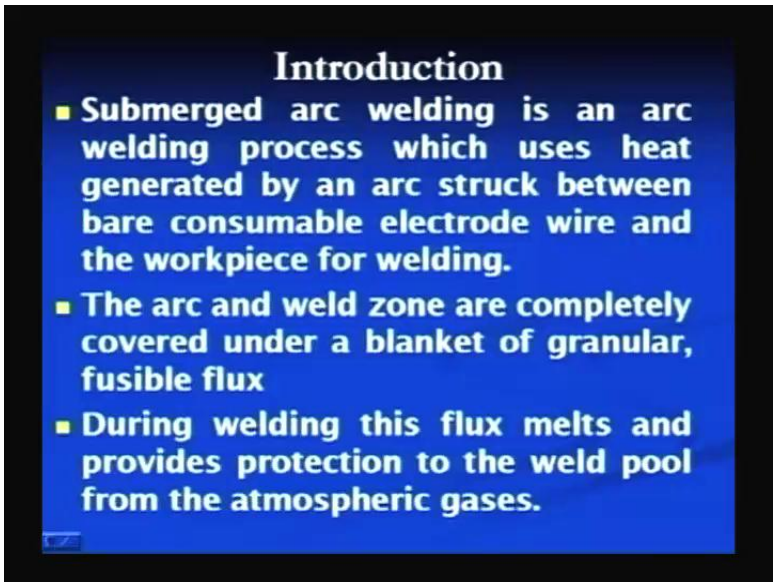

In this process the heat of the arc which is struck between the bare consumable electrode wire and the workpiece. And this arc is submerged under the fusible granular flux which melts and covers the arc and the weld pool itself to protect it from the atmospheric contamination. And this covering of the fusible flux plays a significant role in submerged arc welding, because arc is below the fusible flux. And therefore, it is not visible, and that is why this process is also called submerged arc welding process. Here the arc and weld zone are completely covered under the blanket of the granular fusible flux, and during the welding process, whatever heat is generated that is used to melt the filler metal electrode, the granular flux and to the base metal.

The flux here provides the required shielding action and also the elements present in the flux reacts with the impurities to form slag. So, the flux plays a significant role in submerged arc welding. During the welding this flux melts and provides protection to the weld pool from the atmospheric gases.

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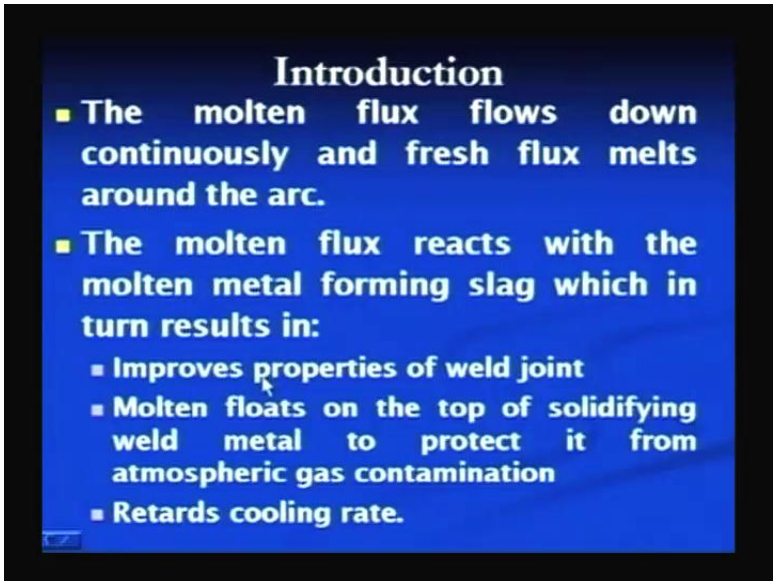

Here the molten flux, the flux which melts because of heat of the arc gradually flows down to the bottoms side and tends to float on the surface of the base molten metal. And thereby forms a continuous layer over the molten metal and this molten flux then reacts with the impurities present in the weld pool. And the molten flux, therefore, flows down continuously, and fresh flux melts and covers the weld pool and arc to provide the protection from the atmospheric contamination.

The molten flux reacts with the molten metal to form slag, and when this slag is formed, it performs number of functions like it helps to improve the properties of the weld joint, because impurities from the molten metal are removed in form of slag. These impurities react with the flux to form slag, and therefore, impurities are removed which in turn improves the properties of the weld joint. The molten slag floats on the top of the solidifying weld metal to protect it from the atmospheric contamination, because the slag becomes lighter than the base metal or the weld pool.

Therefore, it protects the weld pool from the atmospheric contamination, because weld pool does not come in direct contact with the atmospheric air, and it is covered by the molten slag floating on the surface of the weld pool. Because the slag becomes of the lower melting point compared to the weld pool; that is why weld pool solidifies fast. And the slag floats on the surface of the solidifying weld pool, and when slag forms a continuous layer over the weld pool, it also tends to reduce the cooling rate.

And the reduced cooling rates many times are helpful in controlling the defects like cracking or the porosity formation, because the gases dissolved in the weld pool get enough time to come out of the weld pool during the solidification if the cooling rates are low. And that in turn helps to reduce the porosity, and the reduced cooling rate in welding of the steel also helps to avoid the hard molten sticky structure which, otherwise, can develop the cracks after the welding.

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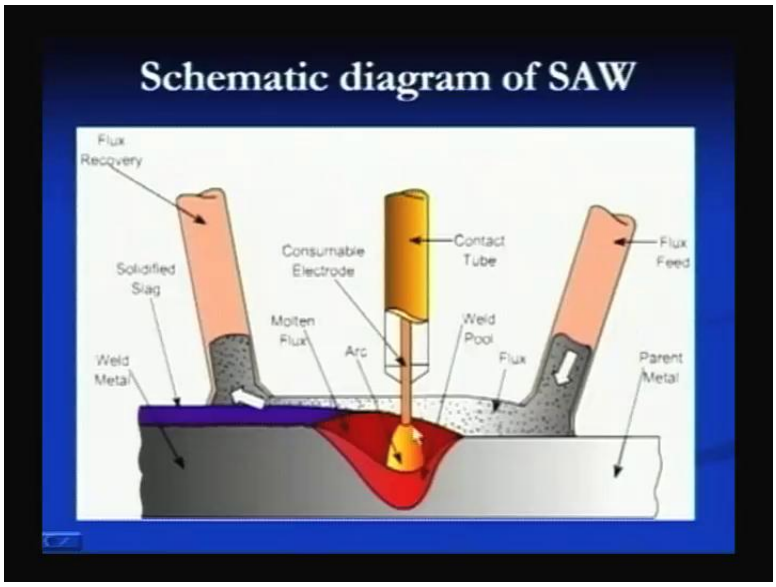

This picture shows the schematic diagram of the submerged arc welding process and how the flux is supplied, where arc is developed, and how the joint is produced. Here we can see this is the base metal, and this is electrode. Arc is struck between the base metal and the electrode, and this is the arc region. And this arc region is covered with the flux; flux is continuously supplied from the hopper. So, flux can be supplied continuously through the pipes from the hopper. So, that arc is always covered with the granular flux, and due to the heat of the arc this flux melts.

And it covers the weld pool which is shown by this darker red color, and here this is the molten slag surrounding the arc, and the top of it we can see the granular flux. And here this red portion indicates the molten slag and molten flux floating on the top surface of the weld pool which is solidifying. And this blue region indicates the solidified slag, and this portion is the weld metal which has solidified.

And to collect a the unused flux, the flux recovery system can also be used, and after the welding, the solidified slag is removed, and this slag removal is important; otherwise, it can be there as inclusions when the second pass is used to fill the gap. So, slag must be removed properly, and it should be chipped off properly. To supply the current to the electrode, normally contact tubes are used. So, the electrode is passed through the contact tubes. And contact tubes are in electrical contact with the consumable electrode, and the workpiece is also connected to the power source terminal to complete the welding circuit.

And when arc is struck between the electrode and workpiece, current flows from the electrode to the workpiece, and then circuit is completed. So, these are the important parts and the functions which are performed by the different constituents, and how the heat of the arc generated helps to melt the slag to produce the weld pool, and how the solidification of the slag and the base metal takes place.

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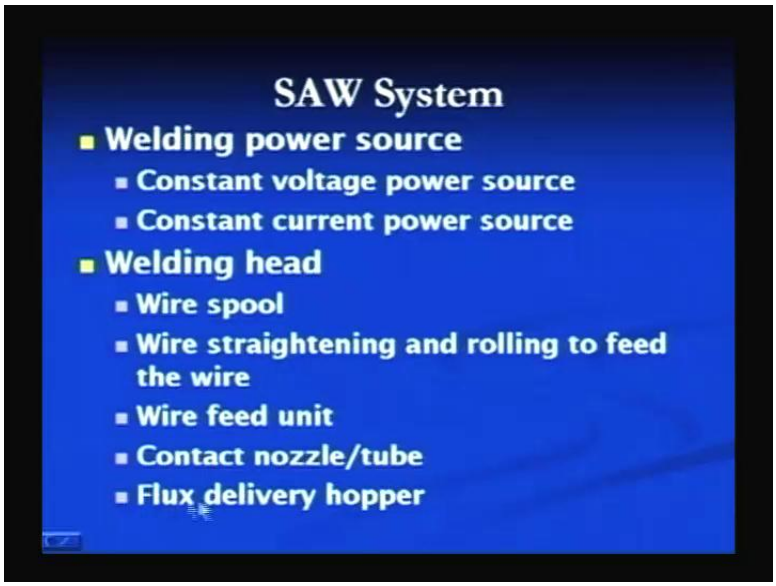

Submerged arc welding system consists of two main components. One is the welding power source. Welding power source can be of the constant voltage type of the power source or constant current type of the power source depending upon the diameter of the electrode which is to be used for the welding purpose. The constant voltage power sources are normally used with small diameter electrodes to get the advantages of self regulating arc. And when the large diameter electrodes is to be used constant current type of power source is normally used.

And here another important component of the submerged arc welding system is the welding head. Welding head includes the number of components or number of parts like wire spool in which the long consumable electrode wire is wrapped around, and it is continuously fed through the contact tube and through the wire feed system. The wire which is wrapped in form of spool is straightened and then rolled through the wire feed system to feed it continuously during the welding. And after straightening and rolling, wire feed unit is a used to supply the consumable electrode in the arc region in order to maintain the arc and arc gap.

And the contact nozzle or contact tubes are used to supply the desired current through the electrode to the arc. So, the electrical contact between the contacted tube and the electrode has to be perfect, so that the power supply and the welding circuit can be completed. And the flux delivery hopper is also used to for continuous and smooth

supply of the flux around the arc region, so that arc and weld pool is continuously covered by the fusible flux, and it is able to perform the desired function.

