Joining Technologies of Commercial Importance
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Lecture - 11
Newer variants of Gas Tungsten Arc Welding

Hello, I welcome you all in this thirteenth presentation on the subject joining technologies for the metals and this presentation will be based on the newer variant of the gas tungsten arc welding process. In the last lectures related with the gas tungsten arc welding process, I have talked that this process is very clean and it is mainly used for producing the critical wield joints.

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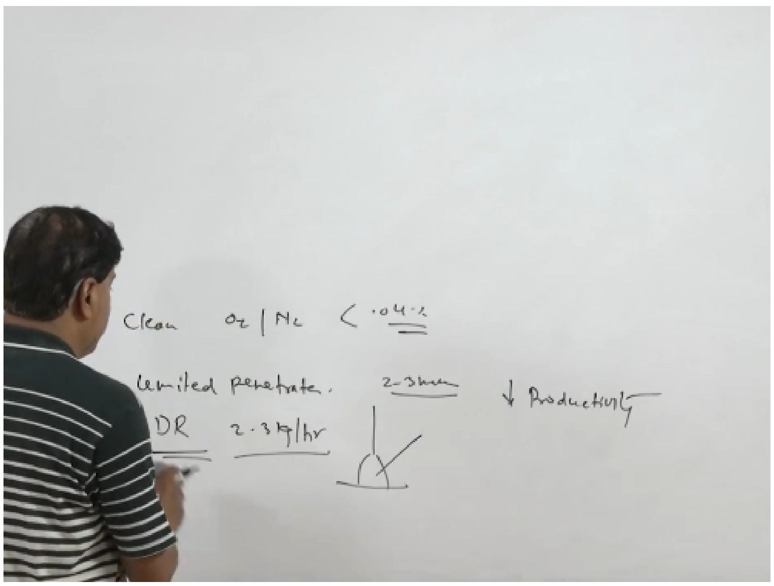

The clean process is because the oxygen and nitrogen content in the wield are much lower then what is generally obtained in case of the other arc welding processes. But this process because of this cleanliness it offers very good quality wield joints but this process suffers with the two aspects one is the limited penetration which is say it is just 2 mm to 3 mm depending upon the wielding condition.

So, in one go we can wield just the plates of 2 mm to 3 mm or if the thicker plates are to wielded then we require large number of the passes. So, in that case if the large number of the passes are required then the productivity gets reduced or productivity is adversely affected. Another thing is that whatever deposition rates, the process is none consumable time type so if the arc is established between the tungsten, electrode and work piece.

We have to feed the electrode externally. So, feeding of the electrode externally lowers the deposition rate, actually the heat input with the process is very low so the melting rate of the electrode which is offered by this process is also not that very high. So, the melting of the filler is also not very high and because of this we will see that the deposition rate is very limited like 2 to 3 kg per hour. So, such a low deposition rate adversely effects the productivity.

Further it requires large number of the passes. So, limited penetration is one aspect and the low deposition rate, reduced deposition rate is another you can say the negative side related with the process because of which it takes very long to complete the wield joints specially in case of thick wields. So, various efforts have been made to modify the gas tungsten or conventional gas tungsten arc wielding process in order to overcome these points related with this process.

So, I will talk about the three variants which are there of this process.

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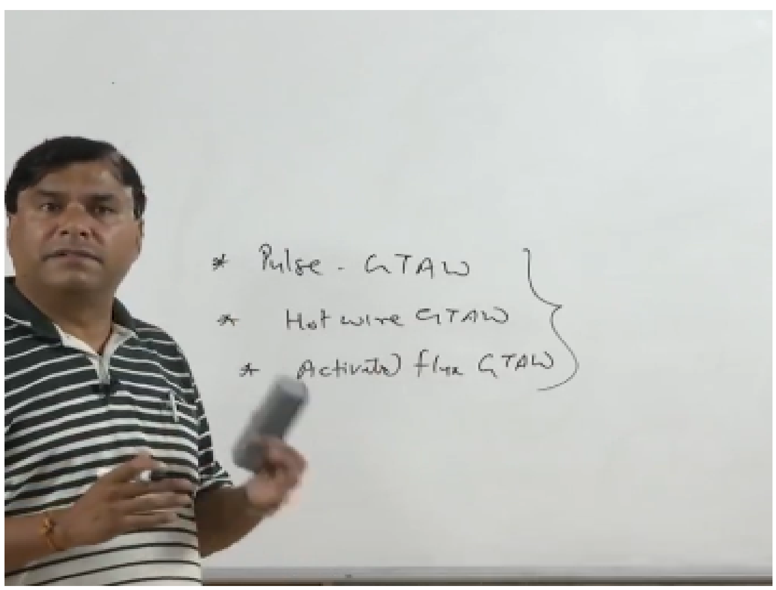

