Manufacturing Process - I
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Lecture -12
Tungsten Inert Gas Welding Part – 2

Welcome students. This is the continuation of the previous lecture on the tungsten inert gas welding process. In the previous lecture, I have talked about the welding power sources, the filler metal which is used in the TIG welding and what are the different electrodes which are used for successful welding by using TIG welding process, and now in this lecture, we will see the things related to the current and voltages which are to be used for the electrodes of different sizes, shielding gas and the variants of the tungsten inert gas welding process along with the applications of the TIG welding. Here for the different electrode diameters.

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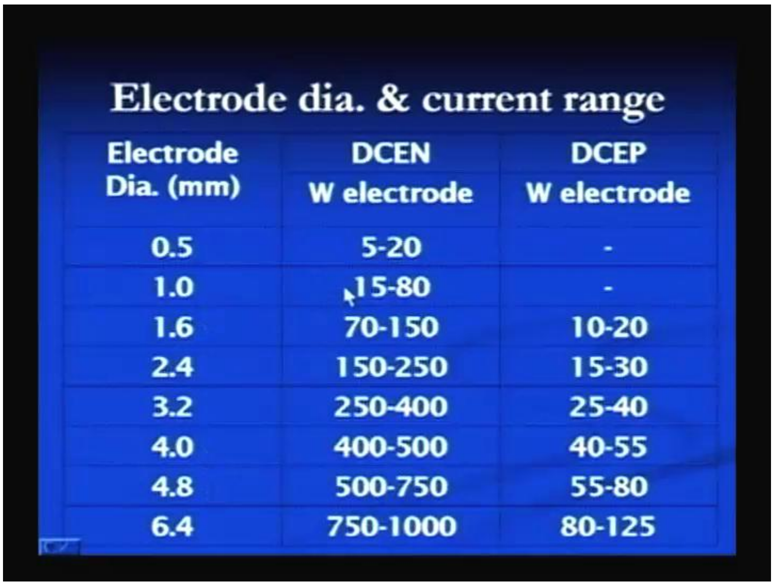

Electrode dia. & current range

Electrode Dia. (mm)	DCEN W electrode	DCEP W electrode
0.5	5-20	-
1.0	15-80	-
1.6	70-150	10-20
2.4	150-250	15-30
3.2	250-400	25-40
4.0	400-500	40-55
4.8	500-750	55-80
6.4	750-1000	80-125

The different current ranges are used because tungsten electrode whether it is pure of tungsten or coated tungsten electrode, the life of the tungsten electrode is largely governed by the current which is used during the welding. For a given diameter of electrode, current range is fixed. Excessive current use or excessive current degrades the life of the electrode. So, here we can see that as there is increase in diameter of the electrode, current carrying capacity of the electrode increases. However, the current carrying capacity is different for DCEN compared to the DCEP.

In general, the DCEN polarity allows the higher current, current carrying capacity for the same diameter of the electrode that is the DCEP. The difference we can see here normally the 0.5 mm diameter, electrodes can carry 5 to 20 ampere welding current. Well, DCEP is not used for these small size electrodes. The same is applicable here also for 1 mm diameter electrodes. 15 and 80 ampere currents can be used. These are not used with the DCEP and 1.6 mm diameter electrodes current ranges from 70 to 150 ampere, and with the DCEP, it is only 10 to 20 ampere.

So, this large difference in the current carrying capacity of the given size of the electrode with the DCEN and DCEP is basically attributed to the amount of heat generated which is in the electrode side when a particular kind of polarity is used. When DCEN is used, it means electrode is negative and only one-third of the arc heat is generated in the electrode side. That is why it allows to use the higher welding currents compared to the case when DCEP is used when two-third of the arc heat is generated in the electrode side which adversely affects the life of the electrode. That is why normally lower current ranges are used with the DCEP polarity for the same electrode diameter. We can see here for 1.6 mm diameter electrode, current range with the DCEN is from 70 to 150 ampere.

Well, for a DCEP, it is from 10 to 20 amperes only and if we see that there is increase in the current carrying capacity for both polarities, the increase in diameter for 6.4 mm. Diameter electrodes with the DCEN current carrying capacity can be in range of 750 to 1000 ampere while in case of DCEP, it is only 80 to 125 ampere.

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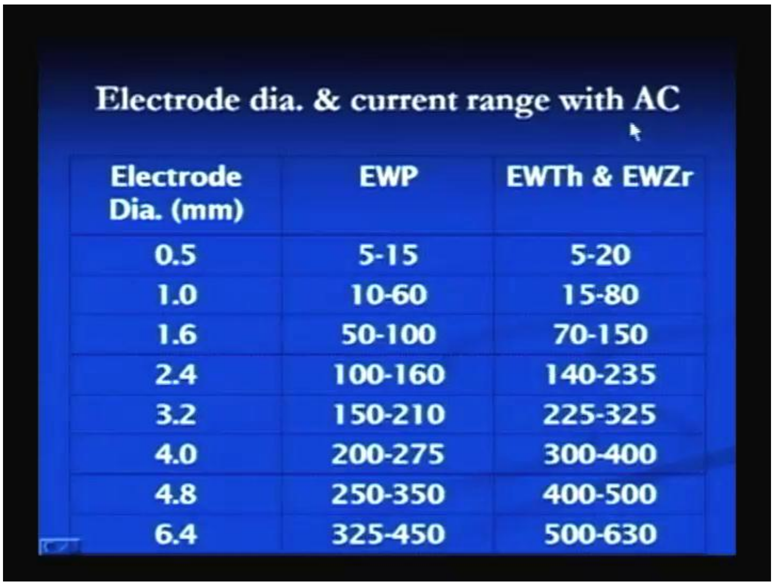

Electrode dia. & current range with AC

Electrode Dia. (mm)	EWP	EWTh & EWZr
0.5	5-15	5-20
1.0	10-60	15-80
1.6	50-100	70-150
2.4	100-160	140-235
3.2	150-210	225-325
4.0	200-275	300-400
4.8	250-350	400-500
6.4	325-450	500-630

We will see here this current carrying capacity and the electrode diameter relationship for the AC welding is different, and here we can see with the increase in electrode diameter, also the current carrying capacity increases when this EWP indicates the pure tungsten electrode and EWTh and EW Zr indicates the thorium and zirconium coated tungsten electrode. So, here we can see that the tungsten, pure tungsten electrodes show the poor current carrying capacity compared to the thorium and zirconium coated tungsten electrodes. For same electrode diameter if we compare the pure tungsten electrode and thorium and zirconium coated tungsten electrodes, significant difference in current carrying capacity.

Here we can see for 1 mm electrode diameter with pure tungsten electrode, current carrying capacity can be in range of 10 to 60 ampere while that in case of the thorium and zirconium coated tungsten electrode, it is in range of 15 and 80 ampere. If we see the large diameter electrode say of 6.4 mm, current carrying capacity for pure tungsten electrodes is in range of 325 to 450 amperes while in case of the thorium and zirconium coated electrodes, it is in range of 500 to 630 amperes. So, here we can see this current carrying capacity for the AC welding is different from the DC welding. DC welding with electrode negative polarity allows the higher current carrying capacity, while with the D AC welding current carrying capacity is somewhat lower for the same diameter of the electrode.

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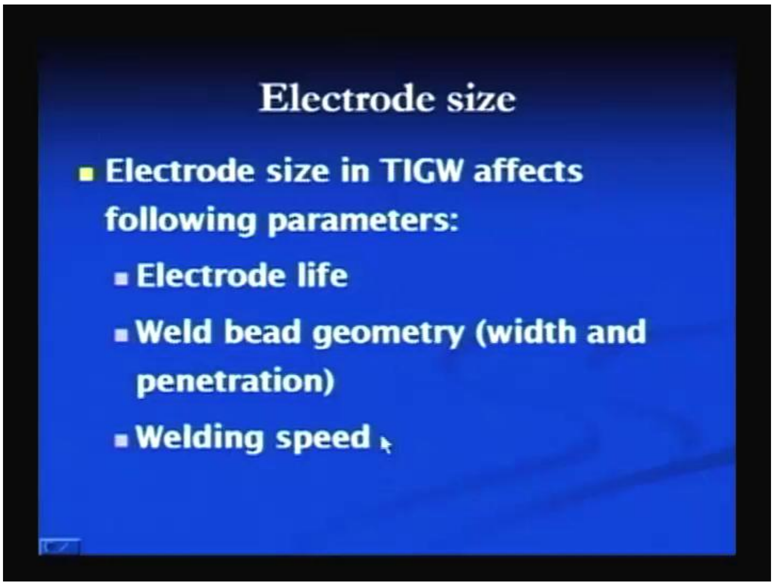

So, the electrode size therefore is very important for longer life of the electrode during the welding under given set of the conditions because the size of the electrode which is to be selected, affects the number of the parameters related to the welding like electrode life is governed by the electrode size. For a given welding current if the electrode size is more, less heat will be generated due to the electrical resistance heating. Relatively we will have to perform for long and the rate of degradation of the electrode will also be reduced. Weld bead geometry particularly if the electrode of the large diameters are used, then that will increase the width and the penetration because the large diameter electrodes will allow to use the higher welding currents, and when higher welding currents are used with large diameter, electrodes will increase the width of the weld bead and also the penetration during the welding. The welding speed is also affected by the electrodes size. If the large diameter electrodes are used, then that will be able to develop more heat and the melting of the base metals will be fast and that will help to increase the welding speed.

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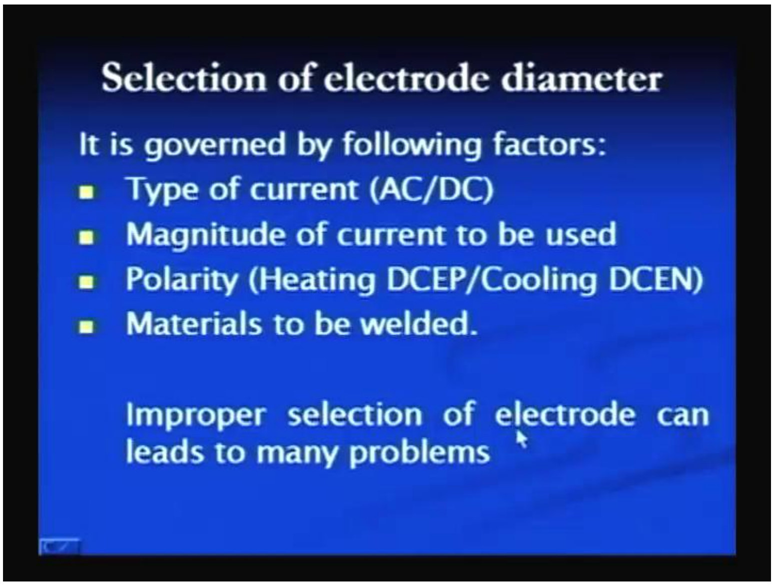

So, the selection of the electrode diameter has to be made by looking into the various aspects related to the welding. Some of the factors which are to be kept in mind while selecting the electrode diameter for its optimum performance and during the welding, it is necessary to see that what type of the welding current will be used during the welding. Here the type of current is important because for a given diameter, we have seen the current carrying capacities are different, and the performance of the electrode also becomes different for DCEN. We get the longer life for a given electrode diameter compared to that of the DCEP.

So, for a given current if the DCEN is to be used, we can use the smaller diameter and if the AC is to be used, then we have to go for the larger diameter and with the DCEP, we have to go for further larger diameters because electrical resistance heating here for a given diameter of the electrode plays a significant role. So, the due consideration should be given while selecting the electrode diameter for the type of current to be used during the welding and here, another important factor is the magnitude of the current to be used. Actually the magnitude of the current to be used depends upon the thickness of the shields which are to be welded. Thicker will be the shields, greater will be the requirement of the heat for melting of the faying surfaces and for higher current, we need the larger electrode diameters, so that electrode can perform for long time. Otherwise, its life will be degraded, reduced significantly because of electrical resistance heating and electrode contamination and here, the polarity is another aspect.