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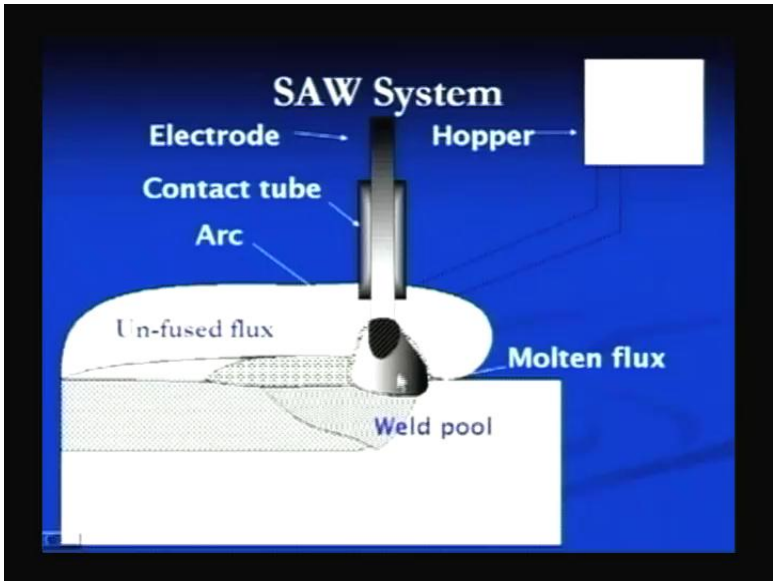

The different parts of the submerged arc welding and how they perform that can be seen from this electrode. From this figure this is electrode being passed through the contact tube. And the arc is generated between the workpiece or the base metal and the electrode, and this is the molten metal droplet hanging at the tip of the electrode. And this under the effect of the heat of the arc this fusible flux which is around this arc is melted, and it forms a cover of this kind. Here this is the unmelted unsolidified slag, and here this is solidified slag; this is the molten weld pool; this is the solidified weld metal. And here this entire zone represents to the arc area, and here this one hopper is used like this to feed the flux continuously ahead of the welding torch, so that is arc is always covered with the fusible flux.

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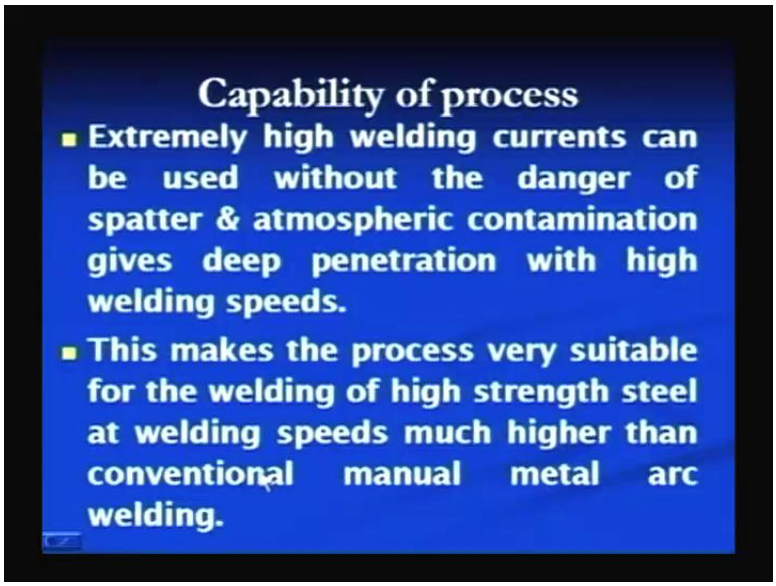

The submerged arc welding is very capable process for joining of the thick seats particularly because of its capability to handle very high current and use high current densities that allows to have the higher deposition rate and the greater depth of the penetration. So, because of high current densities, it allows the deeper penetration and the high welding speeds. And at the same time, since, the arc is covered by the molten flux and the unfused flux, there is no scope of the atmospheric contamination or the spattering.

So, the joint is produced free from the spattering and atmospheric contamination and very smooth joint is produced which can be of the higher penetration. At the same time this process can offer the higher welding speed. Because of these capabilities like high depth of penetration and high deposition rate makes this process very suitable for welding of the high strength steels at higher welding speeds than the conventional manual metal arc welding.

In case of manual metal arc welding, the problem is the electrode length. Electrode length is limited, and electrode has to be changed continuously, and for changing the electrodes the process should be stopped. So, that is a discontinuous process; process has to be stopped at regular intervals to change the electrodes and also that does not allow to use a very high level of currents, because use of high level of current in submerged arc welding can damage to the electrode coating materials. So, the advantage of the high

deposition rates in welding of the steels particularly lies with the submerged arc welding process compared to that of the conventional shielded metal arc welding or manual metal arc welding process.

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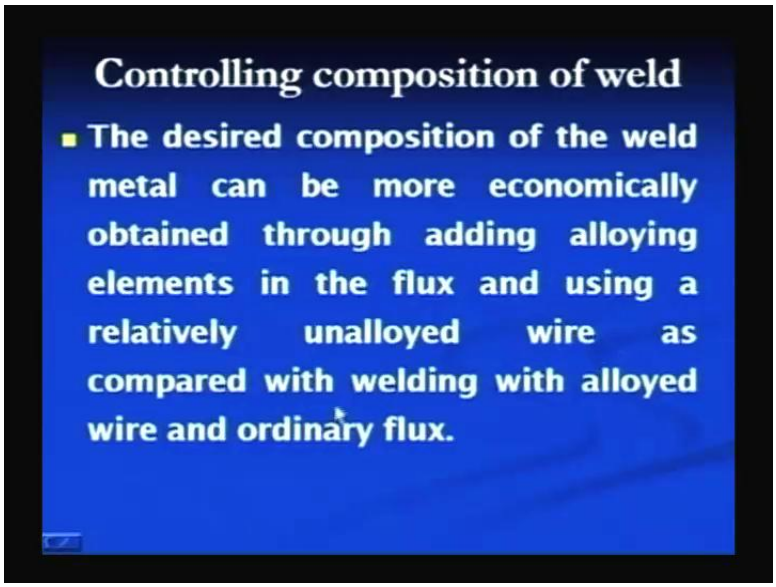

One more advantage is there with this submerged arc welding process is that the composition of the weld metal can be controlled very effectively by adding the desired alloying elements in the weld metal thorough the fusible flux. The elements are added with the flux material which gets melted and then is able to transfer those allowing elements to the weld metal. So, the desired composition of the weld metal can be obtained economically by adding the alloying elements in the flux and using relatively unalloyed wires compared with the alloyed wires and ordinary fluxes.

So, the advantage is that the desired alloying elements can be mixed with the fluxes to obtain the weld metal of a desired composition and that to this can be done very economically. This is another important manifest related with the submerged arc welding process.

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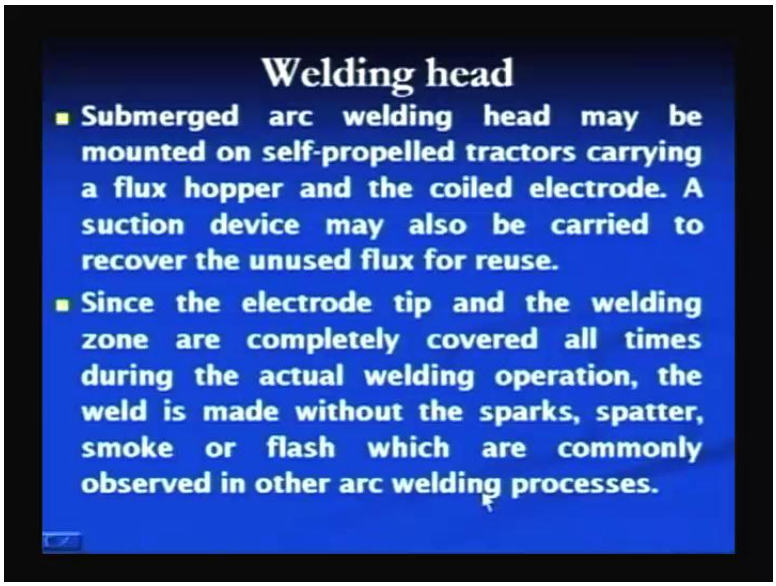

Welding as I have told or mentioned earlier that it has number of components, and the submerged arc welding head it can be mounted on the self propelled tractors carrying a flux hopper and coiled electrode in form of a spool. And a suction device may also be used to recover the unused flux for reusing it. And since, electrode tip and the welding zone are completely covered all the time during the welding operations, weld is made which is free from the sparks, spatters, smokes or the flush which are commonly observed in the other arc welding process. So, these are the advantages related with the submerged arc welding process, because the arc is covered with the fusible flux that makes the arc which is free from sparks, spatters, smokes, etcetera, which are commonly encountered in other welding processes.

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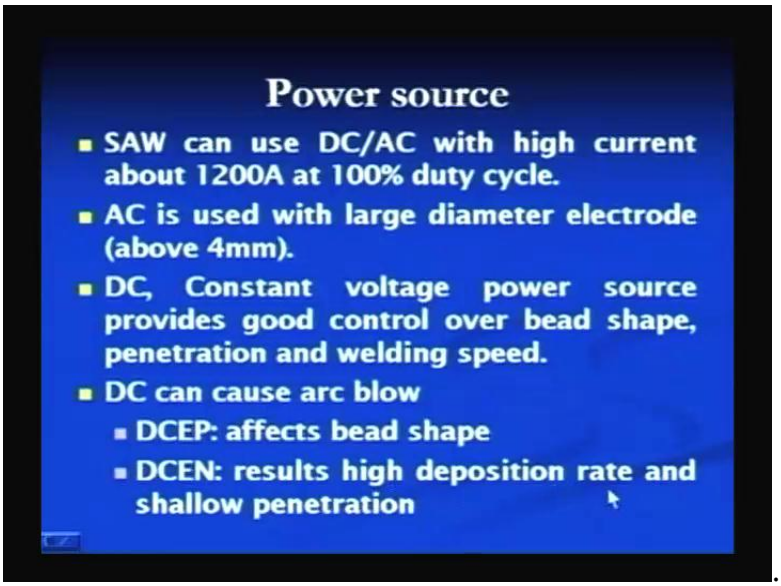

The power source which is used in submerged arc welding process can be AC or DC type, but normally high current ratings are used in submerged arc welding; it can be as high as 1200 amperes at 100 percent duty cycle. AC is used with the large diameter electrodes where variable speed feed drive systems are used to control the arc gap. But DC with the constant voltage power supply systems are used where good control over the bead shape penetration and good speed is to be obtained, because DC offers the advantage of polarity selection and better control over the bead shape penetration and welding speed.