One is pulse GTAW another is hot wire GTAW and third is activated flux GTAW. So, I will talk about the basic principle of these three process and we will try to see how do these work in reducing the negative side of the conventional arc wielding process. So, first of all I will start with the pulse GTAW process.

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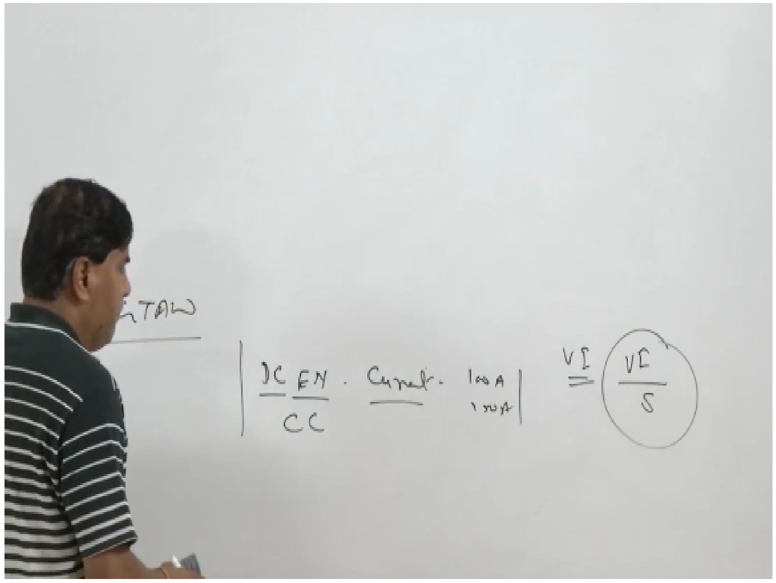

Pulse GTAW process means in the conventional GTAW we supply the DC usually it is DC EN and the current whatever is selected and it is a constant current type of the power source. Whatever current is selected it is mostly constant say 100 ampere or 150 ampere. So, this value is constant and in this case it is easier to calculate the heat input from the VI, like not heat input arc power and then VI by S can be used for determining the net heat input.

But in this case as you have seen that the melting sorry the penetration depth is limited and the melting rate is low. So, efforts have been made to increase the penetration while maintain the low heat input positive sides of the conventional GTAW.

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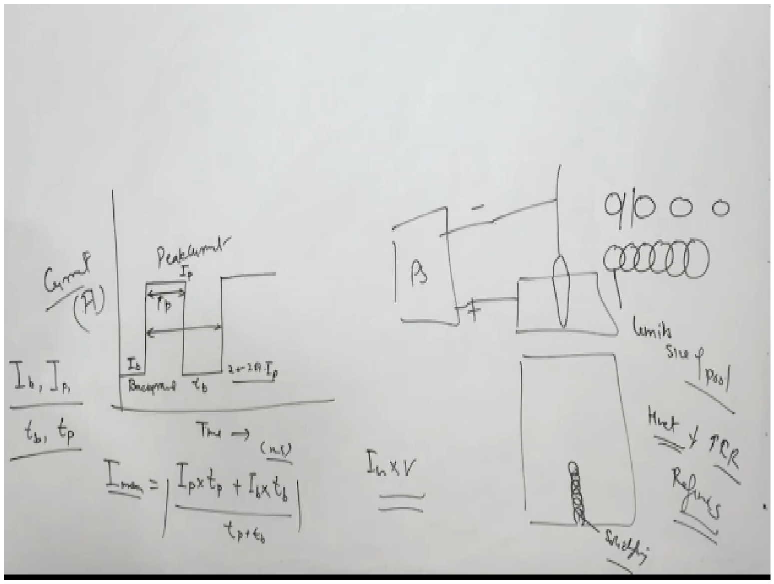