Polarity plays a significant role in selection of the electrode diameter because of the heating which is available during heating of the electrode during the EC DCEP or the DCEN because when DCEP is used, most of the heat is generated in the electrode side which adversely affects life of the electrode, while in the DCEN portion, less heat is generated and because of which less heating takes place of the electrode, and indirectly we can say that when AC is used, there will be continuous change in polarity from electrode positive to electrode negative. When electrode is positive, there will be heating and when electrode is negative, there will be the cooling. So, the polarity plays a significant role in selection of the diameters.

For a given current setting DCEP, for the DCEP we have to go for the larger diameter electrodes compared to that of DCEN. DCEN allows to use the higher current for the given electrode diameter compared to the DCEP. The material to be welded is also important because here it will depend upon the amount of heat which will be required for successful melting of the faying surfaces to produce the joint. Accordingly, the current requirements will be determined for the large diameter. Large diameter electrodes are required for carrying high current when the metal of the high melting point or high thermal conductivity or greater thickness is to be welded. So, if these points are not kept in mind, then improper selection of the electrodes can lead to the many problems in the welding by the TIG process.

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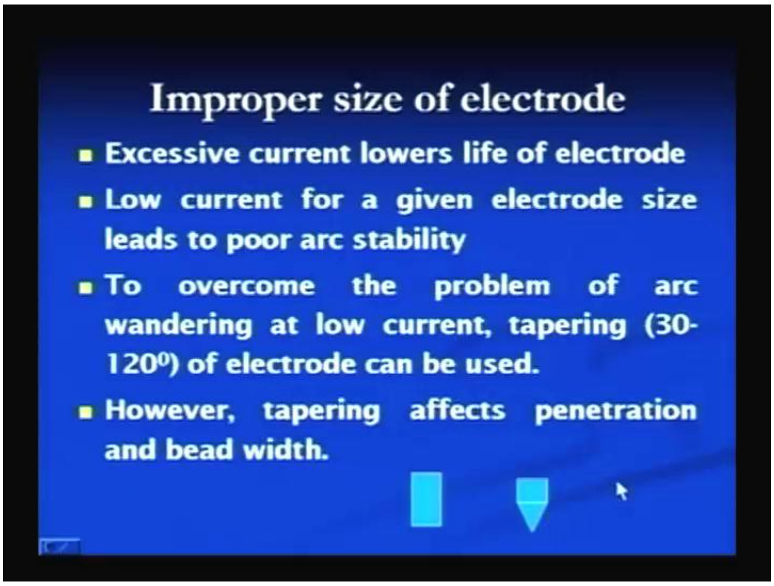

What improper selection of the electrode it can lead to or what are the problems there if the improper electrode is selected?

First one is if for a given current setting if the electrode is not proper, electrode is not of the proper diameter, then it will adversely affect the life of the electrode due to the excessive electrical resistance heating. That means for a given current if the electrode is of smaller diameter, it will reduce the life of the electrode and the low current for a given electrode diameter will lead to the problem of the arc stability and arc initiation because of reduced current intensity available at the electrode tip. So, the low current for a given electrode size leads to the problem of arc stability, and to overcome this problem, one possible way is that electrode tip can be tapered.

The tapering will help to increase the current intensity, and this tapering can be done by making the tip of the electrode conical of which conical angle of the cone can be in range of 30 to 120 degree. This tapering helps to increase the stability of the arc and reduces the wandering of the arc which otherwise can be there with the low welding current and low welding currents are particularly required when very close control over the heat input is to be used for welding of thin sheets of the low melting point metals like aluminum.

So, we can say here the tapering is one way to use the low welding currents which will avoid the problems related to the arc stability and wandering of the arc, but this tapering also affects the weld bead cross-section and its penetration because the tapering affects the penetration and weld bead width. A small arc, the conical angle which is produced after tapering greater will be the depth of penetration and narrower will be the width of weld bead. Here, we can see if this is the tip of the electrode. We will get the wider weld bead and the shallower penetration, but if the electrode tap is tapered like this having certain angle shape, 30 angles which can be there in range of 30 to 120 degree, normally 60 degree angle is used for the better performance of the electrodes.

This tapering helps to obtain greater depth of penetration, but the width of the weld bead is reduced. If the width of the weld bead is reduced, it can impose the problems of the poor fit up. So, poor fit up between the plates to be joint has to be perfect for using this tapered electrode or the electrode having a very conical shape tip.

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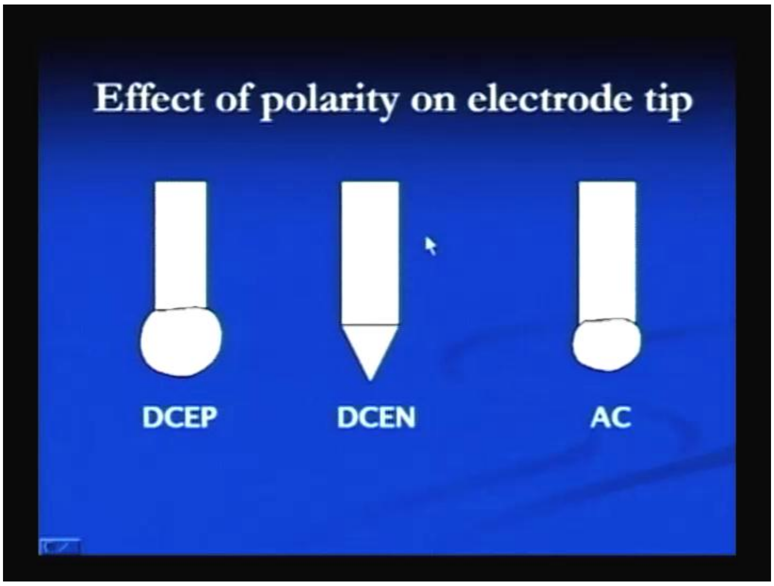

If the electrode is used with the different types of the polarities and different type of the currents, then we get the different types of the electrode tip also after the welding. AC welding results in largely ball shaped tips, and the DCEP also results in the ball shaped tip, but the diameter of the ball shaped tip is more in case of DCEP compared to the AC. When AC current is used because of the low heat generation at the tip of the electrode during the DCEN, that conical shape is maintained. So, the type of the polarity and the type of current also affects the type of the electrode tip which is used for these welding processes.

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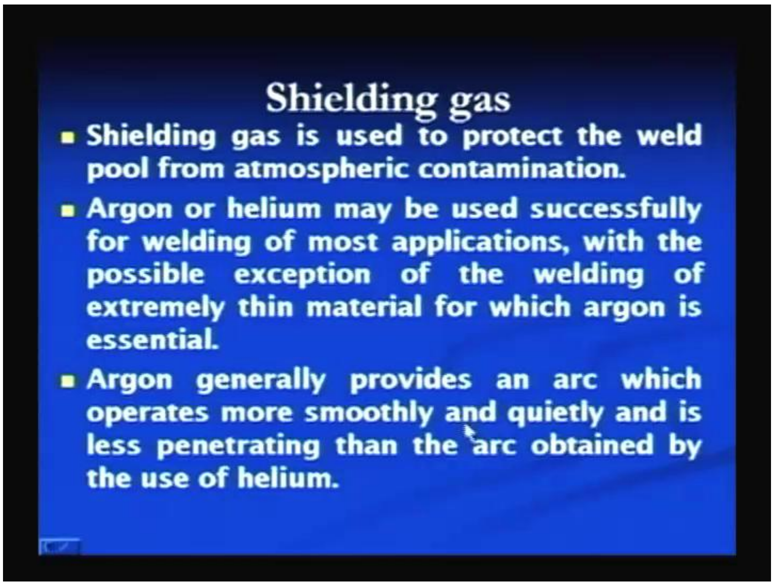

Here the shielding gas in tungsten inert gas welding process plays a very important role in producing the high quality weld joints. We have seen in shielded metal arc welding process the inactive gases are produced by the decomposition of the flux material and the shielding of the weld pool and the arc in submerged arc welding process sub is provided by the fusion of the granular fluxes. In the same way to protect the weld pool from the atmospheric contamination and also, to protect the electrode tip from the atmospheric contamination, it is required to provide proper shielding from the atmospheric, so that the good quality weld joints can be produced. For shielding purpose, normally helium and argon and inert gases are used.

So, the shielding gases are used in TIG welding process to protect the weld pool from the atmospheric contamination. Argon and helium may be used successfully for welding of most of the metals with exception of the welding of the material which are extremely thin. So, here either helium or argon can be used for welding of the most of the metals, but helium is not used for welding of the thin sheets because high heat is generated and arc bands are hotter that can cause the melt through problem during the welding of thin sheets. That is why normally argon is preferred for welding of thin sheet materials.

Argon generally provides an arc which operates smoothly, quietly and is less penetrating and that is why it is good for welding of the thin sheets particularly and the other important points are the plus points related to the argon is that it offers the good arc stability, and the arc which is smooth and burns quietly to generate the heat and melt the faying surfaces.

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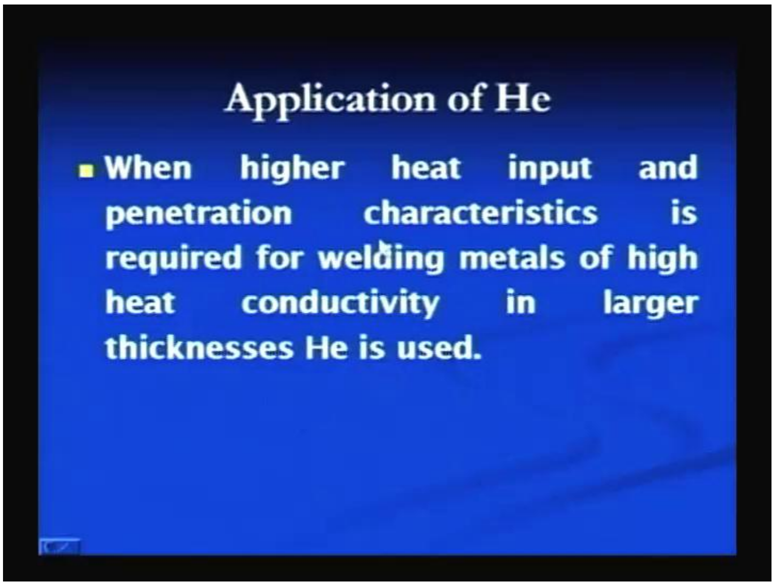

On the other hand, helium offers the higher heat from the arc, but the arc stability is problem related to the helium, and that is why sometimes mixture of argon and helium is also used for protecting the weld pool and the arc region from the atmospheric contamination here because the penetration which is obtained by the helium and the heat which is generated by the helium as the shielding gas is significantly high, and that is why the helium as a shielding gas is used for welding of those metals which need high heat input for melting of the faying surfaces, and also the melting of the very thick sections, melting the faying surfaces of thick sections and the metals of the high thermal conductivity. So, to take the advantage of the high heat where greater penetration is required in welding of the metals of high heat conductivity and greater thickness, helium is normally preferred metal wise.