So, with the small electrode diameters, normally the DC is used compared to the AC. But some problems are related with the DC also, because one of the number of problems is that DC can lead to the arc blow. This arc blow is obtained only in case of DC where arc tends to deflects from its intended path, and if arc is deflecting, then it becomes difficult to control the molten metal and get it deposited over the area where it is required. So, due to the reduced control over the molten metal and difficulty in putting the molten metal in the area where it is required, this arc blow is to be controlled.

And there are number of methods which are used for controlling the arc blow, and one of them is to switch over from DC to AC or to change the ground connection location. On the other hand, when DC is used we can use that DC electrode positive or electrode

negative polarities. So, DCEP primarily affects the weld bead shape, while the DCEN results in the high deposition rate and the shallow penetration.

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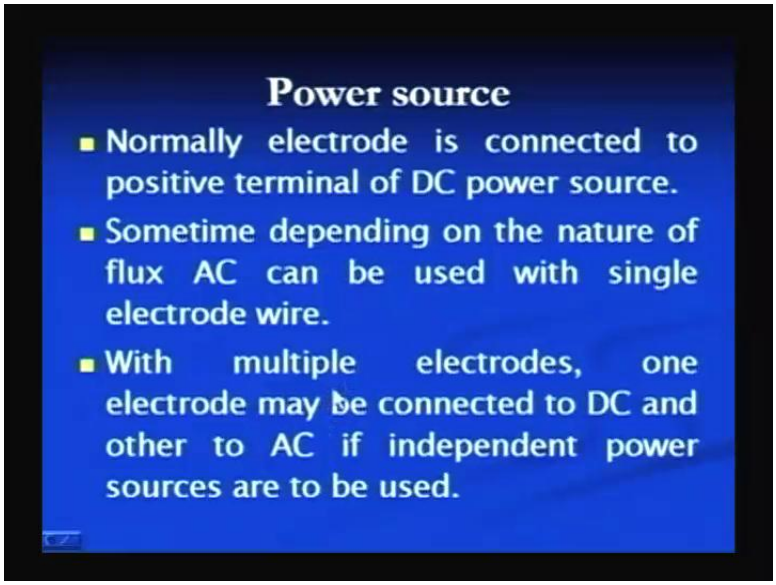

And normally electrode in the submerged arc welding process is connected to the DC positive terminal; means DCEP is the polarity which is a normally used in the submerged arc welding process with the small electrodes. And sometimes depending upon the nature of the flux, AC can also be used with single wire electrodes. And with the multiple electrodes, one electrode may be connected to the DC, and other electrode can be connected to the AC if the different power supplies are available, or the same power source can be connected to the different electrodes in case of the multiple submerged arc welding process.

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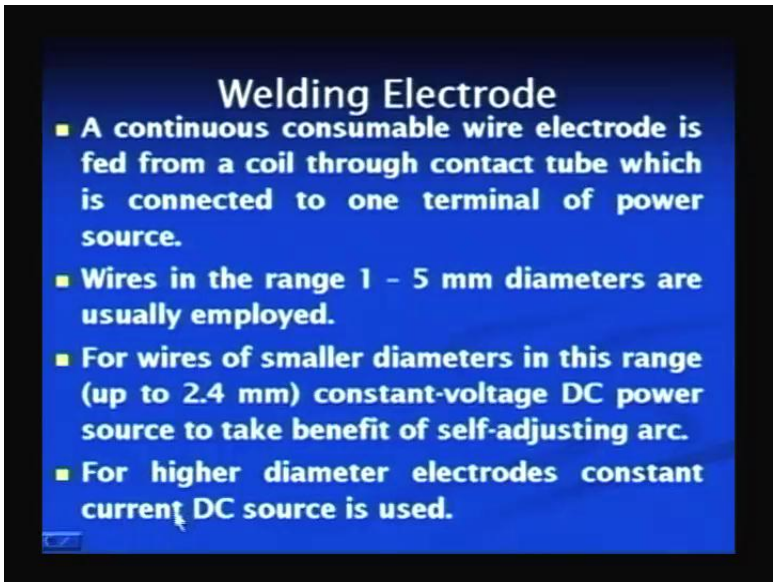

In the submerged arc welding process, we use the electrode which is fed continuously, and it becomes of consumable kind; that is why continuous consumable wire electrode is fed from the coil which is wrapped in form of spool. And this wire is fed through the contact tubes, and contact tube is connected to the one terminal of the power source, and the electrode wires can range from 1 to 5 mm in the diameters. And depending upon the kind of application and the thickness of the plates which are to be welded, the electrode diameter is selected for greater thicknesses; electrodes of the large diameters are selected, so that high current rating can be used for getting the desired penetration and the high deposition rate.

For wires of a small diameter up to the 2.5 mm; that means the electrodes of a small diameters up to 2.4 mm., the constant voltage DC power supply is used, because it offers the advantage of the self regulating arc which helps to maintain the arc length constant when the constant speed feed drive systems are used. So, association of the constant voltage DC power supply with the constant speed wire feed system and the small diameter electrodes we get the self adjusting or self regulating arc which helps to maintain the arc length automatically. And for the large diameter electrodes, DC constant current type of the power source is used, but to maintain the arc gap in this case the variable speed feed drive systems are used.

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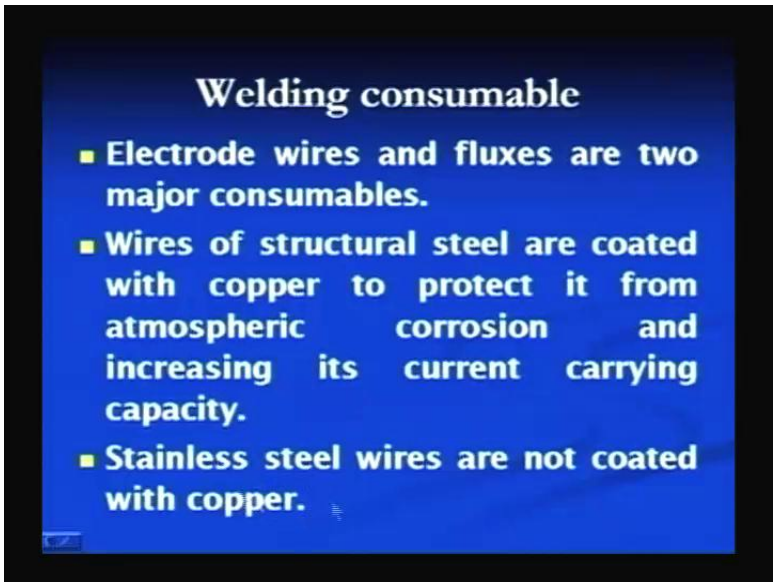

Consumables in submerged arc welding for producing the joints are mainly of the two types, because electrode used is one of them is the consumable electrode in form of wires, and another is the flux, fusible granular flux. And both these consumables play significant role in successful welding of thick sheets. The electrode wire is normally coated with the copper, and the fluxes are made of the different constituents to perform specific functions. The wires of the structurally steels are coated with the copper to protect it from the atmospheric corrosion and for increasing the current carrying capacity.

Because if this steel electrode wires are not coated with the copper, then due to the high current densities, excessive electrical resistance, heating of the steel wires can take place; that may lead to the poor control over the wires, poor control over the molten metal which will be generated. That is why if the steel is coated with the copper, then it will protect the steel from the atmospheric corrosion and will also increase its current carrying capacity. The stainless steel wires are not coated with the copper, because the presence of the chromium itself protects them from the atmospheric corrosion or atmospheric contamination.

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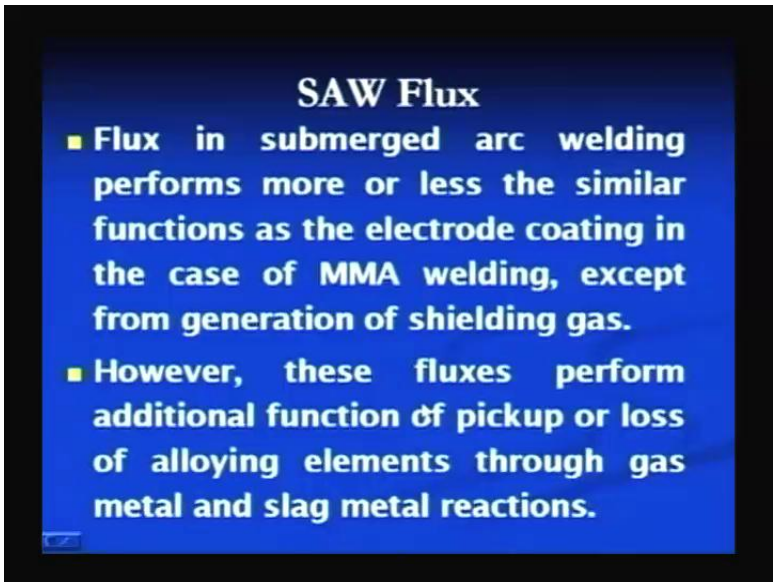

In the submerged arc welding process the role of the fluxes is significant, because it helps to generate a spatter free smooth weld bead. And that is why the proper fluxes with the desired constituents must be used for the submerged arc welding. The flux in submerged arc welding performs more or less similar functions as that of electrode coating in case of manual metal arc welding except from the generation of the shielding gases. In case of the shielded metal arc welding process, we have seen that the cellulosic materials particularly produce the inactive gases to provide the shielding to the arc and to the weld pool to protect them from the atmospheric contamination.

But in case of the submerged arc welding, the shielding gasses are not generated by the fusible flux, because flux melts, and it covers the weld pool and the arc region completely. And that is why there is no direct contact between the molten weld pool and the atmosphere, and that is why there is no need to generate the shielding gases from the fluxes to protect weld pool from the atmospheric contamination. Other functions are performed by the flux used in submerged arc welding are similar to that of functions performed by the electrode coating in SMAW process or shielded metal arc welding or manual metal arc welding process.

However, these fluxes perform some additional functions like pick up or loss of the alloying elements through the gas metal and the slag metal reactions; means presence of the certain alloying elements can cause the loss of the specific elements from the weld

metal or can lead to the addition of the certain alloying elements in the weld metal because of the various reactions which take place in the weld pool and in the arc region.

