Joining Technologies of Commercial Importance
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Lecture - 14
Electro-slag and Electro-Gas Welding Processes

Hello, I welcome you all in this 12th presentation in the subject related with the joining technologies for the metals. And this presentation will be primarily focused on the Electro-slag and Electro gas welding process.

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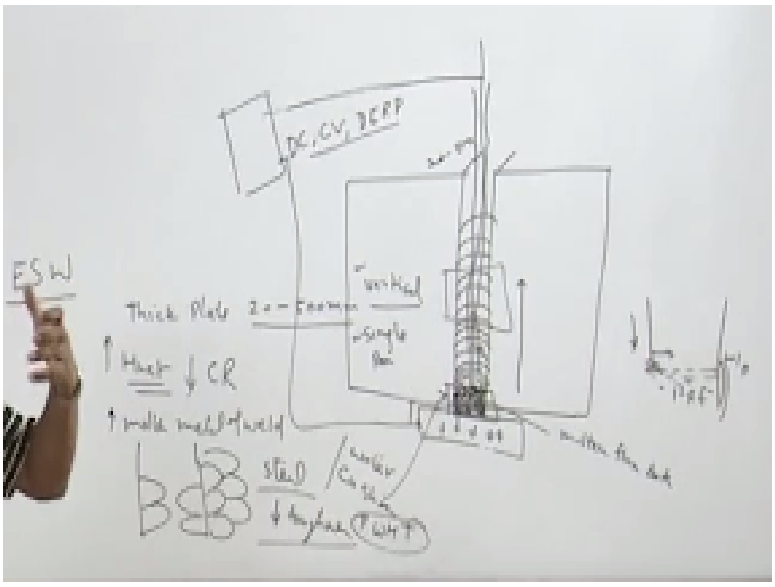

So, basically I will be starting with the start with the Electro-slag welding process. This process is primarily used for joining very thick plates. Thickness may range from like say 20 mm to 500 mm and if you see the nature of the process like say these are the two plates to be welded in the front view. This is the width and this is the height of the plate and there is another plate like this. This is the width and this is the height of the plate.

So, in this case these very thick plates, thickness obviously will be in this direction which may range from 20 to 500. So, in this process how do we start, this process used for mainly for thick welding of the thick plates. We have one backing plate like this and the plates are kept in vertical position orientation is vertical and then first of all we will fill some flux here and then the electrode, guided electrode is fed directly first on to the backing plate.

This is connected to the suitable power supply like say the common power supply is DC constant voltage and it is DC RP, reverse polarity or electrode is positive which is connected to the electrode and here one guided tube will be helping to move the electrode down to the bottom. So, the power is fed and another terminal of course is connected to the base, this backing plate and also to the work piece.

This is how the circuit is completed. Once it touches then arc is started so first arc is initiated between the backing plate and the electrode. This heat of the arc is used for the fusion of the flux. So, gradually heat of the arc melts the flux and forms the molten flux bath. Once the bath of the sufficient depth is created arc is extinguished and current flow is starts from the electrode to the work piece to the molten flux bath.

So, the flow of the current through the molten flux bath to the work piece from the electrode through the molten bath to the work piece generates the heat by I square RT heating and this electrical resistance heating is responsible for heat generation and this heat is used for melting of the faying surfaces as well as melting of the electrode. Electrode is consumed in this process it is continuously fed into the bath.

So, whatever molten metal is generated that will starts settling down. So, at the bottom you will see the molten bath is molten bath settles, molten metal settles and by the heat transfer to the backing plate and also at the sides we have copper shoes to prevent the flow of the molten metal outside, so the copper shoes which are water cooled both the sides are kept copper shoes which are water cooled maintain the temperature with in the safe limit.

So, it will found like, so this cavity the coppers shoes are used both the sides and so cavity is formed which is just like a mold and the molten metal will be there at the bottom. It will start to solidify by the extraction of the heat and gradually the solidification proceeds. So, as the solidification proceeds the entire, the welding head will start moving up so that the welding process completes.