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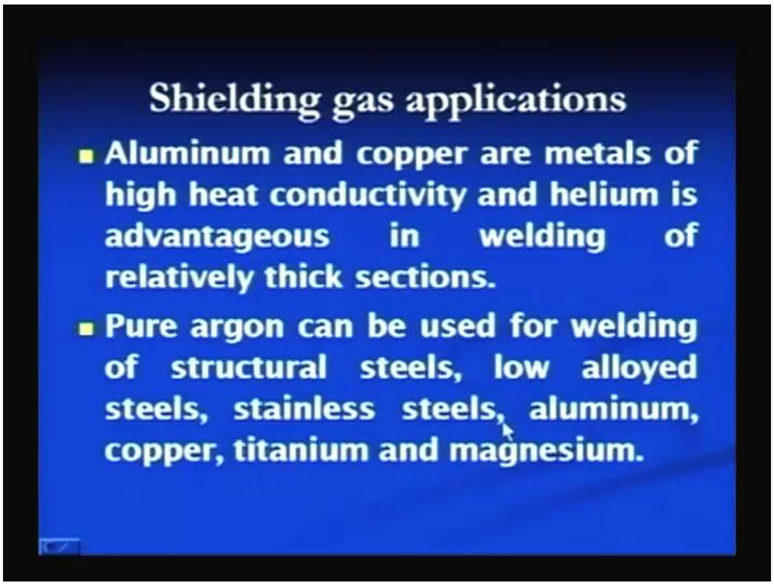

The different shielding gases are used like for aluminum and copper, the metals which are of very good thermal conductivity which offers also good heat conductivity. Helium is useful for their welding, particularly in case of thick sections because both copper and aluminum poses a very good thermal conductivity. So, to make sure that melting of the faying surfaces takes place easily, the helium is used as a shielding gas, so that we can get the hotter and the high temperature and large amount of the heat from the arc for melting the faying surfaces of these metals particularly when thick sections are to be joined.

Pure argon can be used for the welding of the structural steels, low alloyed steels, stainless steels, aluminum, copper, titanium and magnesium. Here the argon as a shielding gas is used for this welding of the steels and other non-ferrous metals particularly when the good quality weld joint is to be produced.

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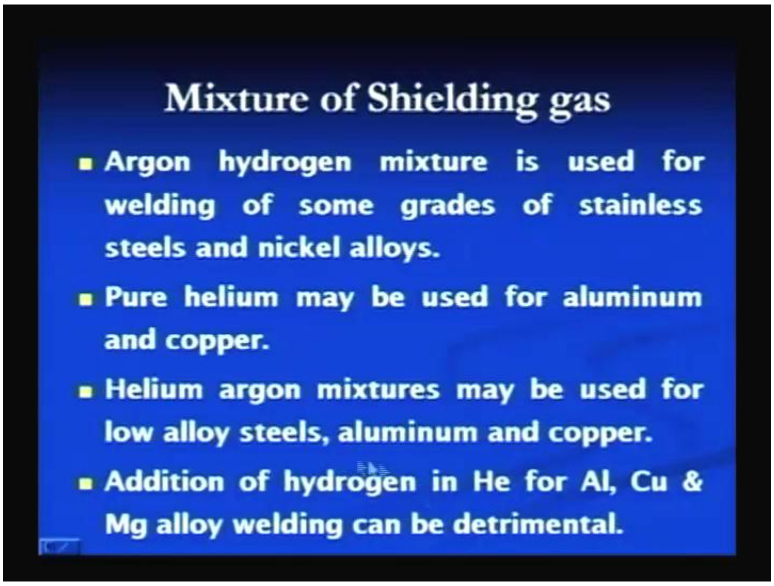

Here mixture of the argon and hydrogen is also sometimes used to weld some grades of the stainless steel and the nickel alloys. In addition of the hydrogen have to achieve the benefits. Similar to that of the helium, at the same time we get the advantageous points of the argon also because argon offers the good arc stability and a smooth metal transfer, and addition of the hydrogen have to burn the arc hotter and get the greater depth of the penetration and in welding of the nickel and stainless steel. That is why mixture of the argon and hydrogen becomes useful for the welding.

Pure helium can be used for the welding of the aluminum and copper because these are of the good thermal conductivity, so that melting can be achieved easily of the faying surfaces. The helium and argon mixtures also may be used for low alloy steels, aluminum and copper, and in addition of the hydrogen in helium for aluminum, copper and magnesium alloys can be detrimental because hydrogen has a very high solubility in aluminum and magnesium alloys. If hydrogen is present in the shielding gases, then chances will be there that hydrogen can get dissolved in the weld pool of the aluminum and magnesium alloys which can lead to be problems of the macro porosity caused by the presence of the hydrogen. That is why it can be detrimental to use hydrogen with the helium in welding of the aluminum copper and magnesium alloys.

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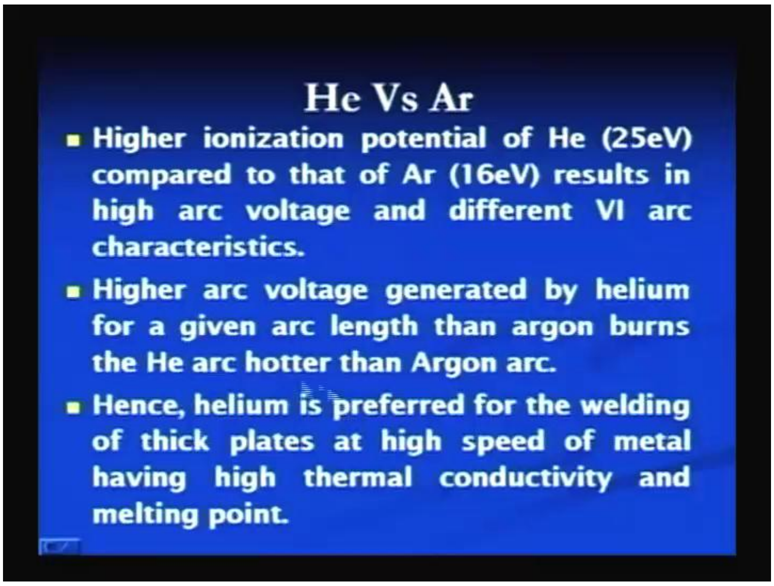

Here the argon and helium are the two extensively used shielding gases in the tungsten inert gas welding process, but we get the significant difference in their performance. What is the reason behind their performance and why the different performances are given by these gases? Those reasons we can see here.

Helium offers the higher ionization potential that is 25 electrons compared to that of argon and this great difference in the ionization potential of the helium and argon results in the difference in the VI characteristics of the arc. For helium, we get the higher arc voltage compared to that of the argon. Because of this difference in the ionization potential, higher ionization potential of the helium causes the higher arc voltage compared to that of argon because of which it burns hotter for a given current setting.

Higher voltage generated by helium for a given arc length than the argon leads to burn the arc hotter compared to that of argon shielded arc. Hence, helium is preferred for welding of thick plates at a high speed of metals having high thermal conductivity and high melting point. That is why helium is used for welding of the metals of high thermal conductivity and high melting point because helium arc burns hotter compared to that of argon arc.

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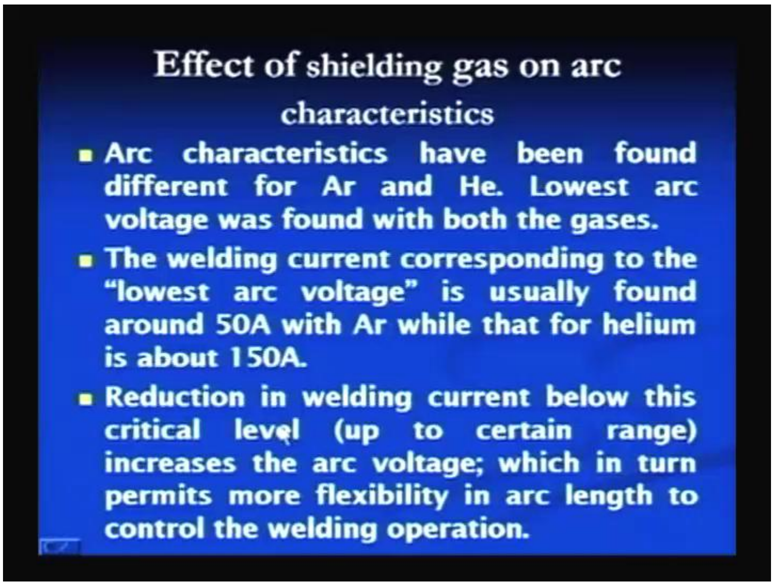

Arc characteristic have been found to be different for argon and helium, and these arc characteristic for both argon and helium shows the lowest arc voltage with both the gases, and that the lowest arc voltage is usually found around 50 ampere with the argon, while the lowest arc voltage for helium is around 150 ampere. Advantage of having the lowest arc voltage is that minor fluctuation in arc length when low currents are used helps to maintain and the flexibility in arc length. So, here we can see arc reduction in welding current below the critical level increases the arc voltage which in turn permits the more flexibility in arc length to control the welding operation.

Here for the welding of thin sheets particularly, if we have to use the lower welding currents, then at the lower welding current side here around the region of the lowest arc voltage, it is possible to have the better flexibility in the arc length to control the welding operation. This will be clearer from the next slide diagram, where it will be shown that what kind of arc characteristic we get with the helium and argon.

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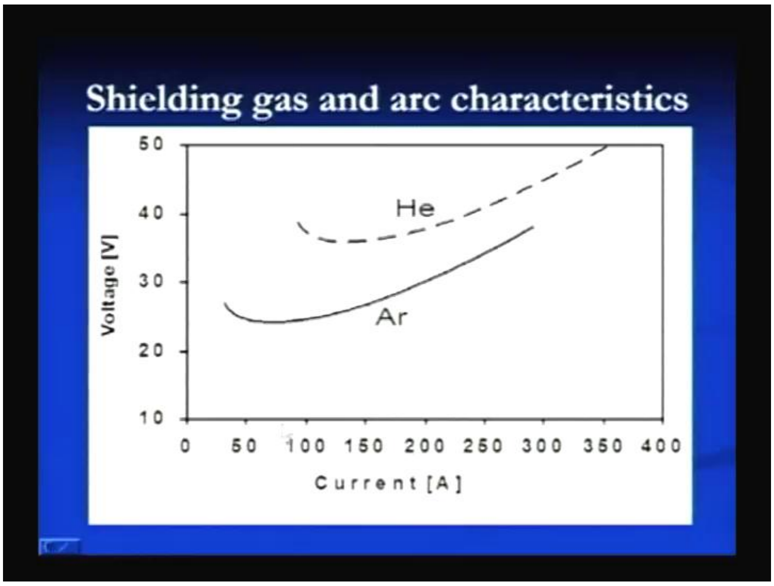

We can see here VI characteristic of the arc. For argon shows the lower arc voltage. For a given current setting here, we can say 150 ampere current, the arc voltage is somewhat 28 while for the same current setting, arc voltage is say somewhat 38. The value in both VI characteristic with both helium and argon shows the minimum arc voltage. Minimum arc voltage is around say 150 ampere with the helium and with the argon, the lowest arc voltage is at about 150 ampere.

Here the lowest arc voltage with 150 ampere current with the argon as a shielding gas gives the arc voltage around 25 volts while in case of the helium, it is 35 volts. When we are welding thin sheets, then we have to use and if are using lower current say 50 to 60 ampere with the argon are around 120 to 140 ampere current with the helium, then minor fluctuation in arc length will allow the greater flexibility in controlling the operation because if there is a change in the arc length in either side, the arc voltage is not affected much in here. So, the minor fluctuation in arc length does not create problem when we are welding at the lowest arc voltage side here which is around 150 ampere for helium and it is around 50 ampere for the argon.