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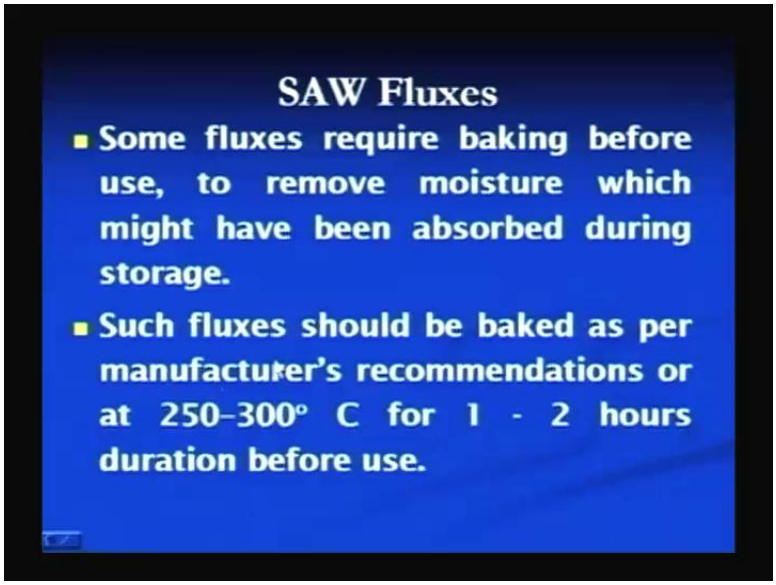

Some fluxes require baking before use to remove the moisture which might have been absorbed during the storage, because these fluxes frequently contain the calcium carbonate kind of materials which are hygroscopic in nature. So, the baking of the fluxes is important to remove the moisture during the storage, and for baking purpose manufacturer's instructions are to be used, or in general, this baking can be done in the temperature range of 250 to 300 degree centigrade for one to two hours before using them, so that moisture can be removed. And the chances for entry of the hydrogen and oxygen in weld metal from the evaporated moisture can be reduced, so that the baking of the submerged arc welding fluxes will help to reduce or to control the hydrogen input or hydrogen entry in the weld metal.

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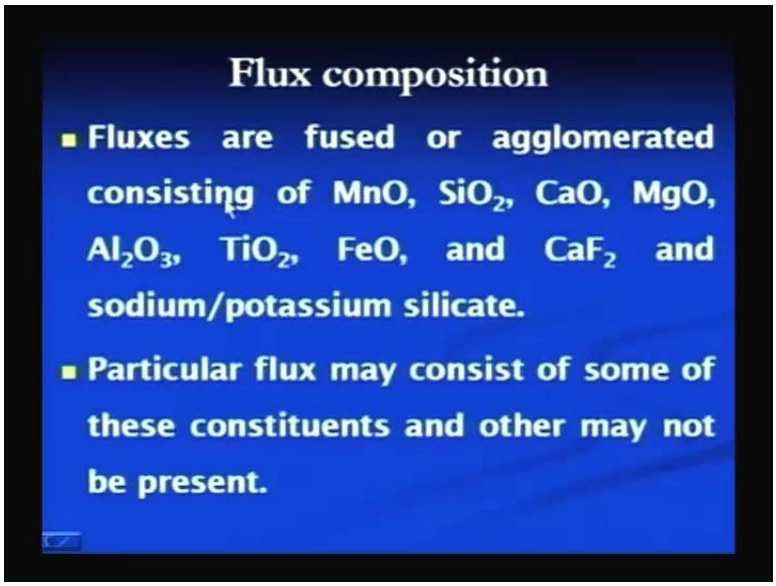

The fluxes which are used in submerged arc welding process contains the number of constituents, and these fluxes are either fused or agglomerated type consist the MnO, SiO 2, calcium oxide, magnesium oxide, alumina, TiO 2, FeO, calcium fluoride and the sodium and potassium silicates. And each constituent performs the specific function during the welding process and particular flux may consist of some of these constituents or others may not be present. So, depending upon the purpose some of the constituents may be added or removed from the fluxes.

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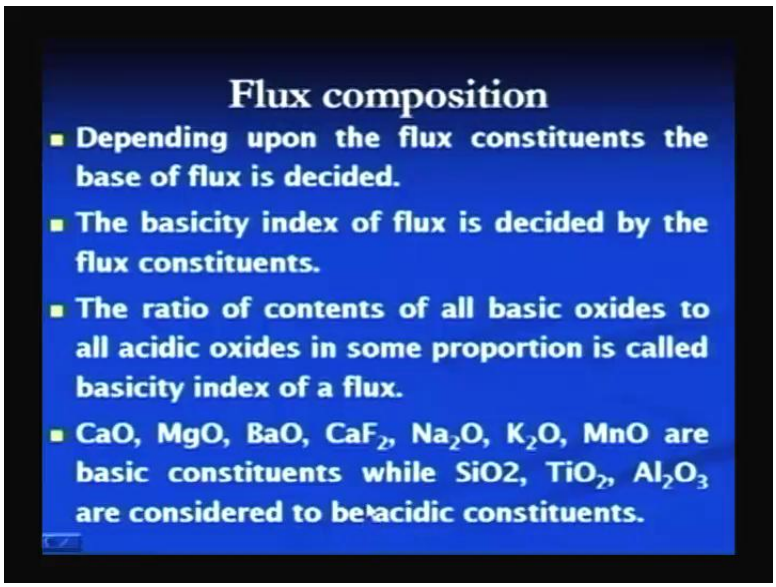

Depending upon the flux constituents, the base of the flux is decided, because the basicity index of the flux is decided by the various constituents which are present. And the basicity index plays a significant role in successful and sound weld joints. The ratio of the contents of all basic oxides to all acidic oxides in some proportion is called the basicity index of the flux. So, that ratio of the basic oxides and the acidic oxides present in the flux is used to characterize the basicity index of the flux like the calcium oxide, MgO, BaO, CaF 2, Na 2 O, K 2 O, MnO are the basic constituents, while SiO 2, TiO 2, Al 2 O 3 are considered to be the acidic constituents. So, the ratio of all basic oxides and that of the acidic oxide is used to quantify the basicity index of the flux.

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As I have said that basicity of the flux plays a significant role in successful welding of the base plates by submerged arc welding process. So, on the both cases the low basicity index and the high basicity index leads to the specific effects, and the effects related to the low basicity fluxes are like this. The welding with the low basicity index fluxes offers the better current covering capacity, the good slag detachability, good bead appearance but the poor mechanical properties and resistance to the cracking.

So, from the mechanical performance point of view, the low basicity index fluxes are not good. On the other hand, the better current capacity will allow to get the higher deposition rate. And the good appearance also is desired, and the good slag detachability will help to remove the slag easily from the bead. But the negative side of the low

basicity fluxes is the poor mechanical property of the weld joint and the reduced resistance to the crack development or to the crack propagation of the weld metal. So, from the mechanical performance point of view, low basicity index fluxes are not desirable, but they play a significant role in getting the proper bead shape and the high deposition rates because of increased current carrying capacity.

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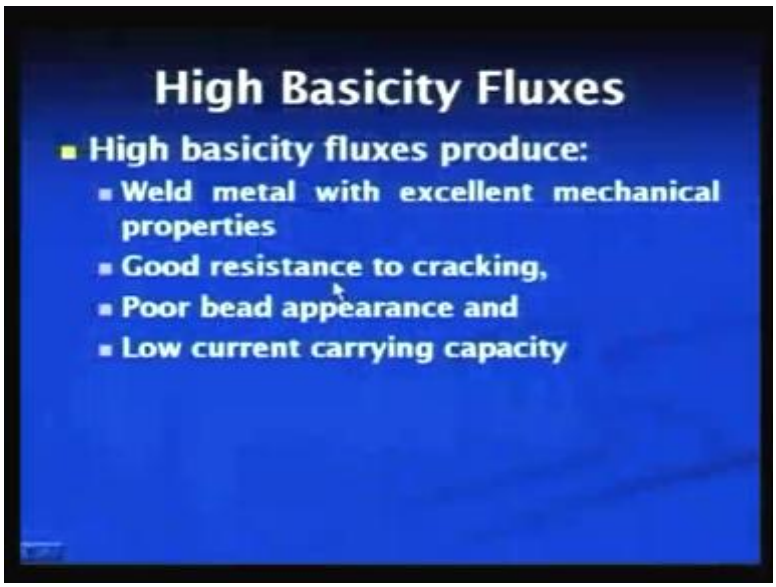

On the other hand, high basicity fluxes produce the weld metal with the good mechanical properties and good resistance to the crack propagation or resistance to the cracking; means resistance to the cracking is good, bead will not get cracked easily when basicity fluxes are used. So, from the mechanical performance point of view, the high basicity fluxes are good, but this result in low current carrying capacity and the poor bead appearance.

So, the benefits which are available with the low basicity index are not available with the high basicity index or the advantage which are available with the high basicity index lead to the better mechanical performance are not available in the low basicity index fluxes. Welding parameters in submerged arc welding play significant role in developing sound weld joint.

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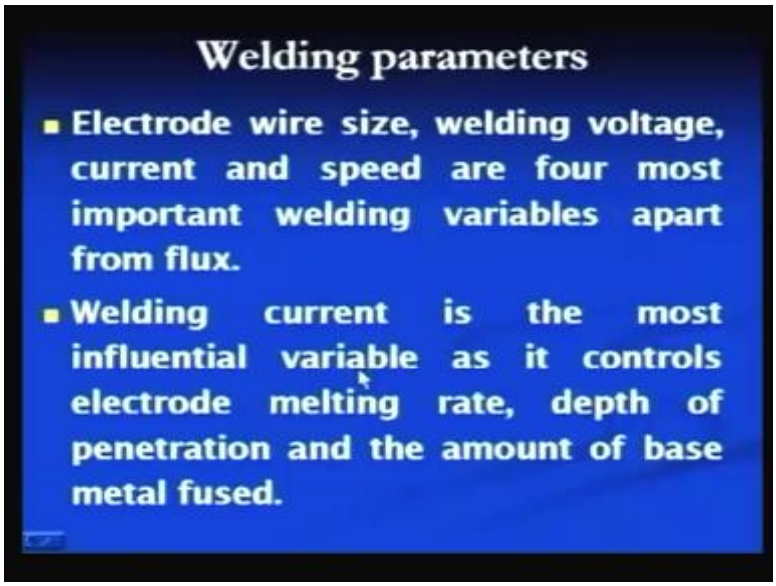

And these parameters like electrode wire size or electrode diameter, the welding current, welding voltage and the welding speed. These are the four important welding variables which play significant role in addition to the fluxes in producing sound weld joint. The welding current is one of the most influential variables, because it affects the deposition rate, penetration and the amount of the base metal, which is fused. So, the dilution, penetration and the melting rate of the electrode is primarily controlled by the welding current. In addition to these parameters, the weld bead geometry is also affected by the welding current significantly.