So, what has been tried like let us vary the current instead of keeping it constant the current is varied. So, here like say the x-axis on the time scale like say mm seconds and here the current value. So, the current in ampere so the current is fluctuated between the two levels during the process. So, here the power source connected say negative terminal and positive terminal. Positive terminal is connected to the work piece and negative terminal is connected to the electrode and here is an arc.

Say this in top few the plate is here and this is the arc location. So, the current value is fluctuated between the two levels like say this is back ground current level and then it is moved up. It is increased to the high level. This increase in level the higher level of the current is called peak current and then again it is brought to the lower level. So, the current is basically pulsated between or changed between the low level and the high level.

So, low level of the current that is called Ib and high level current is called Ip that is the Peak current and the corresponding durations are also called sorry Tp for the duration for which the Peak current exist and the background current the duration for which the background current exist is defined as Tb. So, the cycle is a combination of, one cycle is a combination of the Tp plus Tb.

So, background current is Ib, peak current is Ip and backgrounded pulse period is at Tb and peak current pulse period is Tp. So, since the current is fluctuating between the background and the peak current level so to determine the heat being delivered or the power of arc. We need to find out the mean value of the current.

So, I mean is determined and for that purpose one simple equation is used the value of the peak current multiplied by the duration for which peak current exists plus value of the background current multiplied by the duration for which background current exist divided by the cycle time that is the peak current plus background current. So, this is how the I mean is determined and once the I mean is available it is multiplied with the arc voltage to determine the power of the arc.

Advantage of this is what? Whenever there is a peak current the fusion will take place. So the spot mean the arc will deliver lot of heat fusion will take place through the thickness of the plate then during the background current period heat generation is very negligible because the current value for the big background current is just like say 20 to 25% of the peak current. So, it is very limited and as compared to the conventional welding the current is 150 to 200 times of the normal DC conventional to current value.

So, here the peak current value is kept on the higher side and background current value is kept on the very lower side and so when the background current is present we will see that the heat delivery is very limited. So this weld pool which was formed it will solidify and it will melt through the thickness and it will solidify then another pulse will come it will melt another location.

So, this is how the different pulse has come and they will be melting through the thickness to the plate. It has two effects one if the frequency of the pulse is very less means the frequency of the peak, pulse frequency means the peak current pulse come after long time then we will see that when the arc is moving the gap may be very wide and it may result unmelted zones between the different pulse.

So, this one is to be synchronized well with the welding speed as well as the frequency at which pulse are given so that they overlap enough in order to produce to thickness melting and the continuous weld is made. Advantage is this what? It limits the size of pool. So the maximum grain size is limited to the size of the pool one and this combination as a whole for melting of a given thickness of plate heat input is reduced.

So, whenever pulsing is used pulse GTAW is used it melts the greater, it penetrates deeply but using the lower amount of the heat. So, actually the Hnet associated with the process is less and lower heat input increases the cooling rate, an increased cooling rate actually refines the grain structure. So, there are two things. One limiting the size of the pool and another is the refining the grain structure.

So, both these aspect helps in improving the properties which are obtained by the pulse GTAW process. So, advantage side if we see the pulse GTAW it is able to melt the thicker plates even with the lesser heat input and reduced heat input offers the advantage of the reduced grain size, reduced size of the HAZ, the refinement of the grain structure is one advantage.