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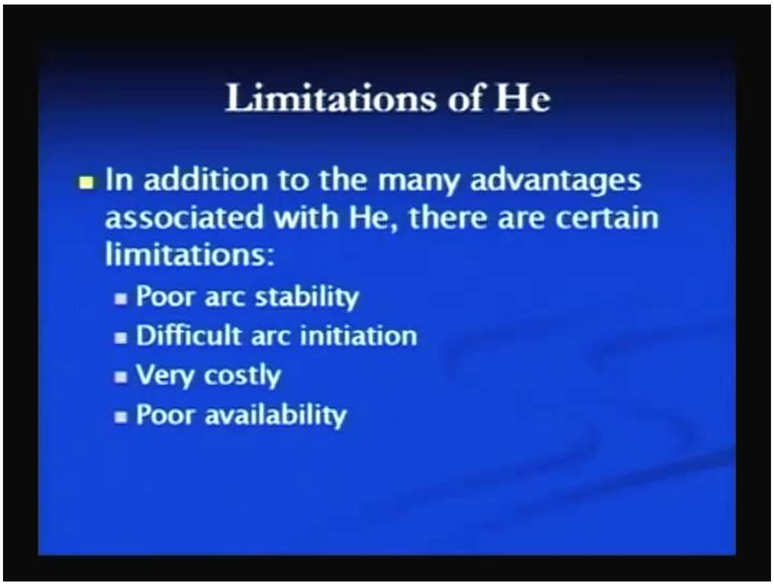

There are certain limitations associated with helium and these limitations are like poor arc stability is difficult to initiate the arc and the gas is very costly and availability is another problem. Because of these regions only, the helium is used only when very critical components arc to be welded for high reliability and high safety purpose. Otherwise, argon is invariably used for welding by the TIG process and if we compare other points related to the argon and helium.

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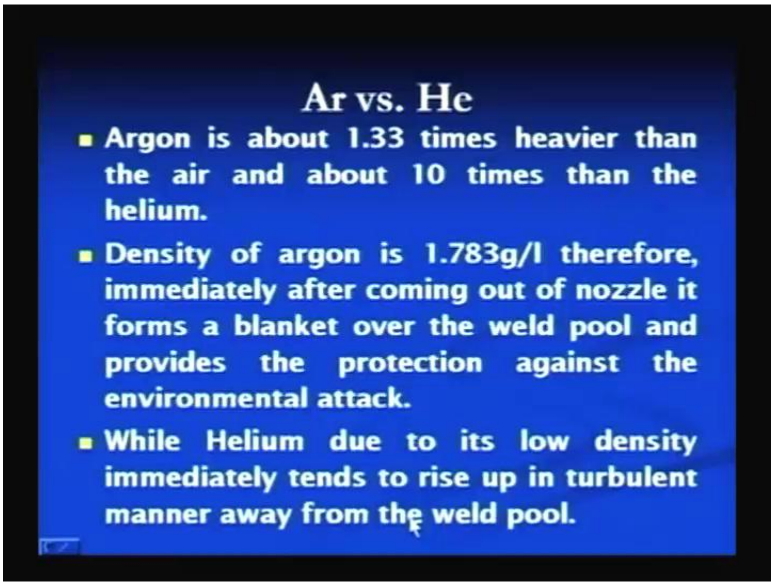

Argon is about 1.33 times heavier than the air and it is about 10 times heavier than the helium, and this density difference plays a significant role in the performance of the helium and argon as shielding gases. The density of argon is about 1.783 gram per liter and therefore, immediately it tends to settle down around the arc region and the weld pool and provide the effective protection against the atmospheric contamination, while due to the low density, helium tends to rise up and in turbulent manner and it goes away from the weld pool. That is why it is required to use the higher flow rate with the helium as the shielding gas than the argon.

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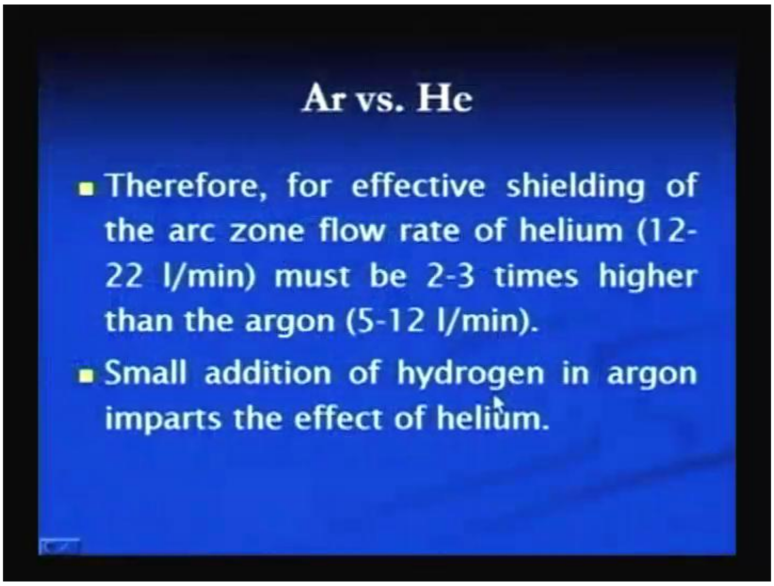

We see for effective shielding of the arc zone flow rate of the helium is around 12 to 20 liter per minute compared to that of argon which is 5 to 12 liter per minute, and this flow rate for the helium is about 2 to 3 times greater than that is required with argon. This difference is attributed mainly to the massive difference of argon and helium. A small addition of the hydrogen in argon helps to get the benefits associated with helium.

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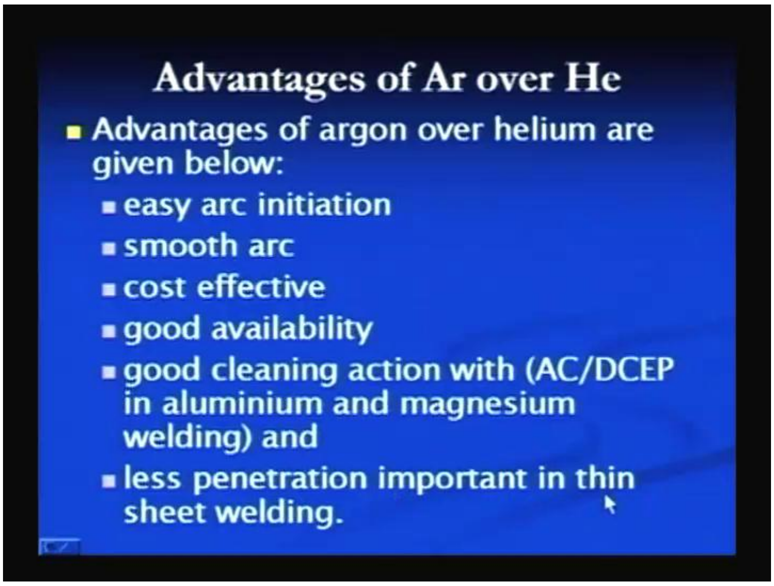

That is why hydrogen is added in a small quantity in order to get the greater depth of penetration and burn the arc hotter, particularly during the welding of thick sections and the metals of high thermal conductivity. There are many advantages offered by argon over helium and these are like the easy arc initiation, and smooth arc is produced. It is cost effective and easily available, and the good cleaning action is offered by argon as the shielding gas when DCEP or AC welding is used. AC current is used in welding of aluminum and magnesium alloys. Another important thing is the penetration depth which is obtained by argon is limited which is required in case of thin sheet welding.

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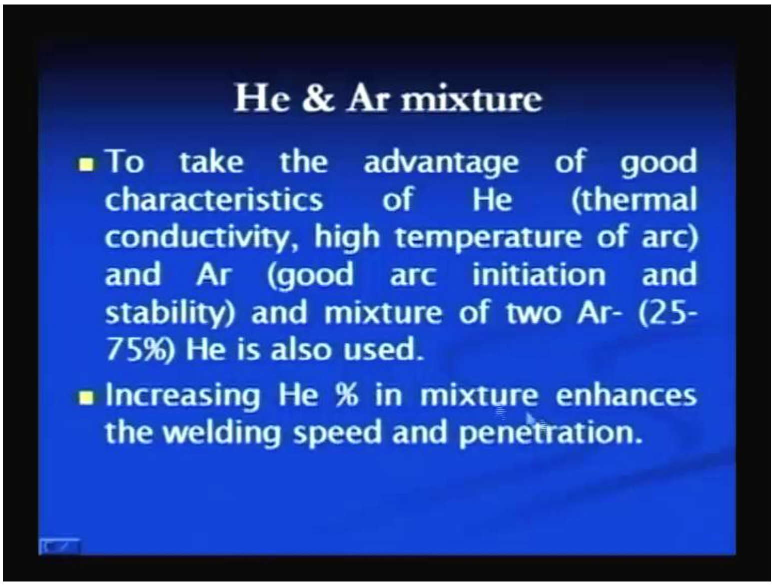

To take the advantage of helium and the characteristics of both helium and argon, many times mixture of both is used where helium can be present with argon in the range of 25 to 75 percent and when this mixture is used, then we get the good arc initiations and arc stability. At the same time, high temperature of the arc which is required for welding of high thermal conductivity material and heavier sections, increase in helium in mixture increases the welding speed and penetration because arc burns hotter which in turn increases the melting rate, and there by helps to get the higher welding speed. The flow rate which is required to provide effective shielding of the weld pool can be in range of 5 to 50 liters per minute, although it depends upon the number of other factors.

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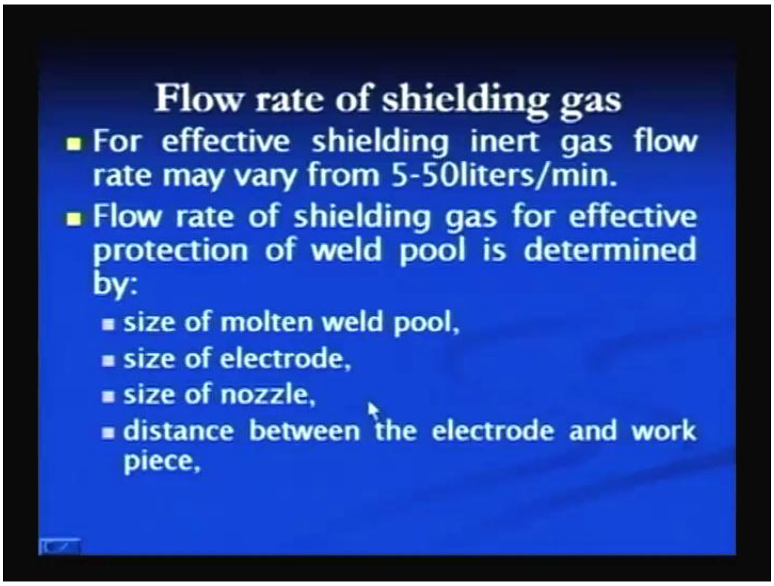

For effective shielding of the weld pool depends is governed by the number of factors like the size of the weld pool. Larger is the size of weld pool, greater will be flow rate required to cover the entire area of the molten weld pool. Size of the electrode and the size in the diameter of the nozzle, both these factors will govern the flow rate which is required to form jet of the shielding gas which can form a blanket of shielding gas around the weld pool.

So, the size of the nozzle also has covered the distance between the electrode and the work piece. Greater is the distance between the electrode and the work piece, greater will be the flow rate required to form effective shielding, but if the distance is reduced, it can adversely affect to the life of the nozzle and also, to the electrode due to the back burn effect and extent of the turbulence. The air flow of the atmospheric air can also affect the flow rate of the shielding gas required for effective shielding, and if the flow rate of the atmospheric air is above 8 to 10 kilometers per hour, then we need the higher flow rate of the shielding gas to provide effective shielding. Optimum flow rate for a given welding condition should be such that we get a form jet of the shielding gas which can cover the weld pool and the arc region effectively.