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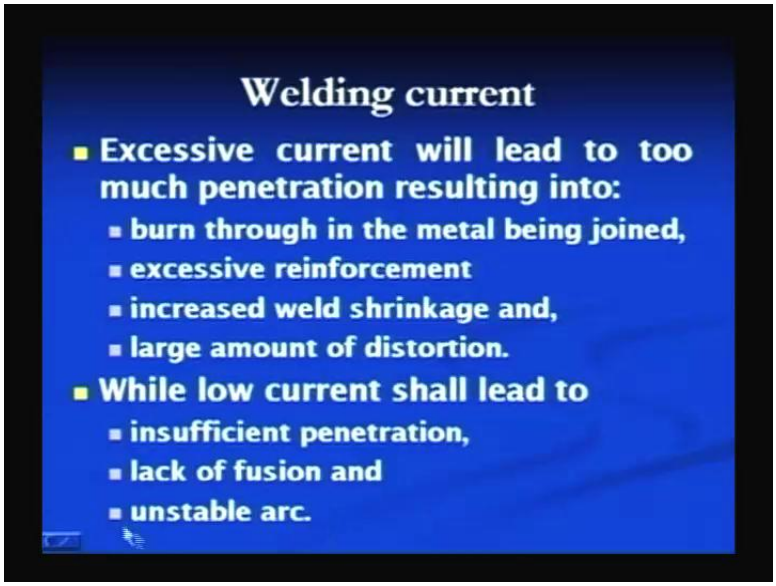

But the use of the optimum welding current in submerged arc welding is also very important, because too high current setting or too low current setting both create problems in production of the sound weld joint. Excessive current will lead to the too much penetration which can cause burn through in the metal being joint, excessive reinforcement, increased weld shrinkage and the large amount of the distortion. All these effects are related to the excessive heat input which can be there because of excessive current which is being used and in turn getting the high penetration.

While, the low current can lead to the insufficient penetration, lack of fusion and unstable arc, because if the current is low the sufficient heat will not be generated, so that the melting of the base mental will not be sufficient and which also will lead to the lack of fusion due to the lack of heat input to the base metal. And if the temperature of the arc is low due to the low heat which is being generated by arc caused by the low current, then arc will also be burning at low temperature, and that, therefore, it will be unstable. Therefore, optimum current setting is very important, because lower current setting and higher current setting both can create problems in getting the sound weld joint.

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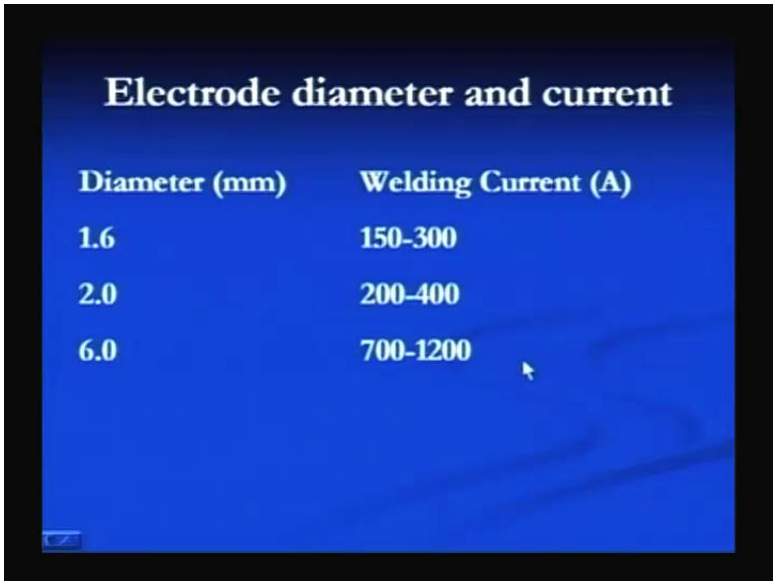

As a guideline here for the steel electrodes, with the increase in diameter welding current should be increased, say, for example, for 1.6 mm diameter electrode, current range can be there from 150 to 300 amperes; for 2 mm diameter it can be from 200 to 400 amperes,

and if we go on increasing the electrode diameter for 6 mm electrode diameter the current setting can be the 700 to 1200 amperes.

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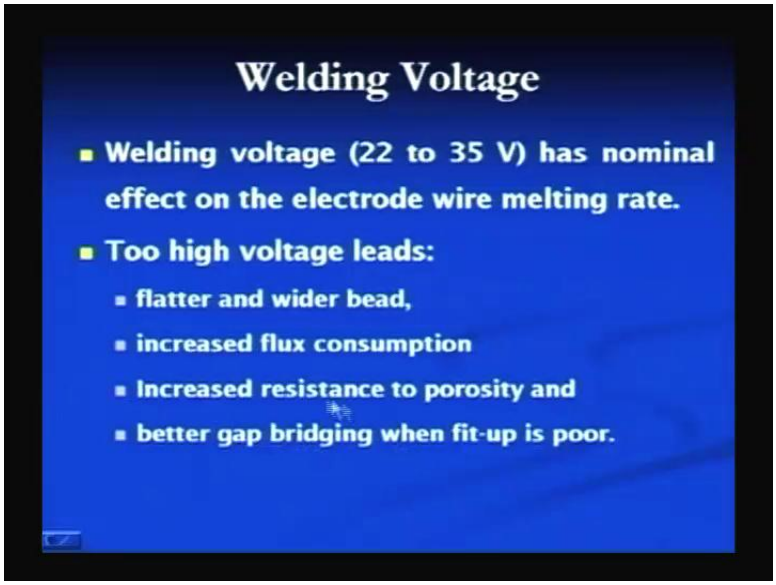

The welding voltage also affects the welding by submerged arc welding process, but its affect mainly on the weld bead geometry. It increase in the welding voltage particularly widens the weld bead. It does not affect the melting rate significantly, and that is why the welding voltage which is normally used in submerged arc welding process is in range of 22 to 35 volts. And it has a very nominal effect on the electrode melting rate but too high voltage setting leads to the flatter and the wider bead increased flux consumption, because wider area is covered.

So, lot of the flux will be fusing during the welding process, and in turn it will be increasing the flux consumption, increased resistance to the porosity because increased heat generation and the reduced depth of the penetration will help the gases to come out easily from the weld pool. And thereby, increase the resistance to the porosity formation, and better gap bridging is possible when fit up is poor because weld bead is wider one. That is why it can take care of the poor fit up related aspects, and that is why gap bridging capability is good when the high voltage is set.

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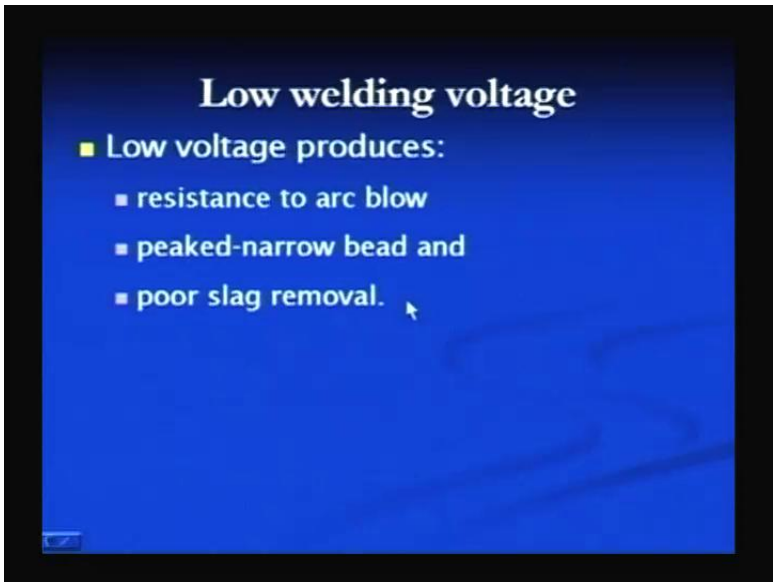

On the other hand, the low voltage setting can also create certain problems like the resistance to the arc blow peaked narrow bead is produced or poor slag removal can be there when the low voltage is set.

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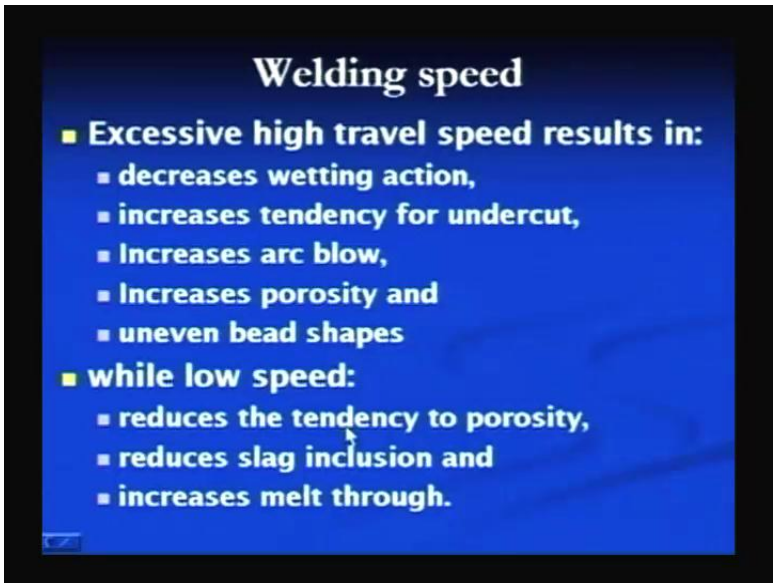

The welding speed is another important parameter, because it affects the weld bead geometry and penetration both. Actually welding speed is the speed by which torch is moved during the welding along the line of the weld and increase in the weld speed reduces the net heat input. And reduction in the net heat input in turn affects the weld

bead geometry that is bit and the penetration of the weld bead. And that is why for obtaining the optimum bead geometry and penetration, optimum welding speed is important, because the welding speed directly affects the net heat input.

If the welding speed too high, then it can result in reduced heat input per unit length, and less material will be deposited accordingly and the less weld reinforcement will also be there and shallow penetration. So, all these effects like reduced material deposition, reduced reinforcement and the shallow penetration; all these three effects we normally get because of the first factor that is the reduced heat input per unit length with the increase in welding speed. For a given current setting, whatever heat is generated because of voltage into the ampere and that will be affected, or that net heat will be reduced with the increase in the welding speed. And that is why for a given VI values, increasing welding speed reduce the net heat input.