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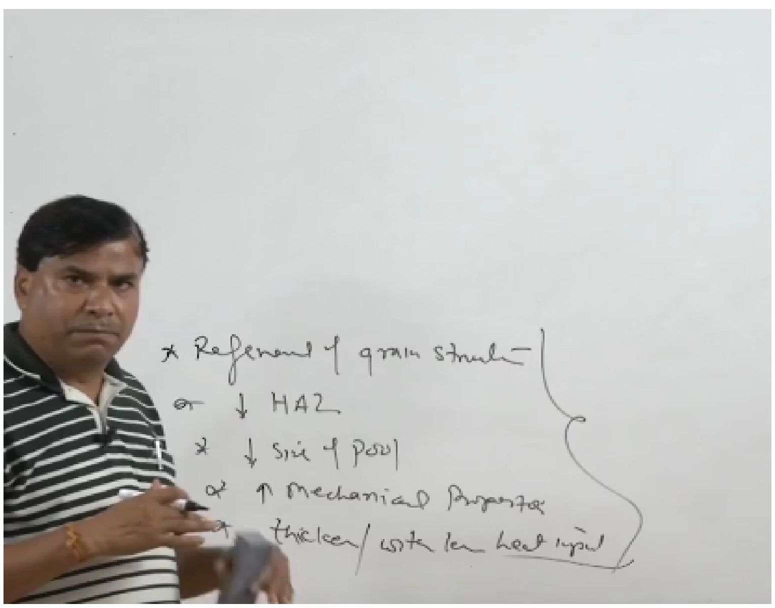

The second is reduced HAZ width and reduced size of the pool and improved mechanical properties. So, these are positives of using the pulse GTAW at the same time we are able to melt thicker plates. I mean the penetration is improved even with less heat input. So, these are the positives of the pulse GTAW. So, all the metal systems which are very sensitive to the heat input they are welded using the pulse GTAW pulsed like harden steel precipitation, harden aluminium alloys.

So, whatever the metal systems they are whose performance is adversely effected with the heat delivery specially to the heat effected zone. So, it is always good to weld them using the pulsed GTAW process. Another variant is the hot wire GTAW.

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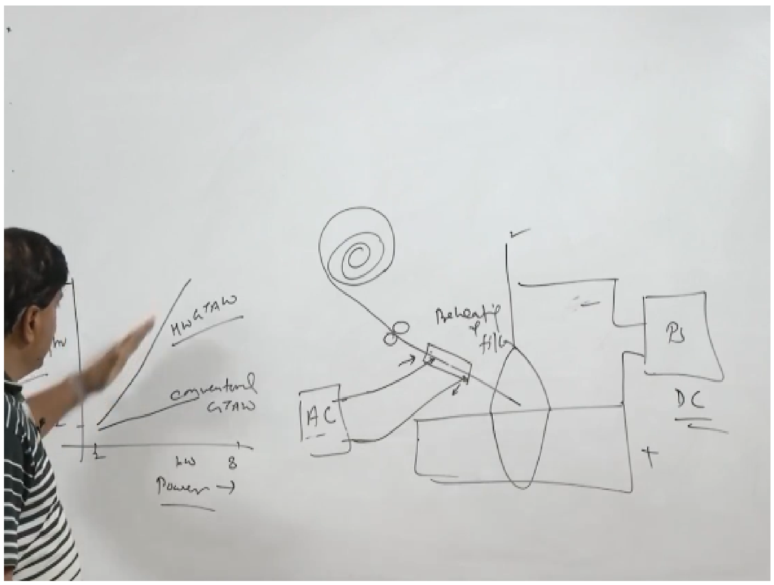

In the hot wire GTAW this variant has been brought in specially for the conditions when we are working with the thick plates. So very thick plate welding requires the filler and since the filler melting is rate is less in case of the conventional GTAW process because it requires lot of heat for melting the fillers. So large size of the wield which is made in one pass is very limited so it may require very large number of passes like 10, 20, 30 depending upon the size of the weld to be made.

So, conventionally the melting rate, the deposition rate with the conventional GTAW process is very limited which is about say 2 kg to 3 kg per hour. So, this actually reduces the productivity or it requires longer time for completion of the weld joint specially the thick weld joints and therefor to overcome this disadvantage the special variant of the GTAW process has been developed where in like say this is the work piece.