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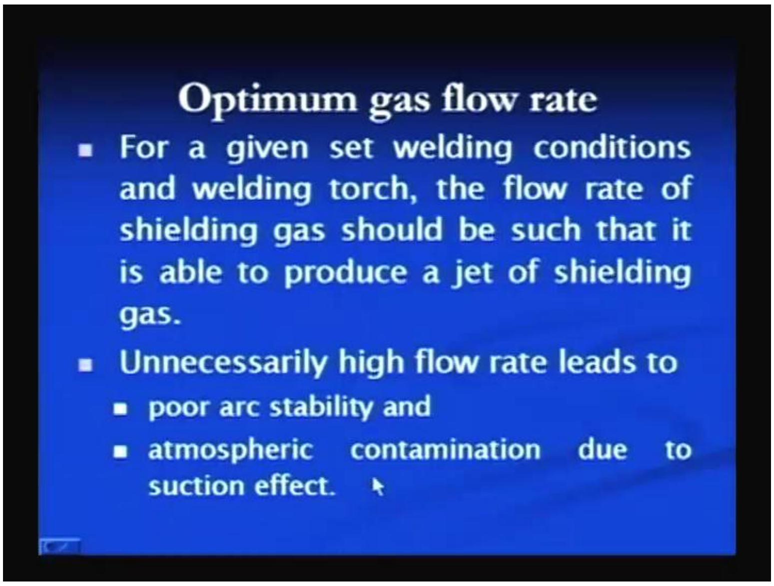

Unnecessary high flow rate should be avoided because it leads to the poor arc stability and due to the suction effect, atmospheric contamination can also be there.

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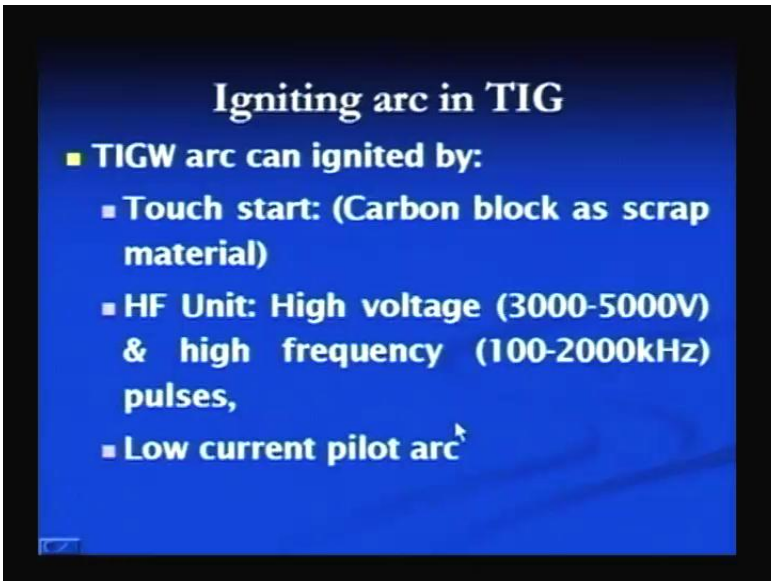

We will see that after all the system, all the sub component of the TIG welding process we have covered and we will see that if the system is ready for the welding, we have to strike the arc first and that arc will be maintained. So, for ignition of the arc what are the different methods available, so that it can be striked easily, and then it can be maintained to develop the heat required for melting of the faying surfaces and produce the joint? Like one method is the touch start method in which electrode touches the carbon block and arc is striked and then, it is touched in the location where arc is required.

High frequency unit which supplies the high voltage 3000 to 5000 volt and high frequency of 100 to 2000 kilo hertz pulses, this high frequency high voltage pulses help to annoy the gap between the electrode and work pieces, and there by generate the electrons required for initiation of the arc. The low current pilot arc is another method which is frequently used for igniting the arc, and there are various ways through which pilot low current pilot arc can be generated.

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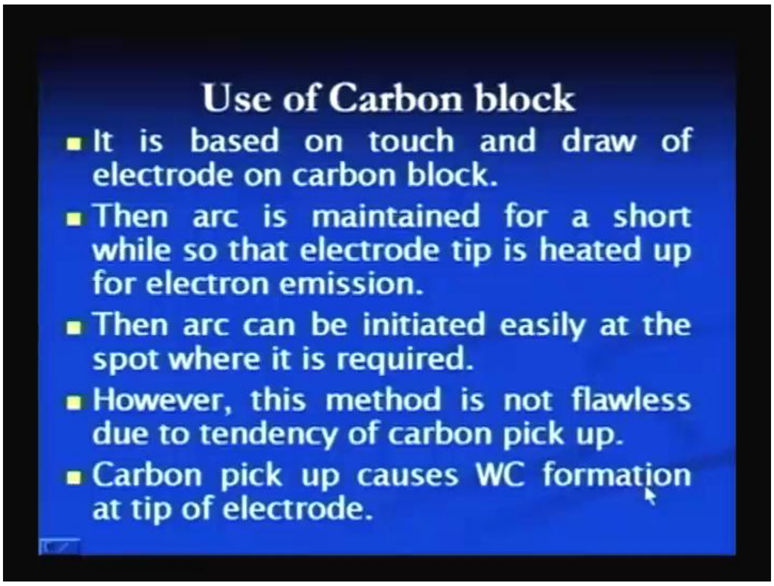

Though we will see the things in greater detail related to the use of carbon block for igniting, the arc for initiating the arc. This method is based on the touch and draw of the electrode on the carbon block. When arc is initiated, it is maintained for some time. So, that electrode tip is heated for the electron emission and then, arc can be extinguished and then, arc is initiated in the location, where it is required easily because tungsten electrode becomes hot after the touch start with the carbon block. Then, it can be used that worn tungsten electrode can be used to start the arc easily in the location where it is required.

This method is not free from the problems because there are number of difficulties associated with this method. One is the carbon pick up when saw circuit is. So, when saw circuiting is there between the tungsten electrode and carbon block, heavy current flow takes place and that develops lot of heat and the high heat leads to the partial melting of the tungsten electrode tip. It picks up the carbon from the carbon block and that forms the tungsten carbide which has the lower melting point. So, pick up of the carbon leads to the formation of the tungsten carbide at the electrode tip.

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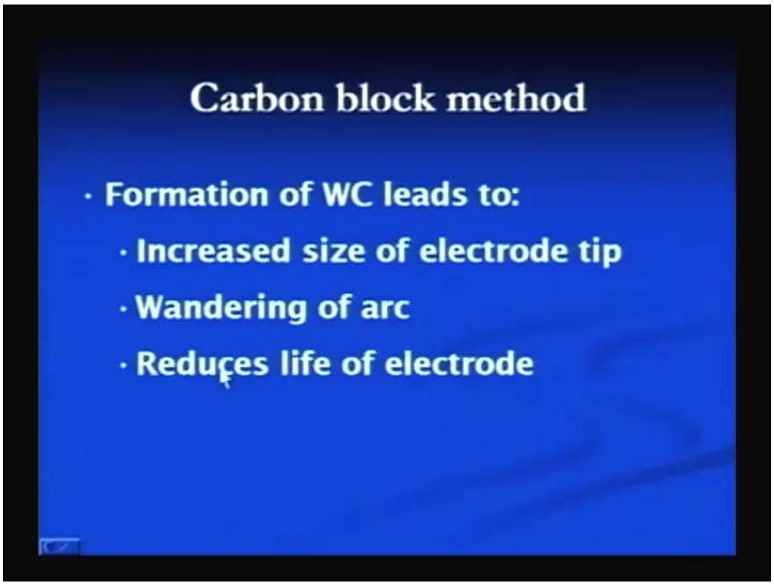

The formation of tungsten carbide at the tip is undesirable because it changes the size of the electrode tip, and it leads to the wandering of the arc and reduces the life of electrode because melting point on the tungsten carbide is somewhat lower than the pure tungsten material.

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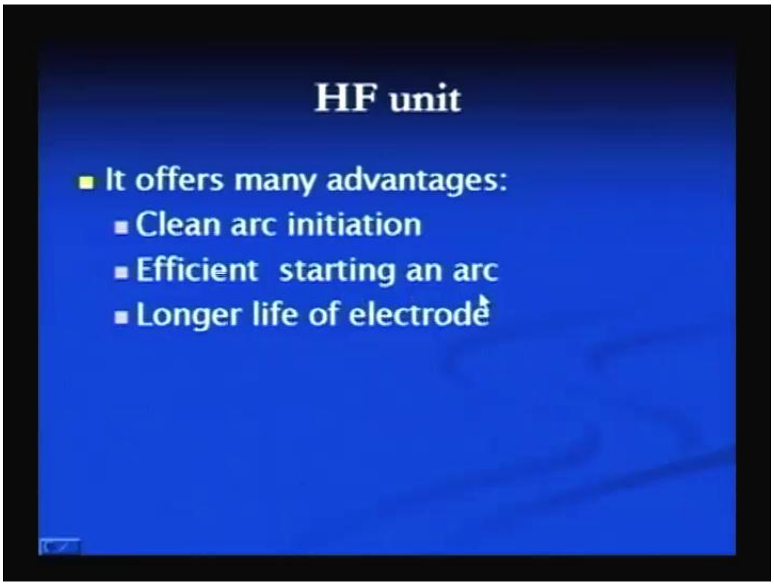

Another method is the high use of high frequency voltage process in which high frequency unit is used. This method offers many advantages like we get the clean arc initiation, no touching of the tungsten electrode to the carbon block, very efficient method and we get the longer life of the electrode with this method.

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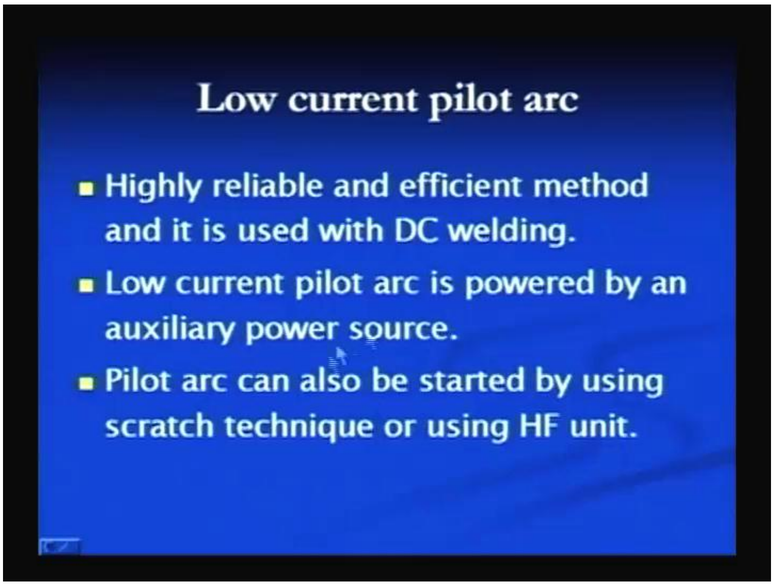

The third method is the low current pilot arc in which for initiation of the arc low current level is supplied first, and once arc is established, then the high current is switched on. So, this method is very reliable and very efficient. It is used with the DC welding particularly low current arc is powered by a separate auxiliary power source and arc pilot arc can be started by any of these methods, so that the problems related to the carbon pick up will be less or if the HF unit is used, then that will also decrease. That will also be able to initiate the arc efficiently.

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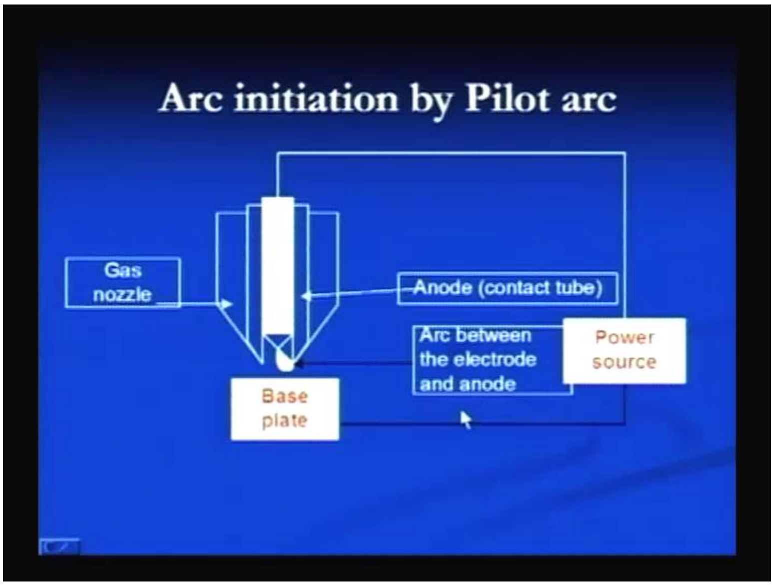

Arc initiation by pilot arc method can be seen here. A separate auxiliary power source is used here, and then arc is initially generated by using the low current between the tungsten electrode and another electrode which may be there with the nozzle. This arc is ignited initially by using the low level of current and then, it is brought to the base metal close to the base metal, so that arc between the base metal and tungsten electrode can be started.