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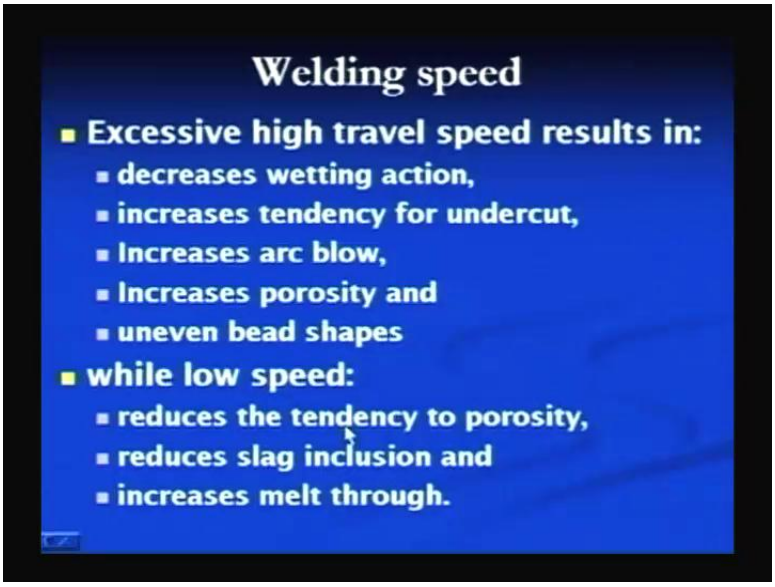

Excessive travel speed further results in decreased wetting action because of the reduced heat input, or less heat is available. And that cools down the weld pool rapidly molten metal droplets rapidly, and therefore, wetting action is decreased. Increased tendency for the undercut increases the arc blow tendency, increases porosity and uneven bead shape is produced. So, if the excessive welding speed is used, then it will further decrease the heat input, and it can create all these problems.

While the low speed also leads to the some undesirable effects like it increases the chances of the melt through particularly; on the other hand, other affects like it reduces the slag inclusion and reduces the tendency to form the porosity. So, these two effects are particularly favorable, because at low speed heat input will increase significantly that will decrease the rate of solidification. Reduced rate of the solidification will make the long time available for the gaseous defects or non-metallic inclusions to come up to the surface and reduce their presence in the weld metal. And therefore, with the reduction in the welding speed, the tendency to form porosity and the slag inclusions are reduced.

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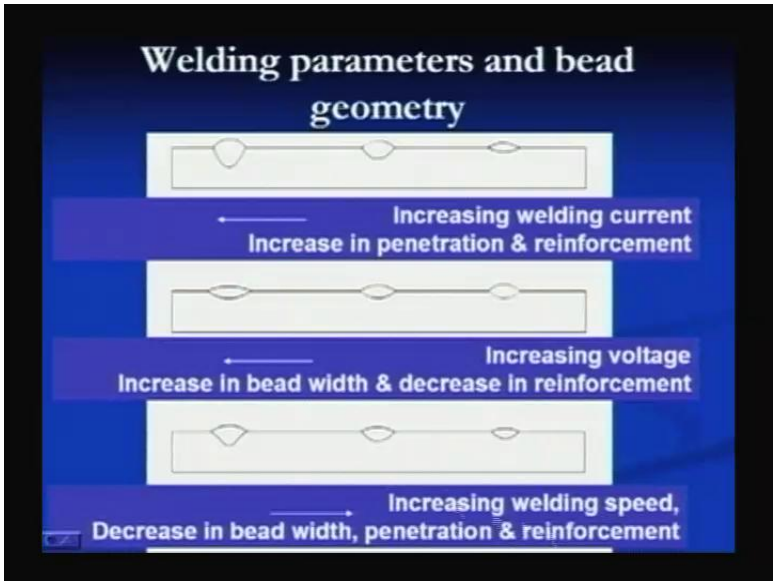

The summarized effect of the welding parameters like welding current, welding voltage and welding speed can be seen from this diagram. Here with the increase in welding current, if you move from here to here weld beads deposited by the different welding currents which are increasing in order low level of current, medium and high level of current. We can see that that the depth of penetration is very limited here in this case, and here depth of penetration is somewhat more, and here it is furthermore. In the same way reinforcement is also more here, reinforcement is less and further less.

So, we can say that increase in welding current increases the penetration and reinforcement both. On the other hand, increase in welding voltage from here to here; we can see that increase in welding voltage increases the bead width. Here width is the least

one incase when the welding voltage is the minimum, while here welding voltage is maximum, and for this case bead width is also high.

At the same time here reinforcement can be seen; reinforcement is more compared to this case. So, the increase in welding voltage increases the bead width and decreases the reinforcement of the weld bead. And the effect of third parameter that is welding speed can be seen from this the diagram; here increase in welding speed right from this side to this side, the weld bead deposited at very low speed and weld bead deposited at the highest speed.

So, here increase in welding speed we can see here when weld bead is deposited at very low speed, we get very wide bead width and very deeper penetration, and here the penetration goes on reducing, and width also goes on decreasing with the increase in welding speed. So, we can say that increasing welding speed from this side to this side decreases the bead width penetration and the reinforcement. All these weld bead geometrical parameters or the parameters describing the weld bead geometry are reduced with increase in welding speed.

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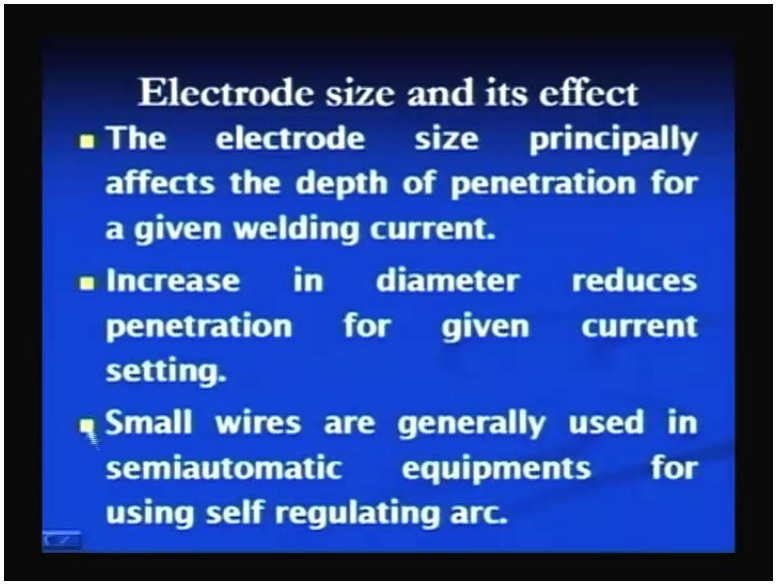

Electrode size mainly affects the depth of penetration for given current setting. Increase in the electrode diameter for a given current setting decreases the penetration depth and increases the width of the weld bead. So, we can say that electrode size mainly affects the penetration, and for given current setting increase in diameter reduces the penetration

for given current setting. Well, the small wires are generally used in semiautomatic welding process for getting the benefit of the self regulating arc. Large diameters can be used with the high currents, but for a given current if the larger diameter electrode is used, then it will reduce the penetration. And small diameter electrodes can be used to take the advantage of the self regulating arc if the very high deposition rates are not required.

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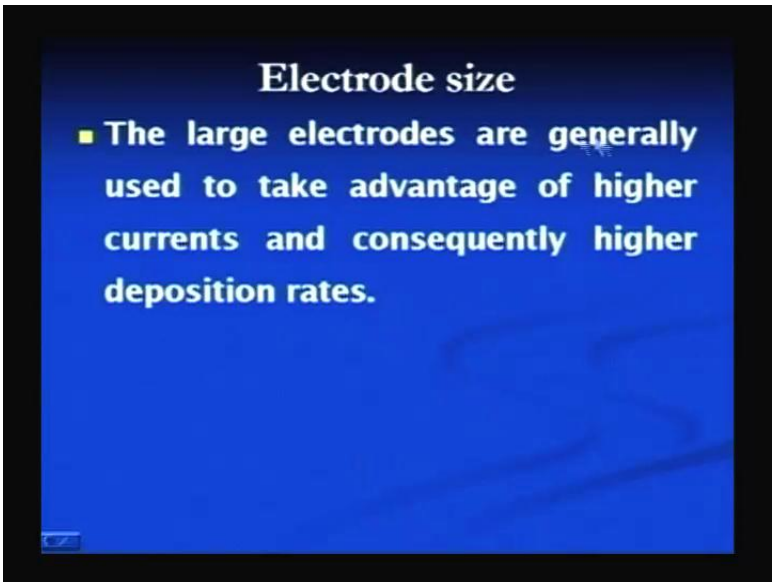

The large electrodes are generally used to take the advantage of the high current, and consequently, the high deposition rates; particularly in welding of very thick sheets where high deposition are required and high penetration is required, large diameter electrodes are selected. And also in the situations where fit up is a problem, large diameter electrodes offer the advantage of the good gap bridging capability than the small diameter electrodes.

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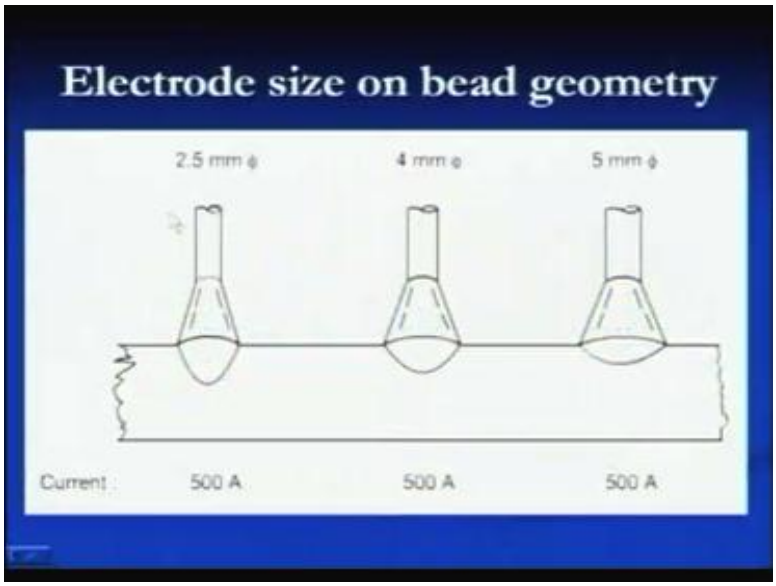

Here we can say for a given current setting if the electrodes of the different diameters are used, then how the weld bead geometry is affected? Here for 500 ampere current, the electrode of 2.5 mm diameter. Then it produces the greater depth of penetration and the limited bead width, and the bead width goes on increasing with the increase in electrode diameter, and the depth of penetration goes on decreasing with the increase in electrode diameters.

