Joining Technologies of Commercial Importance
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Lecture - 10
Gas Tungsten Arc Welding

Hello, I welcome you all in this presentation related with the subject Joining Technologies for metals and in the earlier lectures, I have talked about the fundamentals of the arc welding processes and also other things related with the shielded metal arc welding.

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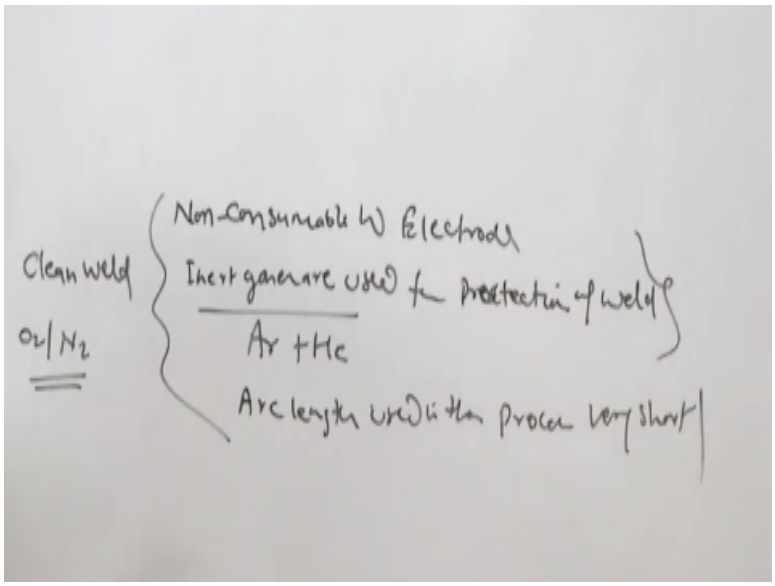

In this presentation, I will talk about the gas Tungsten arc welding process. This process is also known as Tungsten Inert gas welding process. So in abbreviation form it is written as GTAW and TIGW. So there are few unique things related with this process that it uses non-consumable Tungsten electrode, this is one and invariably only inert gases are used for protection of the weld pool. So these are the two very unique things.

Since the process does not use any consumable electrode and only inert gases are used for protection purpose. The commonly used inert gases are argon and helium. Along with this another unique thing is arc length used in this process is very short. So combination of these three things results in very clean weld, where in oxygen and nitrogen content in the weld is very less.

And that is why the cleanest weld among the all arc weld process is produced by the gas Tungsten arc welding process.

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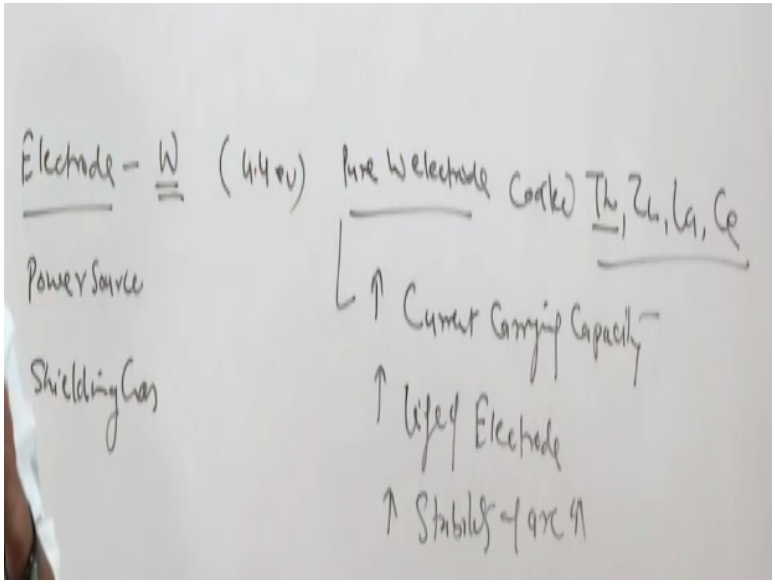

Process vice, they are few components in this process, important things like, the TIG process has unique features like electrode, power source, shielding gas and as far as electrode is concerned, now the Tungsten electrode is used. Tungsten has ionization potential of about 4.4 electron volts. So it is also very good electron metre, but when the high current is supplied during the welding.