So, here separate power source is used to ignite the pilot arc first, and then main arc is established between the electrode and the work piece and for that purpose, the main current supply is switched on, so that desired melting of the faying surfaces can take place.

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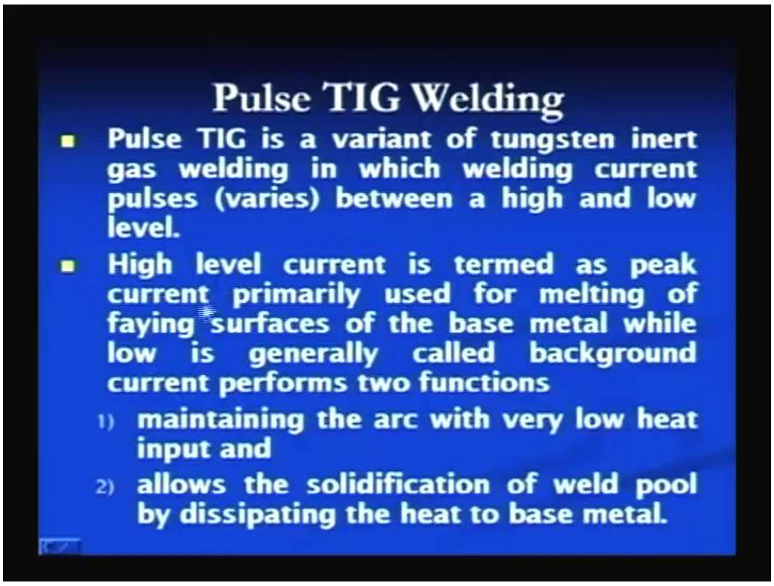

The one variant of the tungsten inert gas welding process is the TIG welding. In conventional TIG welding, we supply the constant magnitude of current continuously for melting of the faying surfaces, but continuous supply of the current for developing the arc and generation of the heat leads to the building up of the heat in the base metal, which leads to problems of the residual stresses distortion and wider heat affected zone which is not desirable. Also, in welding of thin sheets if the heat supply is made continuously, the problems can be there related to the melt through.

So, those problems can be reduced if the high current pulses are made or provided at a regular interval, and the arc is maintained using low level of current. That is the base current or background current. So, in this pulse TIG welding, it is a variant of the tungsten inert gas welding process in which the welding current is varied between bases between the two levels. One is the high level which is known as pulse current or peak current. Another is low level known as background current or the base current. The high level current is termed as peak current and primarily used for melting of the faying surface of the base metal, while low current is generally used for two purposes. One is to maintain the arc with low heat input and allows the solidification of the weld pool by dissipating the heat to the base metal, and this low level of current is also known as background current. In optimum manner, both high level and the low level of the current are selected by considering the number of points related to the kind of weld joint or the kind of base metal which is to be welded.

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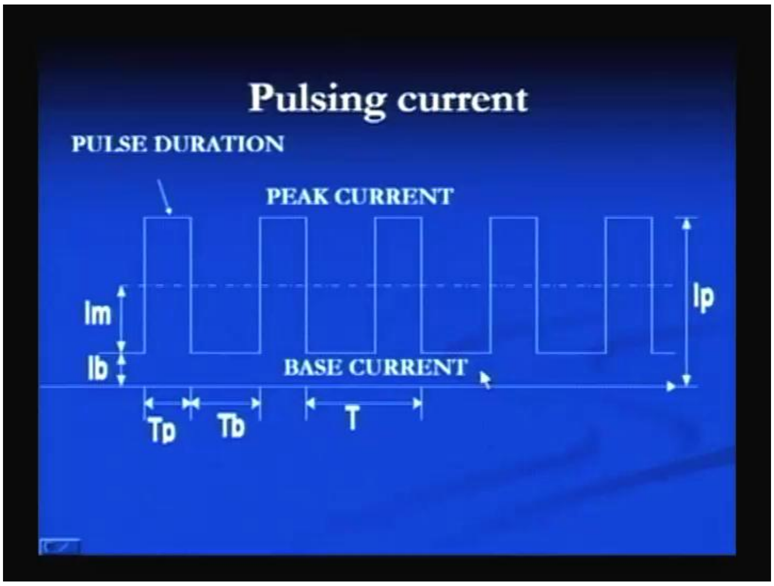

Here we can see schematically how the current varies in the pulse TIG welding. We can see here this is the lower level of current which is maintained throughout. Just sufficient to maintain the arc and during the portion during which the base current is maintained and the solidification of weld pool takes place. As in when the pulse of high current is given which is known as peak current or the pulse current, then during this peak current portion, the time during which pulse current is given melting of the base metal takes place. So, the peak current had been responsible for melting and base during the base current solidification of the weld pool takes place and continuous pulsing between the base current and the peak current leads to a very fine grained structure, and reduced heat input for melting of the metals. This reduced heat input is particularly important in welding of thin sheets.

So, here we can see the duration in which the peak current is maintained is known as peak current duration or base current duration. The value of the current which is of the higher level is known as peak current and the lower level of current which is used in this type of welding is known as base current.

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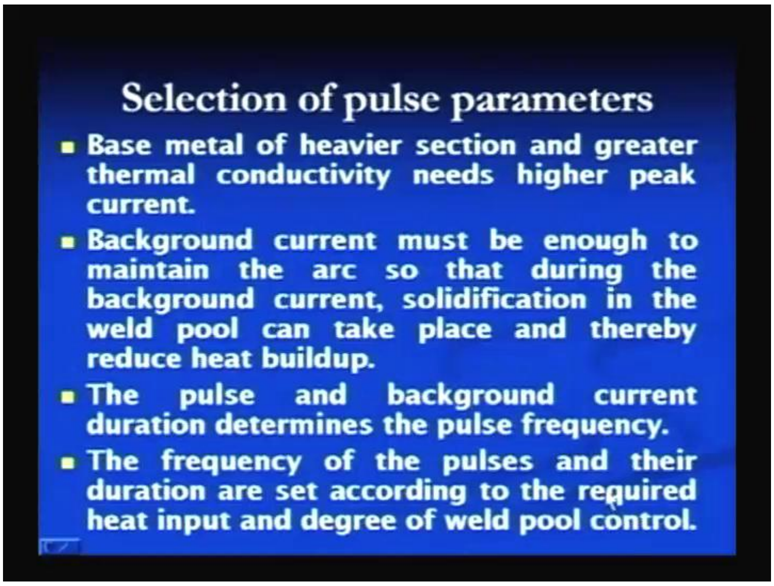

The pulse parameters like the peak current base current and their duration should be selected after giving the due considerations to the metal being welded, and the kind of weld bead geometry and the characteristics required from the weld joint. The base metal of the heavier sections and greater thermal conductivity needs the higher peak current because the higher melting takes place only during the peak current portion. So, if the section is heavier and of the higher thermal conductivity, we need higher peak current and base current must be enough to maintain the arc, so that the solidification of the weld pool can take place and thereby to reduce the heat buildup.

The pulse and background current duration determines the pulse frequency and frequency of pulses and their durations are set according to the requirement of the heat input. The degree of weld pool control which is required to put the molten metal in the desired position where it is required.

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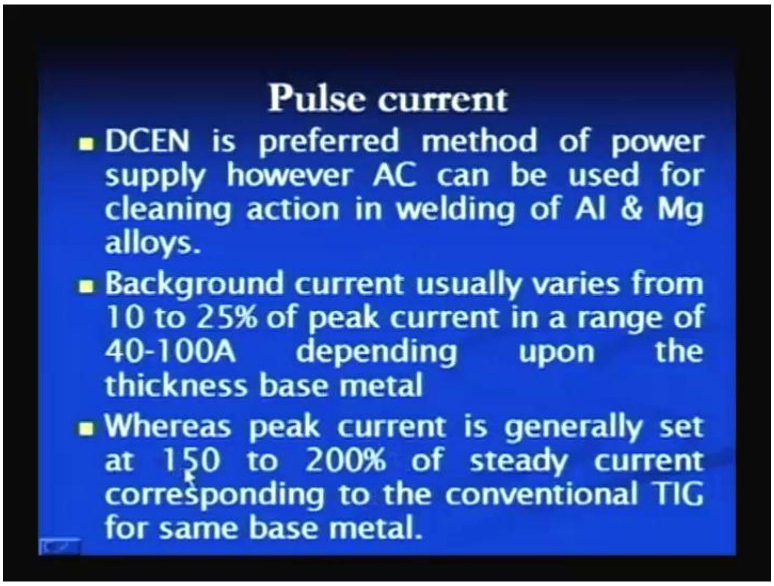

For setting the pulse current DCEN, we have to see certain points like DCEN is preferred method of the power supply. However, AC can be used for cleaning action in welding of aluminum and magnesium, and background current usually varies around 10 to 25 percent of the peak current in range of 40 to 100 ampere. So, the background current is normally low and it can be in the range of 10 to 25 percent with respect to the peak current, and it will depend upon the thickness of the base metal whereas, peak current is generally set at 150 to 200 percent of the steady state current corresponding to the conventional TIG welding for same base metal and same thickness. So, the peak current will be set about 1.5 to 2 times of the current which is required for the conventional welding, while the background current will be set only about 10 to 55 percent of the peak current and that can be in range of 400 ampere.

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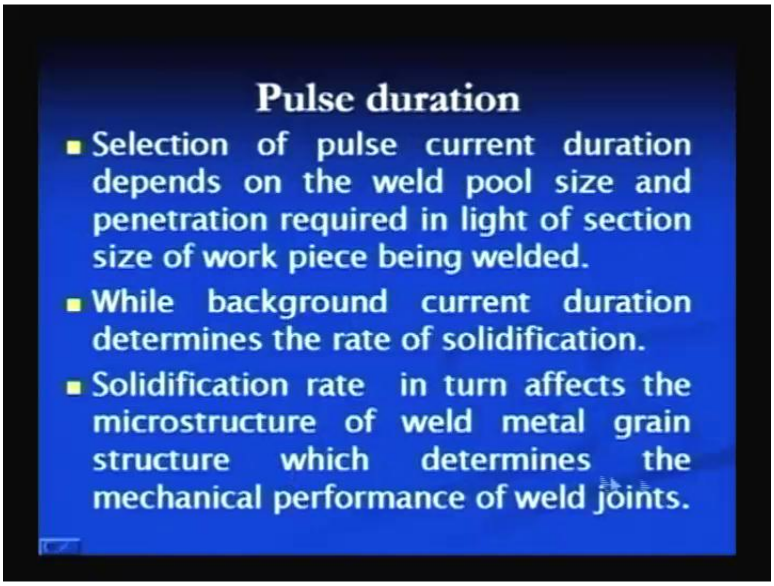

The durations are selected as per the various aspects related to the Weldment which arc produced like selection of the pulse current and duration depends on the weld pool size, and the penetration required in light of the size of section of the work piece. So, if the larger weld pool size is required, then the pulse current duration is increased and if the greater penetration is required, then current value is increased and that greater will be the duration, greater will be the weld pool size and the penetration. So, both of these factors will determine the time for which pulse current is to be maintained, and these factors will be decided by the size of the work piece which is to be welded, while the background current duration determines the rate of solidification.