Here we have electrode and this is the arc. So, one automatic like say this is the spool and here the electrode is being feed but before feeding the electrode directly into through some filler feeding device or electrode feeding device not electrode it is electrode is here but filler feeding device. This filler is feed into the arc zone so that it melts and forms the parts of the weld. So if it is feed directly like this our deposition rate is less.

Because the amount of heat being generated is limited and the heat required for melting of the filler metal is also. So this in-turn reduces the deposition rate or the melting amount of the metal which can be melted, amount of filler which can be melted by this process. So what is done basically using this is say connected to the conventional power source negative terminal to the electrode and positive terminal to the work piece say in this case then we use another heat source another power source which is normally AC.

So, AC it is one terminal is connected to the work piece and another terminal here is connected to the –not to the work. It is connected to this end and here there is another end which is connected to the wire which is being feed. So, it is like this. This is the kind of chamber where from the one side the current the feed and another side it is taken out so one like say AC this is how the circuit is completed.

So, in this zone basically the preheating of the filler takes place. So, preheating of the filler will increase the temperature of the filler before getting into the arc zone. So, this process actually reduces the amount of heat it requires during the melting so for the preheating purpose AC is used so that whenever there is a current flow through arc, current flow through the filler it does not interfere with the arc or the welding current which is generally DC in case of the gas tungsten arc welding process.

So, if DC is used for the heating purpose of the filler wire through the I square r heating then it may interfere with the welding arc and it may lead to the arc blow kind of situation. To avoid that kind of possibility the preheating of the filler wire by I square r heating is achieved by supplying the AC current so that the filler wire is preheated and this preheated filler wire whenever reaches in the arc zone it melts at a faster rate.

So, the deposition rate which is achieved after preheating of the wire or the filler wire which becomes much higher as compared to the case of the conventional GTAW and to see the comparison of this process we will see that here if here we have the power which is being used, power of the arc say it is 2 kilowatts and here say 8 kilowatts then it may result in like 2 to 3 kg and here it may 8 to 10 kg per hour.

So, here we have in y axis deposition rate and in the x-axis the power of the GTAW arc. So, if the power of GTAW arc is increased melting rate increases marginally while in case of the hot wire GTAW process and this one is for the conventional GTAW process. So, there is a significant increase in the melting rate which is 8 to 10 kg per hour like say with the increase in the power of arc.

So, simply that increasing the power of arc increases the deposition rate in case of hot wire GTAW process at very high rate as compared to the conventional GTAW process. So, this is how this process helps to overcome the low deposition rate related issue of the conventional GTAW process. This is particular useful when working with the thick plates and the quality wields are required.

So, the use of GTAW will help in improving, help in developing the quality weld joints while achieving the high deposition rate.

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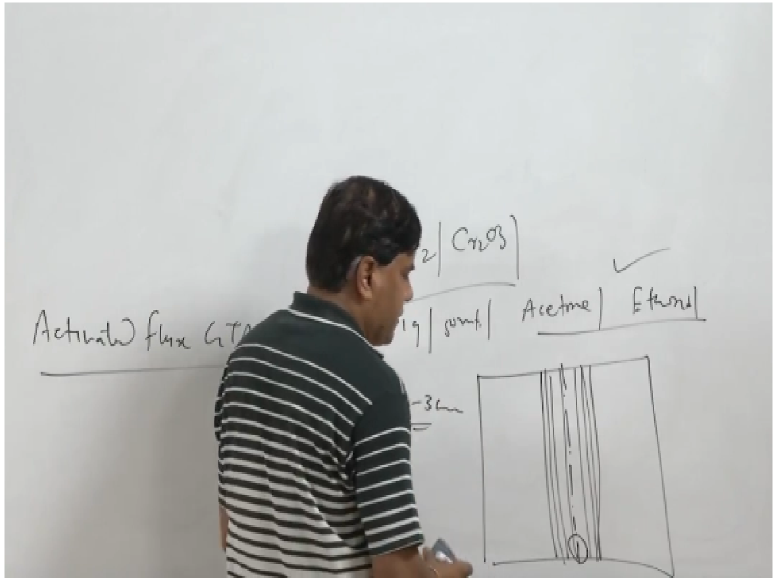

Another newer variant of the GTAW process is use of the activated flux GTAW. Activated flux GTAW process is unique in the sense using the conventional heat input like say 1 2 3 KJ per mm. The process can melt the thick plates as high as 15 mm in one go. So, in this process what is done the conventionally this process can melt say up to 2 mm to 3 mm or maximum 4 mm thick plates in one go.