It gets the heated and the life is adversely affected because of the heating and the erosion during the operation. So frequently the pure Tungsten electrodes are coated with low ionization potential elements like thorium, zirconium, lanthanum and cerium. These have significantly lower ionization potential, application of these elements in coating, helps in increasing current carrying capacity of the electrode, means electrode of the given diameter say 1.5 m size.

How much current it can carry? Say in case of the pure Tungsten if it can carry 15- ampere, then after coating this capacity to handle the current increases, it may handle 220-250 ampere. This ability to handle the current without compromising with the life of the electrode improves when these are coated with the low ionization potential elements. And in term the life of the electrode used improves, and further the stability of the welding arc also increases.

Because these low ionization potential element provide the electrons very easily under the identical conditions and therefore the stability of the arc improves due to the improved charged column density in the gap between the electrode and the work piece.

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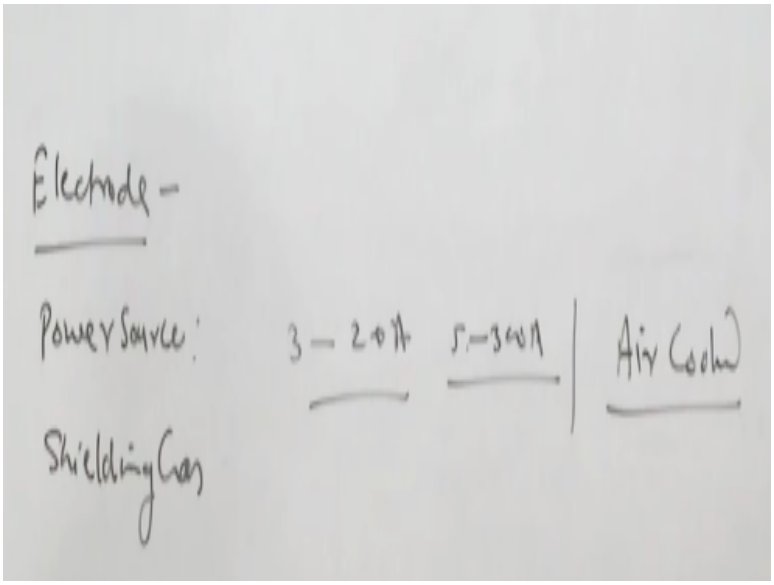

As far as the power source is concerned the power source invariably, the constant current sources is invariably used. And for this purpose, as far as the type of current is concerned, it can work with both DC and AC. AC is normally used when welding the non-ferrous metals to take the advantage of the cleaning action, which is offered by the mobile cathode spots at the same time reasonably good life of the electrode.

While in case of the DC, EN is the normally the polarity, which is used during the welding in case of the TIG process. If we use the DCRP or reverse polarity or electrode positive polarity, then in that case excessive heat generation in the electrode side can adversely affect the life of the electrode, and therefore it will require much frequent replacements of the electrode or re-sharpening of the electrodes.

If you see the electrodes which are normally used, their size can vary from 0.3 mm in diameter to 0.8 mm in diameter and length can vary from 75 mm to 600 mm. So actually these electrodes are used in this form where as soon as they get degraded or they get damaged, they are sharpened to have the desired angle, included angle at the tip. So preparation of the Tungsten electrode is frequently needed when they lose their shape in order to have proper shape of the electrode.

The power source, as I have said, it is constant current type of power source is invariably used with the AC or DC type of the currents. As per the capacity, the GTW process power sources can have range say of 3 to 200 ampere or 5 to 300 ampere current rating. It is about the maximum current, which can be drawn from the power sources.

So, normally the low capacity power sources are air cooled means the welding torch as the air cooled while the high capacity torches, which will be handling much higher value of current and during the welding they get heated excessively and to maintain the temperature of the electrode, therefore cooling of the torch is applied.