So, we can say for a given current setting if electrode diameter is increased, then depth of penetration decreases and the width of the weld bead increases. The submerged arc welding processes can use the single electrode or the multiple electrodes. And accordingly, there will either be a single arc or multiple arcs can also be there.

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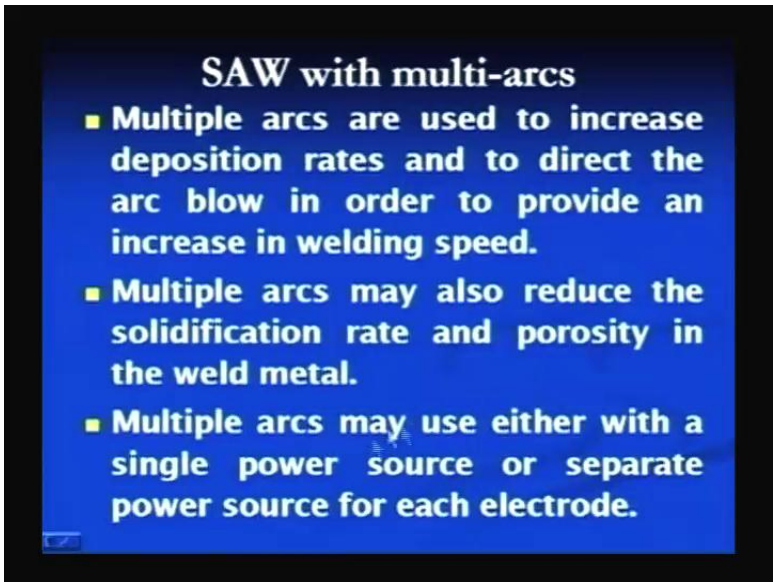

Multiple arcs are normally used to take the advantage of the high deposition rates and also to use the arc blow in useful manner in order to provide the increase in welding speed. So, if the number of arcs is there we will get the high deposition rate and the welding speed will also increase is particularly important in welding of very thick sections. The multiple arcs may also reduce the solidification rate and the porosity in the weld metal, because presence of the number of arcs will be increase in the heat input to the base metal and reducing the solidification time.

So, that in turn will decrease the cracking tendency and the porosity in the weld metal indirectly. The multiple arcs may use either the single power source or the separate power source for each electrode. So, depending upon the kind of arrangements for multiple arcs there may be single power source or the number power source for each electrode.

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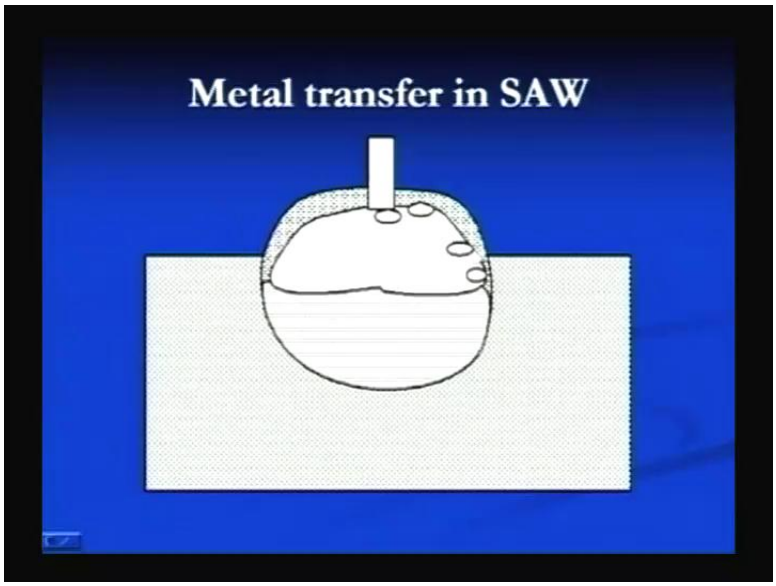

During the welding as I have told that the consumable electrode melts, and it gets transferred to the weld pool. The way by which molten metal is transferred from the electrode tip to the weld pool is found different under the different welding conditions. So, the metal transfer aspects in the submerged arc welding are slightly different from what is noticed in the metal inert gas welding or the shielded metal arc welding process. Here when the welding current is low under those conditions, the molten metal droplet is transferred through the fused flux wall. And here this is the weld pool, this is the arc region; another droplet is being transferred through the molten flux which is there in fused condition.

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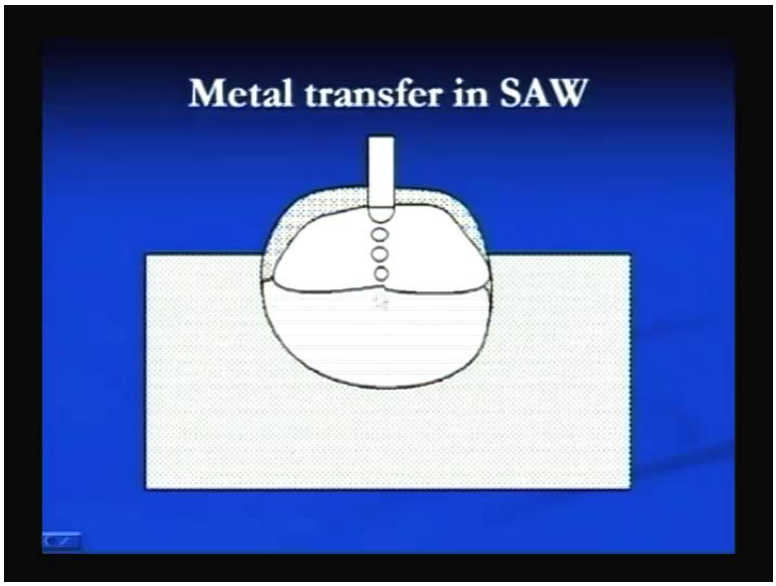

And at somewhat higher current, the droplet is detached and somewhat larger size droplets are transferred in the line of the electrode access.

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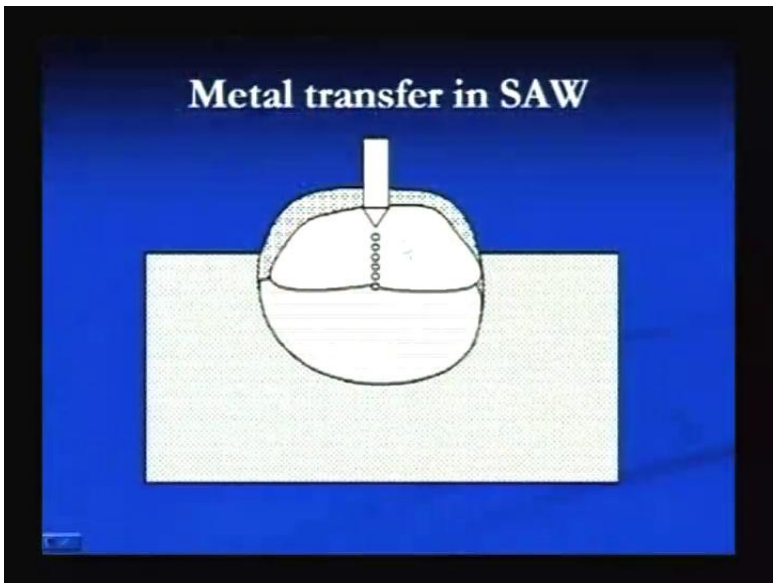

And further higher level of current helps to get the final droplets in the line of the electrode, and this is because of high pinching force that is obtained at the tip of the electrode, so that whatever droplet is being formed at the tip of electrode; that is not able to gain very large size. But before gaining a large size, it is pinched of by the presence of

high electromagnetic pinch force, and that is why we get a spray kind of appearance in this process.

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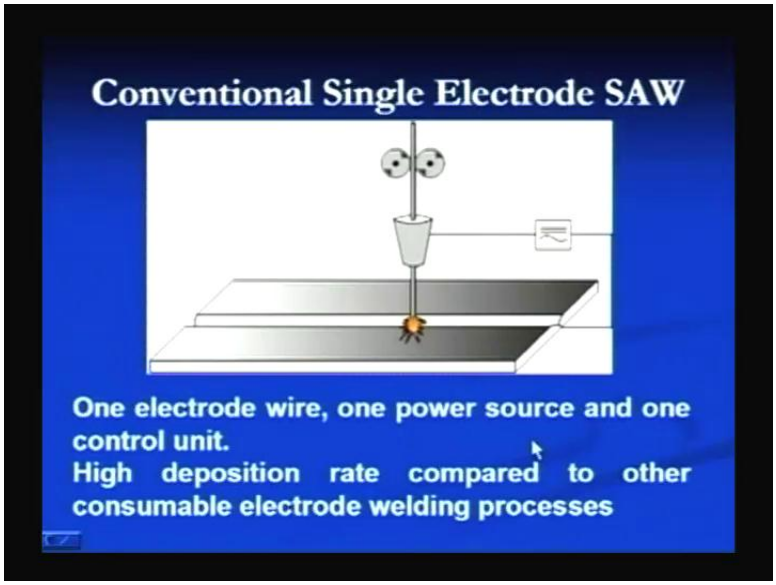

The conventional single electrode submerged arc welding process can be seen in this diagram here. These are the rollers which are used to feed the electrode. And the electrode passes through contact tube which is connected to the power supply, and we get arc here, and this entire welding head is moved along this line. So, in this case one electrode wire, one power source and one controlled unit is used, and we get the high deposition rate compared to the other consumable electrode welding process like shielded metal arc welding process or metal inert gas welding process.

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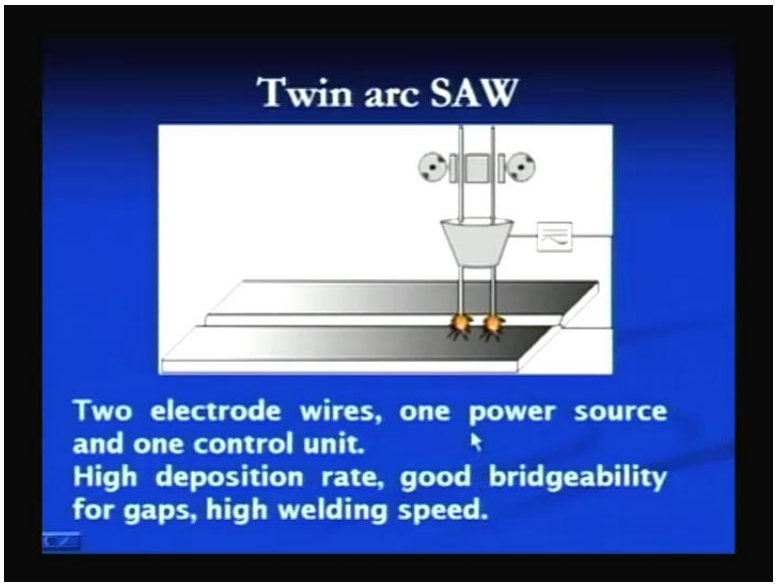

In the twin arc submerged arc welding process, we use the two electrodes, and these are powered by the same power source; the two separate wire feed units are used, and here we can see the two arcs are produced. So, in this case the two electrode wires, one power source and one control unit is used. We get the advantage of high deposition rate, good gap bridging, good birdgeability or gap bridgeability is there with this process, and we get the high welding speed because high deposition rates.