So, this is basically in one go the entire height of the weld entire length of the weld is completed in one go. So, this is single pass weld. This is single pass vertical uphill weld because the welding starts from the bottom and will continue to move in upward direction.

So, it is vertical uphill welding and joint is completed in single pass. So, the process single pass and the vertical uphill kind of situation exist herein.

And then we will see since the I square RT heating, heating generation is by I square RT. So, the flow of heat through the molten metal to the base metal will be taking longer times. So, lot of heat is supplied to the base metal means Hnet for the process is quite high and the molten metal of the weld also remains in the molten state for longer time. So, because high net results in high heat input, high net heat input results in the lower cooling rate.

So, lower cooling rate causes the coarse grain structure in the weld as well as larger heat effected joint. So, these are the two negative sides related with this process. The heat input is too high because of this the weld joint which is formed the weld metal which is formed has a coarse grain structure and heat effected joint is also very coarse especially in case of the steels, the coarse grain structure I h h.

And the heat effected joint lowers the toughness drastically and that is why the post weld heat treatment becomes necessary to reduce, to improve the toughness and normally the normalizing heat treatment. Normalizing heat treatment is done of the hardenability steels which are welded by the Electro-slag welding process to improve the toughness of the heat effected joint.

You know that in normalizing process normally we go in the oxidation temperature and then hold it there for having the homogenous austenite formation and thereafter cooling in the ambient conditions led to the formation of the fine per light degraining structure, which in turn helps to improve the toughness of the weld joint.

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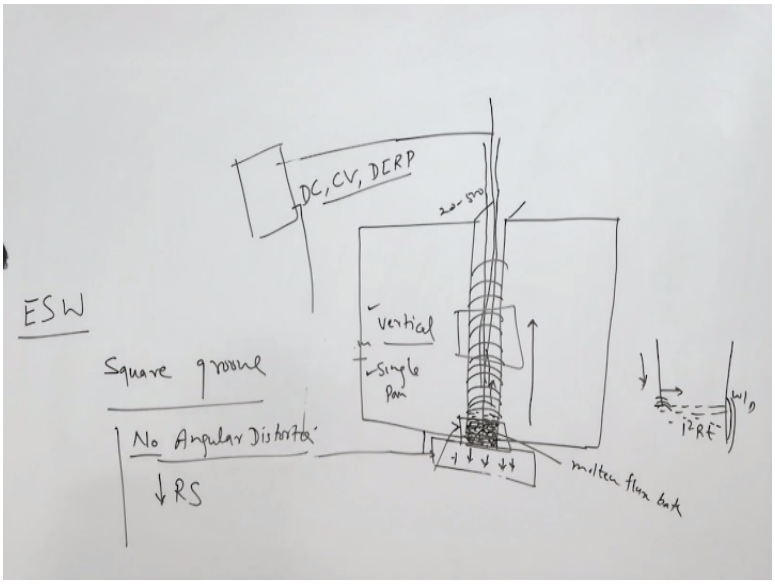

So, if you see the joint is square grove type. So, what all sink it takes place that is symmetrical and symmetrical transvers shrinkage of course it is there but in this situation there is no angular distortion. There is no angular distortion in this case and the slow cooling conditions, high heat input and symmetrical shrinkage results in the reduced residual stresses. Now, we will go further in to the details of the process especially when we are working with the heavier plates.

So, we know that if the plate thickness is too high like 500 mm or half meter in that case one electrode will not be sufficient for the development for uniform distribution of the molten metal as well as the heat so that and through the throughout the thickness weld can be made sit.