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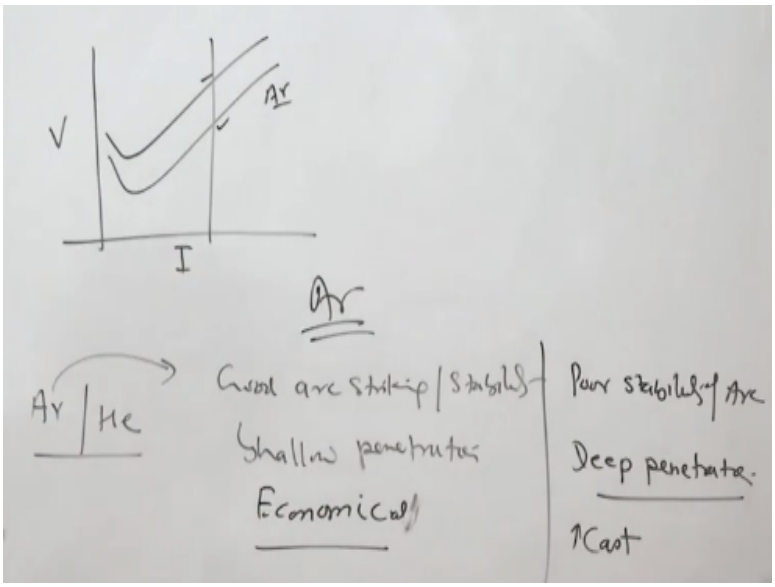

So sometimes water cooled torches are used as far as this GTW process is concerned. So the torch is another member and they are also categorised based on the kind of current that they can handle as I said, 3 to 200 ampere or 5 to 300 ampere, or much higher, so high capacity current capacity torches are water cooled. So another thing is about the shielding gas. Shielding gases are commonly used are argon and the helium.

We know that argon the low ionization potential as compared to the helium, helium offers much higher ionization potential. So whenever we work with the argon, because of the low ionization potential it offers very good arc striking or arc stability. So arc strike or arc stability becomes very good means arc initiation and arc stability becomes very good, when it is used as compared to the helium, it offers somewhat shallow penetration.

So it is good for the welding of somewhat less thickness plate as compared to the helium and in addition to this, what you will see, that the cost of the argon is much lower as compared to the helium. So it is very economical as compared to the helium. On the other hand, so all these factors are for the argon, low ionization potential offers very good arc stability and arc initiation, shallow penetration and economical because of the lower cost of the argon.

On the other hand, higher ionization potential results in somewhat poor stability of arc, this is one and very deep penetration is offered or produced when helium is used. So the logic behind this is that the arc characteristic is affected when the helium is used, which means like here we have the voltage and here we have current. So when helium is used, if this is the characteristics for argon, so use of the helium changes the arc characteristic means under the identical conditions the arc voltage improves.

So for the same current we work with the higher arc voltages. So it generates excessive heat, more heat generation when the helium is used resulting in the higher temperature of the welding arc which in turn increases the depth of the penetration during the welding. But the cost of the helium is much higher as compared to that of the argon. So our economy gets disturbed because of this helium application.

Other shielding gases are very rarely used like carbon-di-oxide is not used which, because it will decompose in the arc environment provide the oxygen. The oxygen will contaminate the Tungsten so it is not good to use other inactive gases like CO2.

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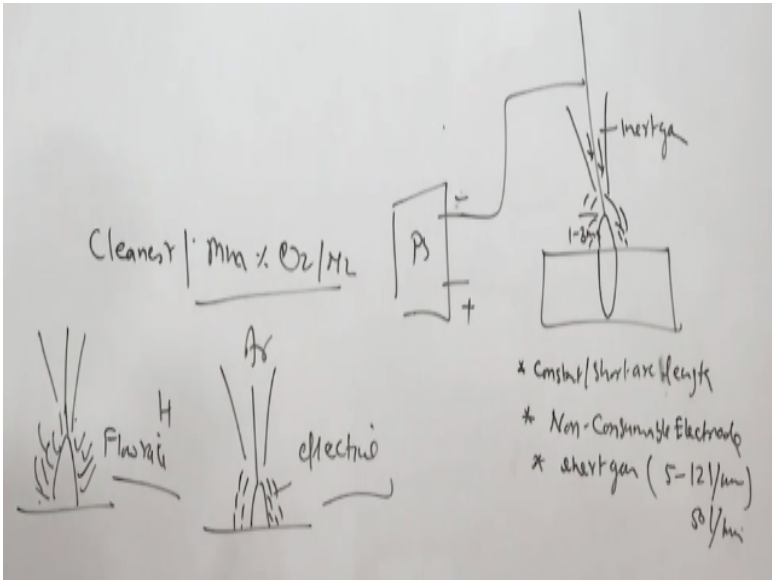

So now I will talk about the reason behind why it offers the cleanest weld means with the minimum percentage of the oxygen and nitrogen in the weld. So here, the schematic of the system with like this, we have power source positive and negative terminals. So negative terminal is connected to the electrode, say this is electrode, Tungsten electrode and here is the work piece.