The same now like say this is say this is 3 mm thick plate may be able to melt through thickness like this wider wide width and the somewhat lesser depth of the penetration. But when the process is modified differently then what we will see that the situation is just reversed where in like say this is the top few and here this is the line of, this is the width and the center line of the weld.

So, what we do in this process one layer of the activated flux like various activating fluxes like TiO2, SiO2, Cr2O3, molybdenum oxide, etcetera. These fluxes are normally like say one gram in 50 ml either acetone is used or ethanol is used so a mixture is made in form of the paste and this is deposited over. One paste is applied over the surface of the base metal to be joined and once the paste is applied the welding arc is fed.

Welding arc is applied over the surface of the paste so what we will get in this case the geometry of the weld bead is modified like anything under and how it is modified that is what we will see after the welding when GTWA arc is supplied after application of the activating fluxes then the weld bead geometry is completely modified. We may get much deeper penetration and very narrow width.

So, this width gets reduced while the depth is increased and efforts has been made to weld in one go the stainless steel, austenitic stainless steels up to 15 mm and while having the width of the 12 to 13 mm only. So almost same equal to the means the width to the depth ratio of about .9 to 1 also has been achieved and this kind of thing help in reducing the angular distortion and increasing the depth of the penetration for improved productivity.

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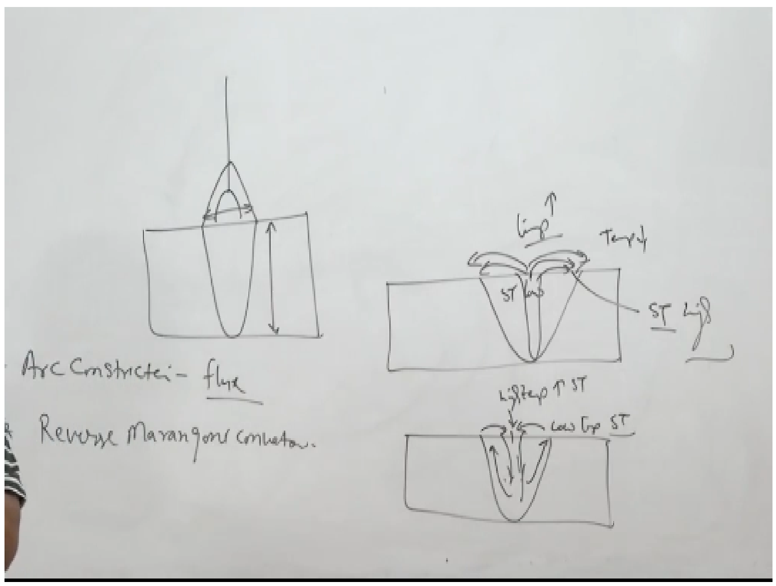

So, how this kind of effect is realized for this purpose means for this dramatic change in the increasing width, increasing depth and the reducing width is achieved for this purpose. The two theories have been advanced and these are related with the one is arc constriction which occurs due to the application of the fluxes and the second is reverse Marangoni convection which takes place.

So, I will explain what it is basically in conventional arc wielding processes you know the width is more and depth is less. So in this case in conventionally the molten metal flows from the low surface tension to the high surface tension area since the temperature at the sides is less and the temperature at the center is high so we will see that the surface tension is high at the sides and it is low at the center.