So, how much control over the properties and grain structure is required, that will affect the background current duration, the small arc, the lower the background current duration, greater slower will be the solidification rate and longer is the background current duration and greater will be the solidification rate, and higher the solidification rate, finer will be the grain structure and accordingly, better will the mechanical properties. The solidification rate in turn affects the microstructure of the weld metal and the grain and its grained structure which determines the mechanical performance of the weld joint.

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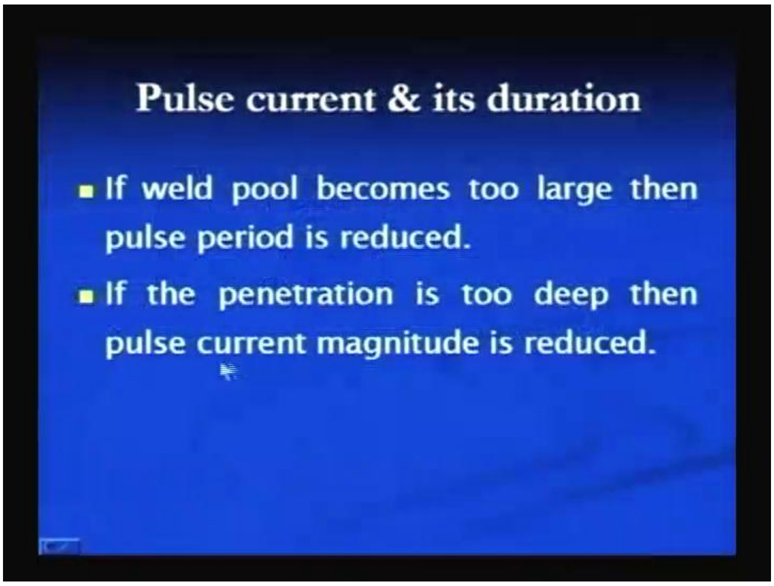

If the weld pool becomes too large, then pulse period is reduced. So, if the weld pool is of the size which is greater than the requirement, then the pulse period is to be reduced and if the penetration is too deep, then pulse current magnitude is reduced.

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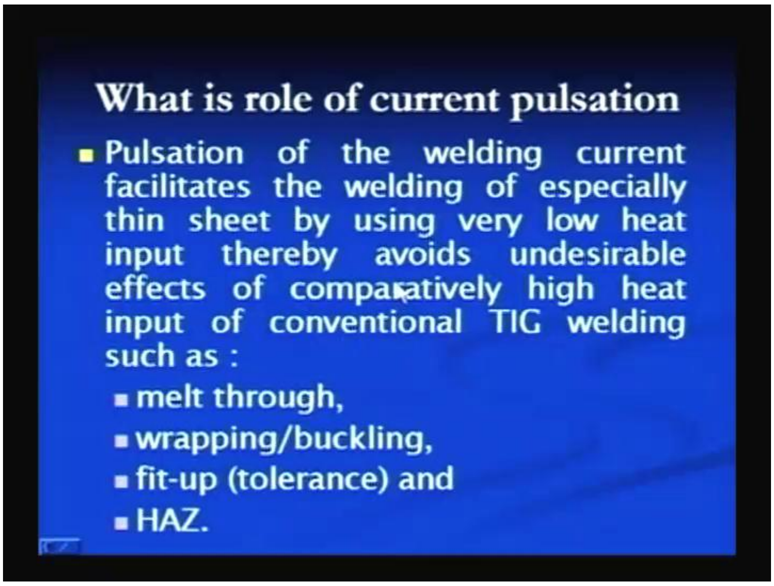

The role of the current pulsation in welding is to be seen that when current is pulsed between the background and the peak current, how it affect the performance of the weld joint. So, for that if we see that pulsation of the welding current facilitates, the welding of especially thin sheets by using very low heat input and thereby avoids undesirable effects of comparatively high heat input of the conventional welding process because in welding of the thin sheets by the conventional welding process, we may have the problems like melt through wrapping and buckling due to the development of residual stresses and fit up problems can be there and the wider heat affected zone. So, if these problems are to be controlled, then arc pulsation have to reduce the welding up of the heat and thereby helps to avoid the undesirable effects related to the high heat input which is observed in conventional welding.

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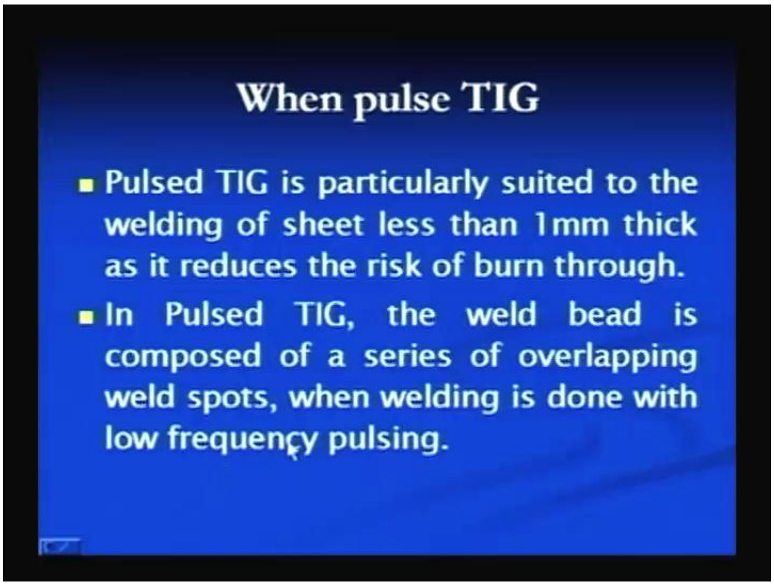

When pulse TIG is to be used, pulse TIG is particularly suited for welding of the sheets which are less than one mm thick because it reduces the risk of burn through arc, the melt through defects. In pulse TIG welding weld bead is composed of a series of overlapping weld spots when welding is done with the low frequency.

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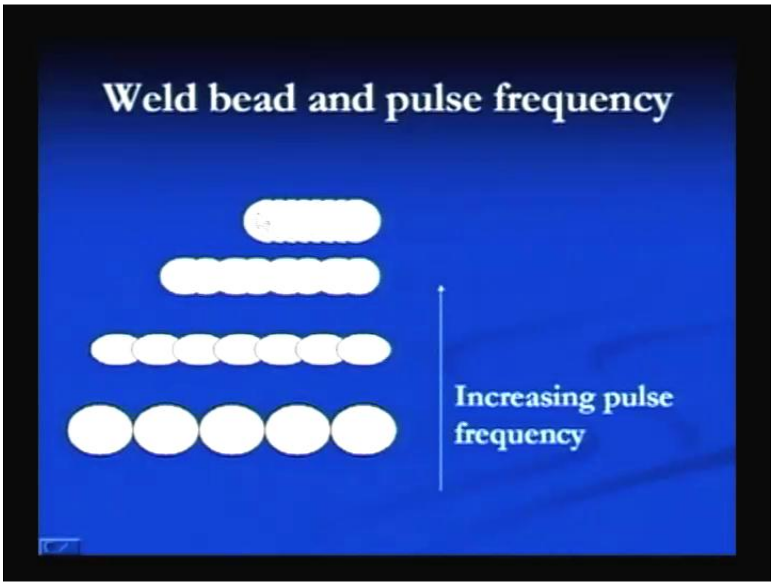

We will see in the next diagram that when the welding is done using the difference pulse frequencies, we get the different kind of spots at very low pulse frequency. The spots are just touching to each other and if we go on increasing the pulse frequency, these will start overlapping each other and normally 50 percent overlapping is used in pulse TIG welding of these spots to produce continuous and sound weld joint.

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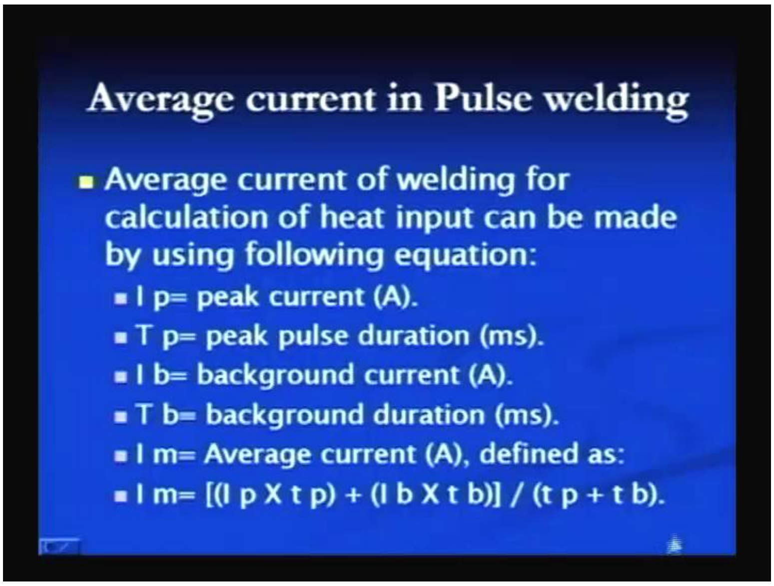

The average current sensor in the plastic welding current fluctuates from the base met between the base metal and the peak base current and the peak current. So, for the purpose of calculation of the heat input, it is necessary to see what will be the representative value of the welding current which can be used for calculation of the heat input. So, the average current in pulse welding is calculated using one equation like average current of the welding for calculation of the heat input can be made by using the following equation.

Ip is the peak current in amperes, Tp is the peak pulse duration in milliseconds and Ib is the background current in amperes. Tb is the background duration, Im average current and it is defined as Im will be equal to Ip into tp plus Ib into tb divided by tp divided plus tb. So, this is how the average peak, the average current in pulse TIG welding can be calculated to determine the amount of heat input using the arc voltage and effect of the pulsing on weldment is significant.

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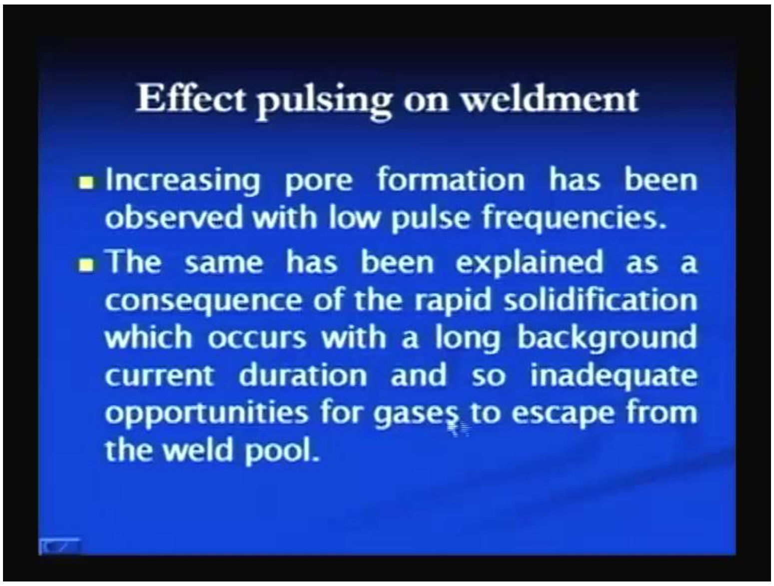

If the pulse parameters are not selected properly, it can lead to some of the problems like the porosity information increases with the low pulse of frequency, and when low pulse frequency is used, then heat input is reduced to such an extent that fluidity reduces and the rate of solidification increases significantly which in turn decreases the time for gases to come out of the weld pool. That leads to form the porosity and this porosity formation has been explained as a consequence of rapid solidification which occurs with the long background current duration and inadequate opportunities for gases to come out of the weld pool.