So here we have torch having the nozzle and through this our inert gases will be coming out. So here this gap is generally 1-3 mm in case of the GTW, means arc length is 1-3 mm. And the electrode is moved consistently over the surface of the work piece. Since the electrode is non-consumable, arc length is very short and it is well protected by the inert gases all around. So the possibility for entry of the gases from the atmosphere into the weld pool is very limited and that is why it offers the clean weld.

So the constant and short arc length is one reason behind reduced possibility for entry of the gases into the weld pool, another is non-consumable electrode. In other processes, electrode also contributes in entry of the impurities into the weld pool, because electrode tip melts and gets transferred into the weld pool, but here it is non-consumable. So there is nothing like, which will get transferred into the weld pool as far as the impurities like gases are concerned.

So non-consumable electrode is another reason behind its limited, means very less percentage of, presence of very less gases in the weld metal. And another is it mostly relies only on the inert gases. Inert gas flow rate normally it may vary 5-12 litre per minute. This is the common use, but it may go as high as 50 litre per minute. So helium, the flow rate of the helium is much higher may be 2-3 fold of the argon.

Because helium is lighter just after coming out of the nozzle, it starts to moving up. So if this is the nozzle, this is electrode, when we supply argon, argon being heavier than the air, it starts to settle down all around the weld pool and the welding arc, so provides effective protection, while in case of the helium, helium being lighter than the air, so as soon as it comes out of the nozzle, it starts to move up.

So in order to have moving up means, it will not be protecting the weld pool and the arc effectively, because immediately after coming out it starts moving up, since it is lighter than the atmospheric air. And because of this, the flow rate requirement for the helium is much

higher than the argon. And however once if the flow rate is sufficient for given set of the conditions like arc length, the speed of the welding.

Then we will see that the protection provided by the helium is quite good. Only thing is that the cost of the helium is high, the stability offered by the helium for the arc is poor, because of the low ionization, because of the high ionization potential as compared to the argon.

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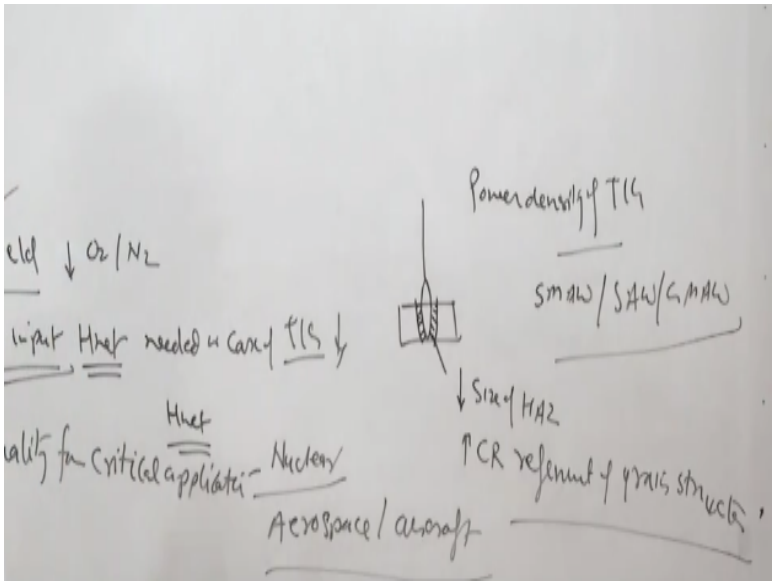

And because of these reasons in addition to the effective, in addition to the capability to produce clean weld, in terms of the low concentration of the oxygen and nitrogen, the TIG offers another unique feature or ability among the arc welding process, that is capability to melt with very low heat input. So the net heat input, which is needed in case of the TIG process. This is very less as compared to the other process.

The reason for this is simple; the electrode arc length is very short, the diameter of the electrode is very small and the area over which heat delivered by the welding arc is very short, and power density of the TIG is much higher than the SMAW shielded metal arc welding SAW, GMAW. So, as compared to these three processes, commonly used arc welding processes TIG offers the higher power density.

So the amount of heat required for fusion of the given thickness of the plate is less. So the heat input required by the TIG process is less. So Hnet is less due to the higher power density as compared to the other arc welding process. If the Hnet is less so it facilitates the melting even with the lesser heat input.