So, because of this most of the time molten metal flows from the center towards the sides. So, heat is transported towards the sides and we get that much wider and wider weld is made instead of transporting the heat down to the root or the bottom of the plate so that the depth of the penetration can be increased. So, this is one thing which is insured through the reversal in Marangoni convection.

It has been proposed that these fluxes reverse this flow pattern and when the flow pattern is revered like at the high temperature the surface tension behavior is just reversed, high temperature causes high surface tension and low temperature low surface tension. So, because of this the flow pattern is reversed and when the flow pattern is reversed we will see that whatever heat is being delivered by the arc it is transported because of the reversal in flow.

Now, the flow is down at the center and going up from the sides. So because of this whatever heat is delivered that is transported directly to the bottom of the plate so that in turn helps in increasing the penetration. And arc constriction is another hypothesis where in the use of the flux basically constrict the arc and earlier if the arc was wider it is width is reduced and it is applied over the smaller area and once the arc is constricted heat is localized over a smaller area.

And then it is transported effectively through the Marangoni convection which in turn helps in increasing the depth of the penetration. So, these are the two effects which have been attributed to the –for the increase in depth of penetration and reduction in the width of the weld. So, because of this and the nature of this process is such that the depth is increased, width is reduced this in turn helps in reducing the angular distortion, this is one.

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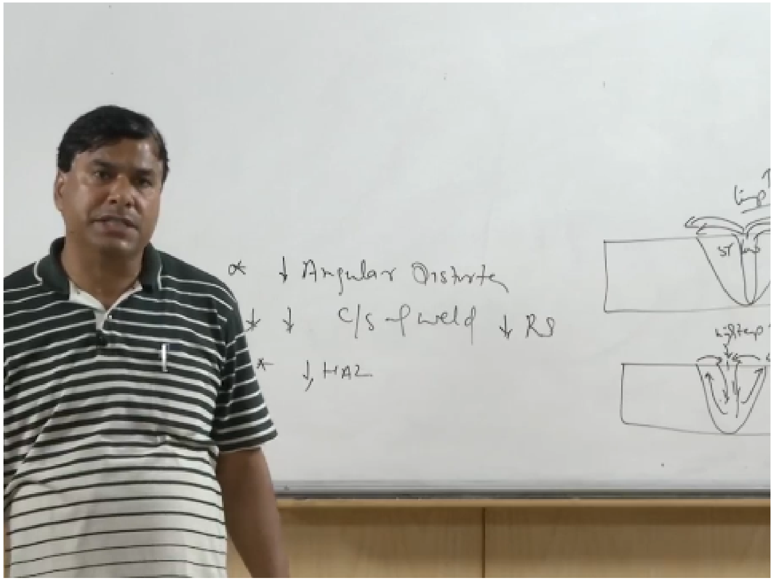

It reduces the cross sectional area of the weld which in turn helps in reducing the volume of the weld metal which will be shrinking and reduction in volume of the weld metal will in turn will reduce the residual stress magnitude. So, 25% to 30% of the residual stress magnitude is generally observed as compared to the conventional arc GTAW process. Another thing is that our HAZ width is reduced because heat input is reduced for the given thickness.

So, reduced heat input further helps in improving the performance of the weld joint. So, now I will conclude with this that a lot of efforts have been made for improving the capability of the conventional GTAW process for increasing the like say increasing the heat input sorry increasing the depth of penetration, using the activated fluxes. So that the deeper thickness means thicker plates can be welded in single pass as high as up to 15 mm for austenitic stainless steels.

And normal ferritic steels also can be welded up to 8 mm to 10 mm under the optimized conditions of the fluxes as well as the heat input. And further effort has been made to increase the deposition rate using the preheating of the filler wire so that the amount of heat required for melting of the filler wire can be reduced. And using the pulse GTAW process which melts the deeper using the pulses of the peak current and the background current.

And this in turn helps in reducing the heat input while achieving the deeper penetration and developing the quality weld joints. So, these are the three kind of newer variant of the GTAW process have been talked about. In the next lecture I will talk about the newer means unconventional welding processes. For example, like the radiation based process electron beam welding and the laser welding. Thank you for your kind attention. Thank you.