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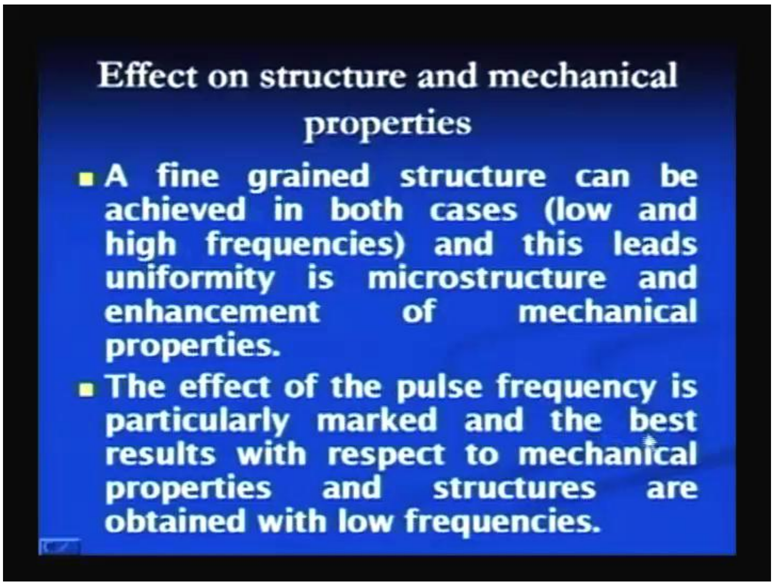

When pulse frequency and the pulse parameters are selected properly, then we get a fine grained structure. In both the cases when low and high pulse frequencies are used, but their structure which is obtained by using the low pulse frequency offers the better mechanical properties. So, effect of pulse frequencies particularly marked and best results are obtained in terms of the mechanical properties in structure with the low pulse frequencies.

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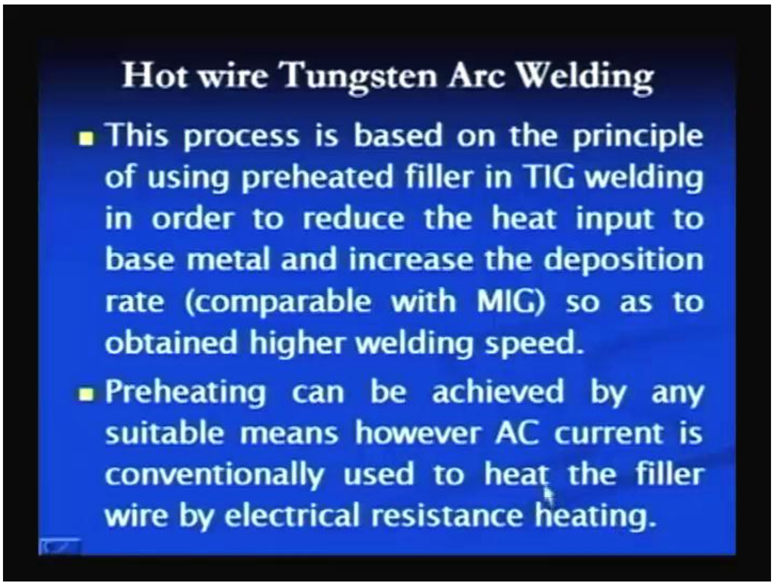

Another variant of tungsten inert gas welding process is the hot wire tungsten arc welding. In this process, this process is based on the principle of heating the hot wire so as to reduce the heat input and increase the deposition rate and very high deposition rates can be obtained by the hot wire tungsten arc welding process. These deposition rates are almost comparable with the metal inert gas welding or gas metal arc welding process. That is why this process is good particularly when high deposition rates arc to be achieved and this heating of the filler wire is carried out by using AC current which is applied using a separate auxiliary source, and heating is done on the basis of arc by using the principle of electrical resistance heating.

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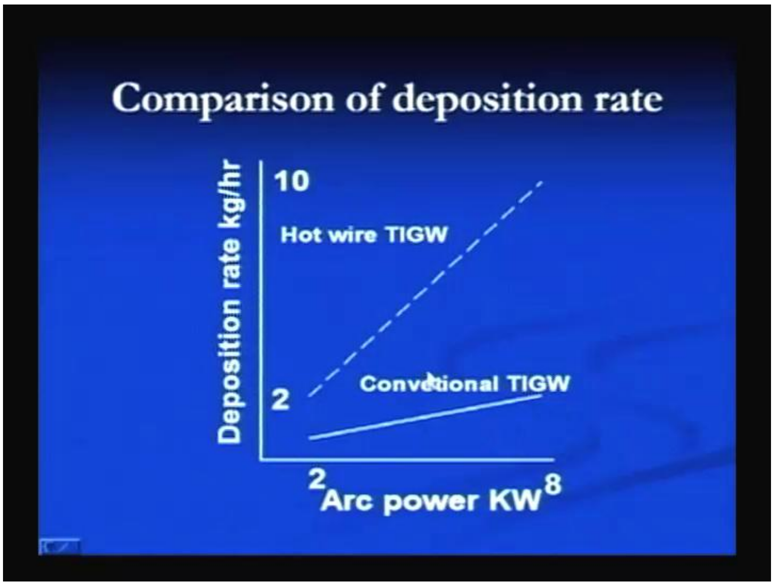

AC current is passed through the filler wire and by electrical resistance heating. It is heated and then, it is fed in the arc region, where it melts and gets deposited in the region where it is required and if we compare the conventional TIG welding process and the hot wire tungsten inert gas welding process, then for the same arc power, we get the significantly different deposition rates say for 2 kilo watt arc power with the conventional arc welding process, we get somewhat somewhere say 1 kg per hour deposition rate, while in case of the hot wire tungsten inert gas welding, it is 2 or 2.5 kg per hour.

If we compare here for 8 kilo watt arc power, the conventional welding is around 3 kg per hour and here if we see, it is about 10 kg per hour. So, the difference in the deposition rates with the hot wire TIG welding process and the conventional TIG welding process are significant, and the deposition rates are almost comparable with the metal inert gas welding process.

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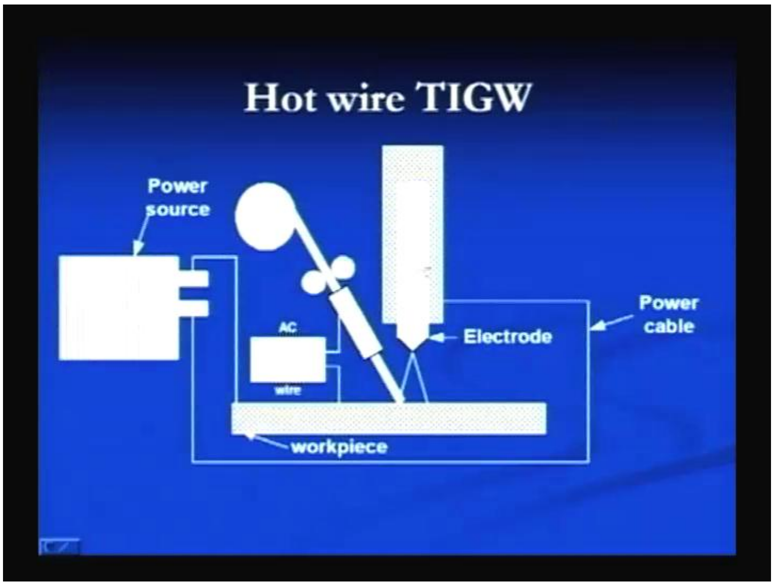

We can see here the schematic diagram of the hot wire tungsten inert gas welding process. This is the auxiliary power source and this is the filler wire which is fed automatically by supplying the AC current. Here this filler wire is heated and the filler wire is fed in the arc region, where melting takes place and this preheated filler wire helps to obtain the high deposition rates.

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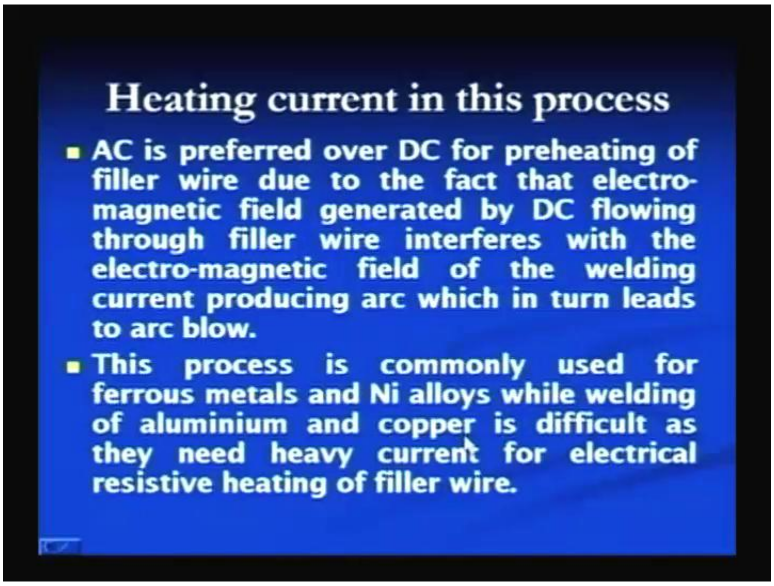

Normally AC is preferred over the DC for the preheating purpose to avoid the problems related to the arc low because there can be interfering effect between the electromagnetic fields which are generated by the arc, and by the flow of the DC current through the filler wire which is to be heated. This process can be commonly used for ferrous metals, but it is difficult to use with the aluminum and copper because preheating becomes difficult of high electrical conductivity metals like aluminum and copper.

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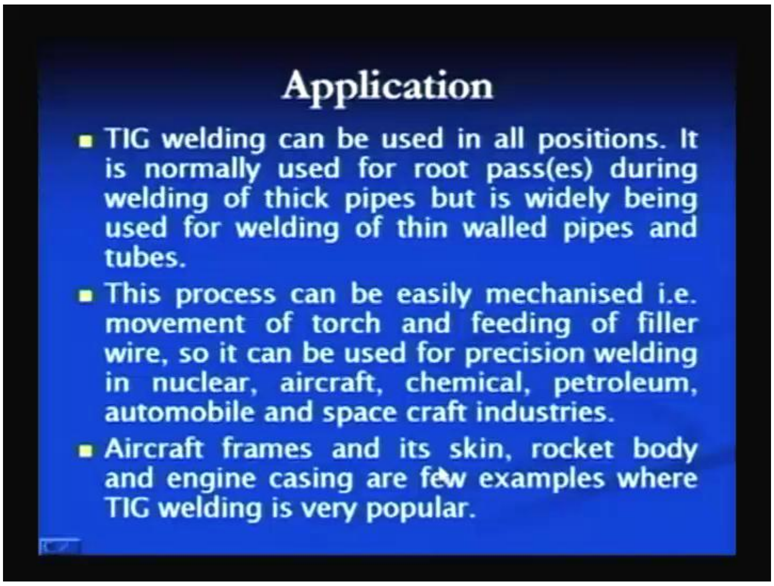

This process is significantly used in variety of applications, and almost all kind of materials in all positions. The welding can be made and normally this process is used in welding of the thin walled pipes and the root pass joining of the thick plates, and these processes can be easily mechanized for the moving of torch and feeding the filler wire, so that the joints can be produced with great precision in the different sectors particularly in aircrafts and the chemical industry, petroleum industry and nuclear industry.

So, here now I will summarize this lecture. We have seen the different components of the tungsten inert gas welding process, and the two variants of the tungsten inert gas welding process, while the pulse TIG welding and the hot wire tungsten inert gas welding process and this process is very versatile, and used for welding of thin sheets particularly and producing the high quality weld joints.

Thank you.