And this goes in the favour, that when heat input is less, the heat affected zone being formed on both the sides of the weld joint is limited and the high cooling rate conditions resulting in the final grain structure in the weld. So these two combinations like reduced size of the heat affected zone and to increased cooling rate leading to the refinement of the grain structure in the weld. These two features result in the much improved quality of the weld joint.

So here lesser heat input and the cleaner weld, these are the 2 very positive sides related with the TIG process and that is why this process is mainly used for producing the quality weld joints for critical applications, which includes the development of the joints for nuclear applications and aero space and air craft components.

Because the quality of the joint is much better due to these two reasons the cleaner weld, reduced heat input helps in improving the size of heat affected zone final grain structure and so the much better quality of the weld joint is formed. This is truly irrespective of the metal system whether it is aluminium or the ferrous metal systems and that is why for all critical applications TIG welding is invariably preferred over the other arc welding processes like submersed or shielded metal arc or gas metal arc.

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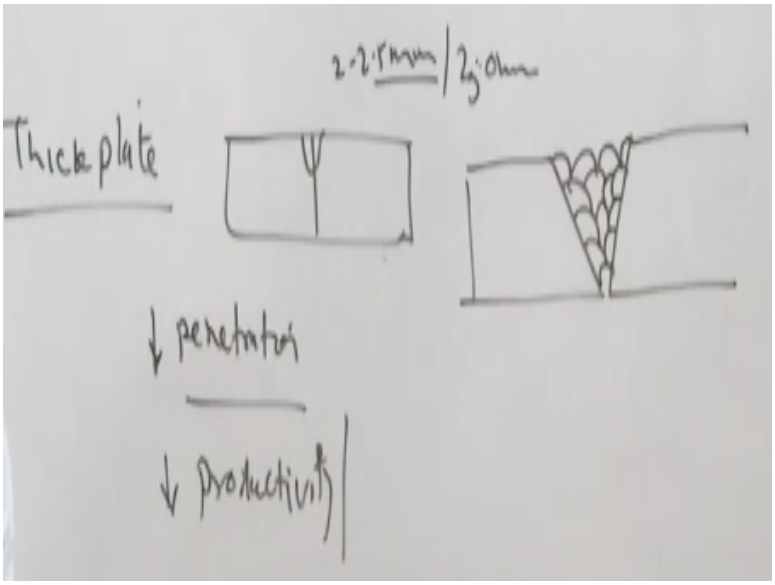

But the gas Tungsten arc welding process suffers with the one major limitation and that is, since the process, here like in case of the welding of the thick plates it offers the two kinds of the problems, one is normal GTW process offers the maximum penetration around 2-2.5 mm or in very severe condition very high heated condition may be 3 mm in single pass. So GTW

single pass is not tried with the thicker plates, except some modifications in the process are made.

So the limited penetration is one less penetration available with the GTW process is one major limitation and when we are working with a thicker plates, then it requires very large number of the passes for completing the weld joint. These may be high like 10 pass, 12 pass, 20 passes depending upon the number of, depending over the size of the groove, type of the groove, which has been made.

So increased number of the passes requirement again lowers the productivity of the process, so the process becomes slow.

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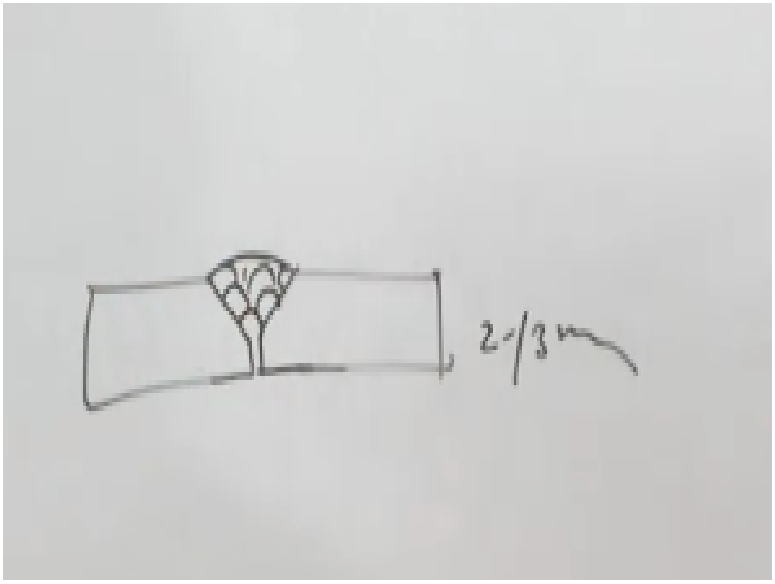

So in this case what we need, the process may work in case of thin plates, the process may work without any filler like thin sheets can directly be joined using the autogenous approach like plate of the 3 mm thickness, these are the two plates. It can by application of the TIG arc we can directly fuse them together and after the solidification will be getting the weld joint.