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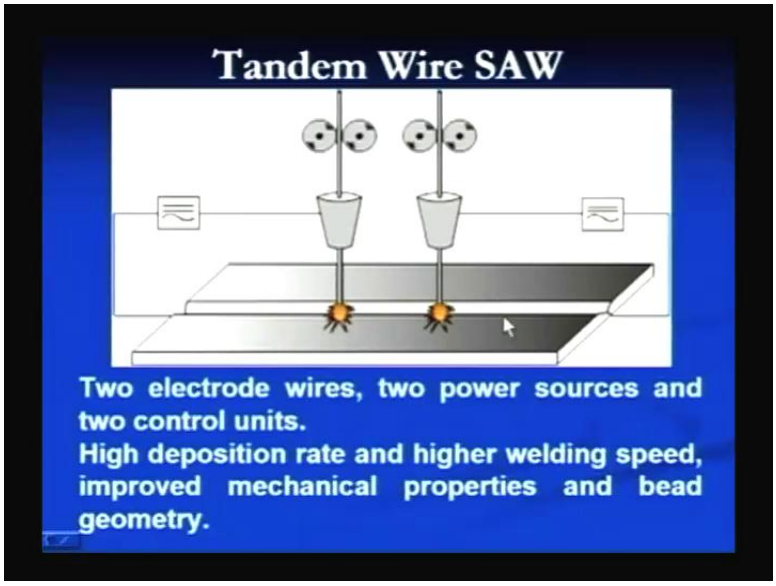

In the tandem wire submerged arc welding process, the two electrodes are used. Here we can see the different wire feed units are there, then the two electrodes are supplied by the two different power sources. So, here we can see the two electrode wires, two power sources and two separate control units are there and high deposition rates and high welding speed with the improved mechanical properties, and weld bead geometry is obtained with this kind of the submerged arc welding system.

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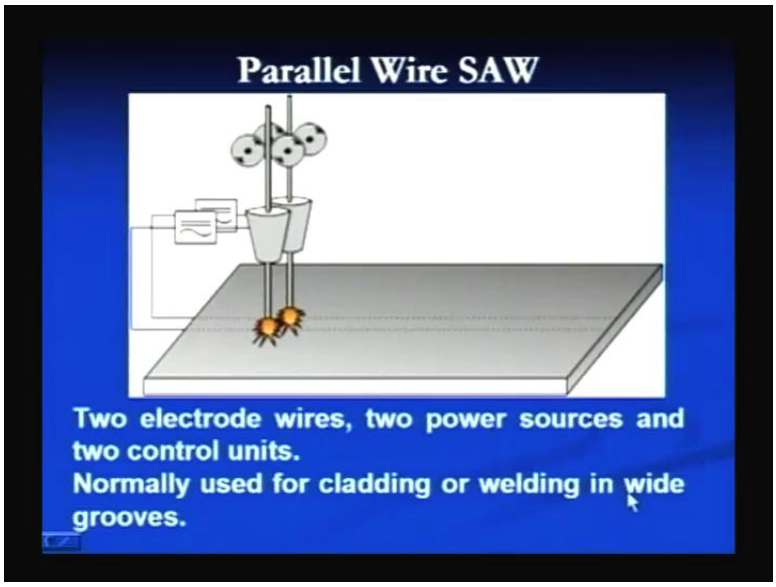

In parallel wire submerged arc welding system, the two wires move together. And in this case also these two wires move parallel during the welding, and this process uses two electrode wires, two power sources and the two control units. Normally this process is used for cladding purpose or when very wide groove is there for joining the two plates.

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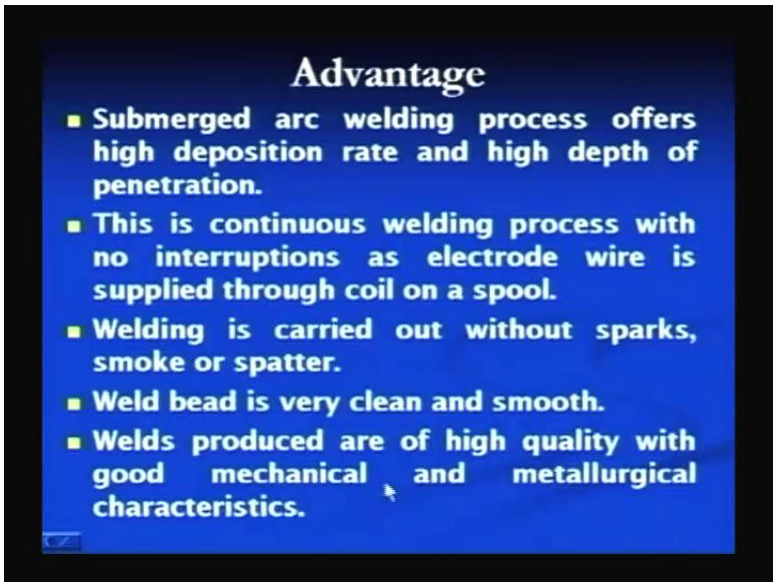

Advantages of submerged arc welding process are many. So, few important are like the high deposition rate and the high depth of penetration. And because of these two factors, only this process is significantly used in heavy engineering industry where very thick plates are to be welded. Here this process is continuous with no interruptions as electrode is consumable, and it is fed through a coil, which is there in form of a spool. And welding is carried out without a sparks, smoke and spatter, and weld bead is very clean and smooth, and welds produced are of high quality with a good mechanical and metallurgical characteristics.

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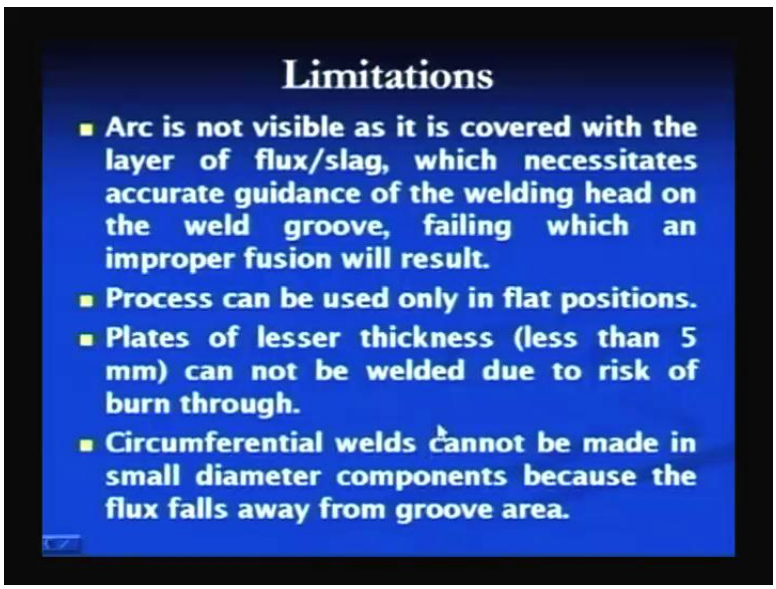

But they have certain limitations also related to this process; that arc is not visible, because it is covered under the flux or slag. And that is why it is necessary that accurate guiding system is used for the welding head, so that it moves only along the line of the weldment where metal is to be deposited. If it does not happen, then improper fusion will result and we may not get the desired weld joint. The process can be used only in the flat positions, because it is difficult; otherwise, it will be difficult to put the cover of the flux around the arc region.

And the plates of the smaller thickness cannot be welded due to the risk of the burn through. So, it is common not to use this process below 5 mm thickness; otherwise, there will be chances of the burn through. And circumferential welds particularly of the small diameter components cannot be welded, because when the flux will be placed in the arc area it will get fall down. And therefore, will not be able to use the submerged arc welding process for producing circumferential welds particularly in the small diameter components.

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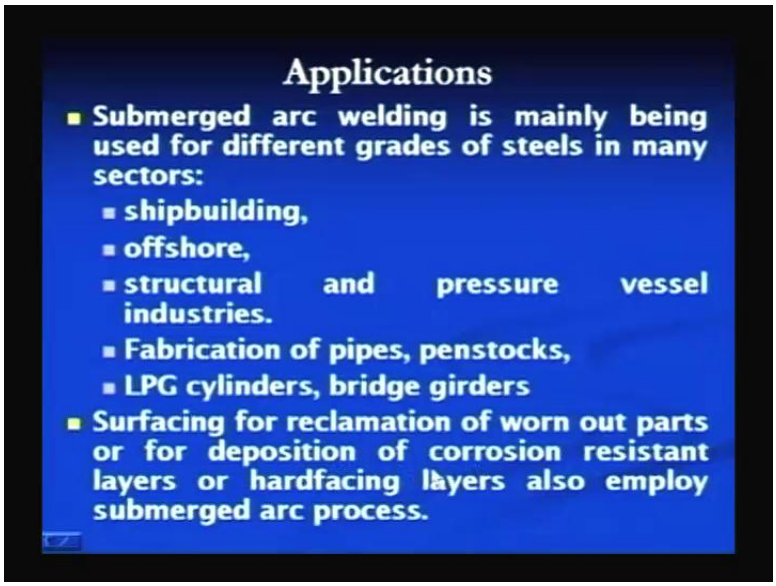

The specific applications of the welding process are like this process is mainly used for the welding of the steels of the different grades in many sectors like shipbuilding, offshores, structural and pressure vessel industry, fabrication of the pipes and penstocks, the LPG cylinders and gap and bridge girders. And this submerged arc welding process is also used for the reclamation of worn out parts or for deposition of the corrosion

resistant and wear resistant materials on the worn out components, so that we can get the longer life.

So, here now we can summarize this lecture which was based on the submerged arc welding process. We have seen that this process offers the advantage of the high deposition rate and high penetration rate because of which it can be used effectively in heavy engineering industry like ship industry, pressure vessel industry or other industries, where very thick plates are to be welded. At the same time selection of the welding parameters like welding current, welding voltage and welding speed is important for producing the successful weld joints. So, if we use the better understanding which has been developed on this submerged arc welding process effectively; I think the sound weld joints can be produced by this submerged arc welding process effectively particularly in case of thick plates.

Thank you.