But if the plates have to be welded then we need to prepare a proper groove, and in that case the groove will go in like this and in that case we have to apply filler. So the process may work with filler or without filler. If thin sheets have to be welded, then no filler of course is needed and autogeneous weld will be made. But if the large size grooves are to be filled, then filler is to be applied.

So the filler metal is applied separately or externally during the process which further complicates the application of the process, but for the want of the quality for the requirement of the quality in any case people look for the gas Tungsten arc welding process. Now we will talk about another variant, which has been developed for more of the industrial application that is the gas metal arc welding process.

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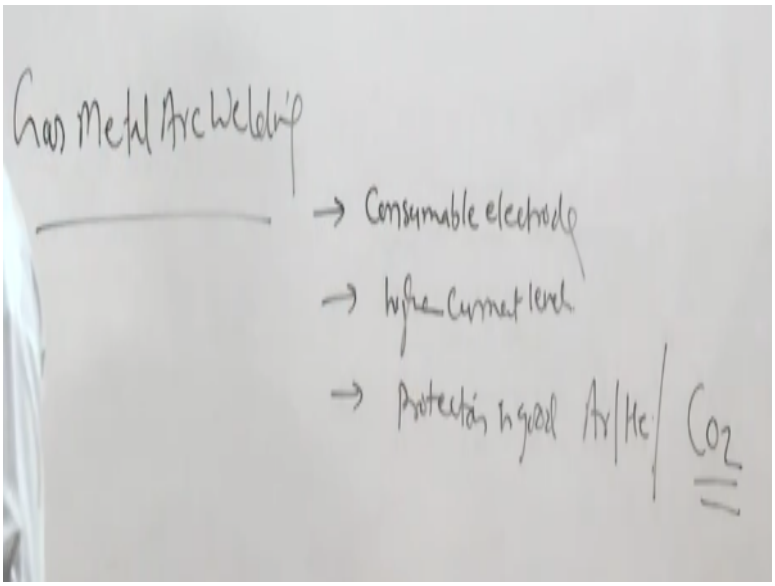

Gas metal arc welding process was, it takes care of most of the negative aspects related with the gas Tungsten arc welding, how? Because this process uses consumable electrode and it works with much higher current levels, 2 and 3, the protection is also reasonably protection is good, because it mostly uses the helium or argon as the shielding gases.

But for the less critical applications, maybe it can work with something like CO2 or the mixture of other gases like argon modified with oxygen or argon with carbon-di-oxide or helium and argon mixtures, the various combinations of the other gases also used. But since this process is different from the gas Tungsten arc welding process in the sense that it uses consumable electrode and because of this and it uses the gases like argon, helium or argon with oxygen or argon with hydrogen or helium argon mixture or CO2 with argon.

So various gases are used, but this not only limited with inert gases, even inactive gases are also used in case of the gas metal arc welding process.

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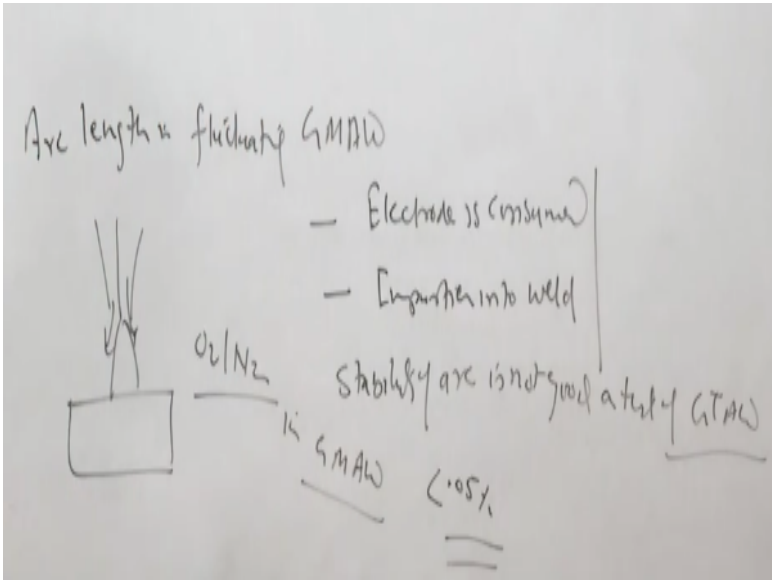

So the two things one arc length is fluctuating in case of the gas metal arc welding, why? because the electrode is consumed, this is one, and another one the electrode itself when melts and the molten metal is transferred into the pool, it transfers some of the impurities into the weld. And when the gap is fluctuating, the stability of arc is not good as that of the GTAW, wherein we were using the non-consumable electrode short-arc length inert gases.

So now we can see here, if the arc length is fluctuating this is the nozzle, inert gases are coming out and if the arc length is fluctuating, then the protection being provided by the shielding gases will not be that effective and because of this, the oxygen and nitrogen concentration in GMAW weld is somewhat greater than what is offered by the GTAW process.

So still this is clean or cleaner than like say, it is still less than 0.05% of the oxygen and 0.03 or 2% of the nitrogen. So it is still cleaner weld but not as clean as that is produced by the GTAW process, so because of the, still the quality of the weld in terms of the oxygen and nitrogen content in the weld is quite good. The process is very commercially used, very much commercially used reason being that the process uses the consumable electrode.

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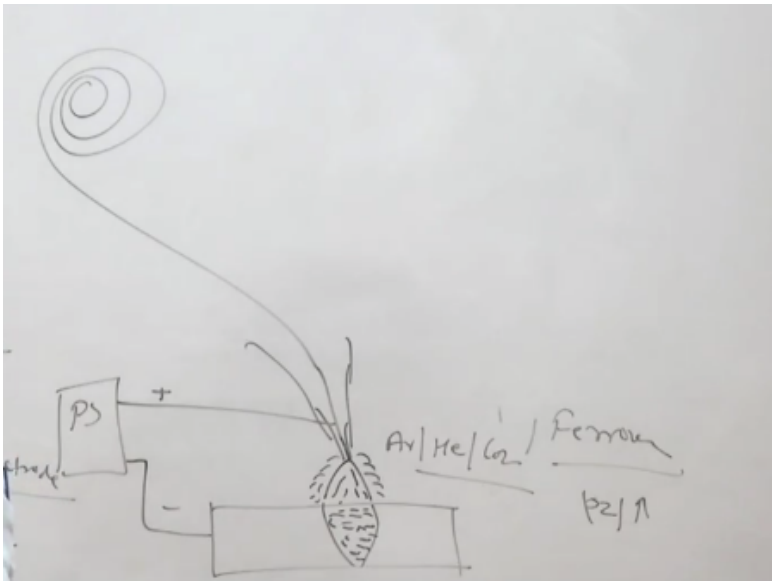

So here you see, the electrode wrapped in its pool feds through the cables to the nozzle and then through the nozzle, it comes out the shielding gases will also be coming out. And here the electrode develops the arc between the work piece mostly in this case, the power source connected to the positive terminal of the power source is connected to the electrode and negative is connected to the work piece.

And the arc is established between the electrode and the work piece so basically heat of arc melts both electrode as well as base. So the combination of both these two will be resulting in filling in of the groove much faster and while providing the protection with the help of all suitable shielding gases like argon, helium or carbon-di-oxide, CO2 is mainly used with the ferrous metals only not with the others.

Because it also provides effective cleaning, however, whenever CO2 is used oxygen concentration in the weld is somewhat more as compared to the case when helium and argon is used for development of the weld joint. So this is process effectively counters the negative side of the GTAW process by using the consumable electrode. And whenever the consumable electrode is used the productivity of the process is very good.

Productivity of the let us say GMAW process is much better as compared to what we have seen in case of the GTAW process and also very clean weld is made and because of these two effective reasons the process is very successfully used in the industry for making the weld joints for all critical and the semi-critical applications. So here this was the background of

GMAW process and how it is different from the gas Tungsten arc welding process and why it is used in the industry.

So here now I will conclude this presentation. Basically I have talked about the fundamentals of the gas Tungsten arc welding process, importance of the various components and why this process is good or what kind of the positive is related with the process and the negatives relate with the process are. So in addition to that, how the gas metal arc welding process helps in overcoming the negatives of the gas Tungsten arc welding process. Thank you for your attention.