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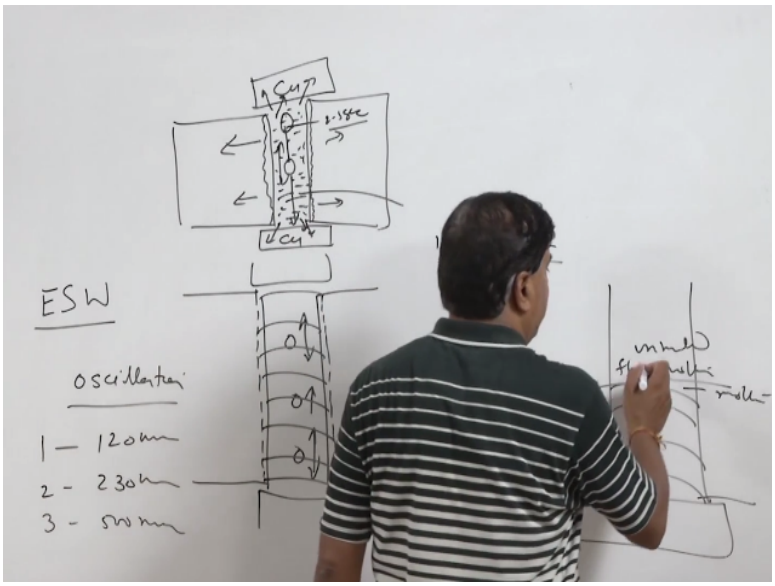

In the front view we are seeing the height and the width of the plate and if the same is so and if the same is seen the thickness wise so in the thickness wise if the cross section is like this, so, if the electrode position is at the center this side we have, both the sides we have copper shoes to widen the flow of the molten metal outside. So, here in the entire joint there will be molten, slag molten metal like this heat will be dissipated by the copper shoes also.

Because these are water cooled and it will be dissipated by the base metal also. So, one electrode is sufficient to supply the molten metal and cause enough melting of the faying surfaces of the base metal up to 75 mm thickness. But if the thickness of the plate is much more than it will not be sufficient say, so if the plate thickness is the 100 or 125 or 20 mm in that case the copper shoes becomes far away from the electrode position.

And it may not be possible to melt the faying surfaces of the base metal effectively and feed the molten metal up to the copper shoes effectively because here the cooling rate is much higher near the copper shoes. So to feed with the molten metal as well as to ensure the melting of the faying surfaces it is necessary that there is some movement is given to the electrode.

So, you will see that oscillations are given to the electrode in that case maybe one electrode is sufficient with the oscillation literal movement towards the copper shoes. So, whenever we reached to the electrode reaches to the near the copper shoes it is held there for some time is some dual period is given maybe 2 to 5 seconds here so that more heat is delivered near the copper shoes to counter the heat being extracted by the copper shoes.

And to ensure that the base metal melts and faying surface of the base metal melts. Similarly, the movement of the electrode is done both the sides at the sufficient speed so that heat distribution of the heat between the copper shoes is between the copper shoes and along the thickness of the plate is uniform and sufficient melting takes place. But when the thickness is much more in that case one electrode may not be sufficient.

So one electrode is used up to say 120 mm thickness with the oscillation two electrodes are used in case of say 230 mm and 3 electrodes up to 500 mm thickness. So, in this case if you are using one electrode, then one electrode will kept at the center and then it oscillated both

the sides otherwise will have to use 2 electrodes like this and they need to be oscillated both the sides.

And in case of the 3 electrodes of course one will be kept at the center and 2 at the sides and oscillation, literal oscillation will help in uniform distribution of the heat between the copper shoes all along the thickness of the plates so that the sufficient melting of the base metal takes places and through thickness means sufficient melting of the faying sufficient takes places for development of the weld joint which will have largely uniform distribution of the heat as well as the molten metal between the copper shoes.

So, this is about the oscillation of the electrode and normally if we will see this process walks with the 100% duty cycle because process once it is started is not discontinued if it is discontinued we will see that incase of this if it is discontinued say this half portion has been completed and here if it is stopped then all that flux which is un-melted and molten flux and molten metal everything will get solidified and this will result in lot of inclusions porosity at the surface on restarting the weld again.

So, its preferred that this, the process is not stopped in course of the welding, once it is started and in one go it is completed and if interruptions take place then it will bring in the presence of inclusions, porosity, etc. at the interface wherever from it is started second time. So, the process walks with the 100% duty cycle.

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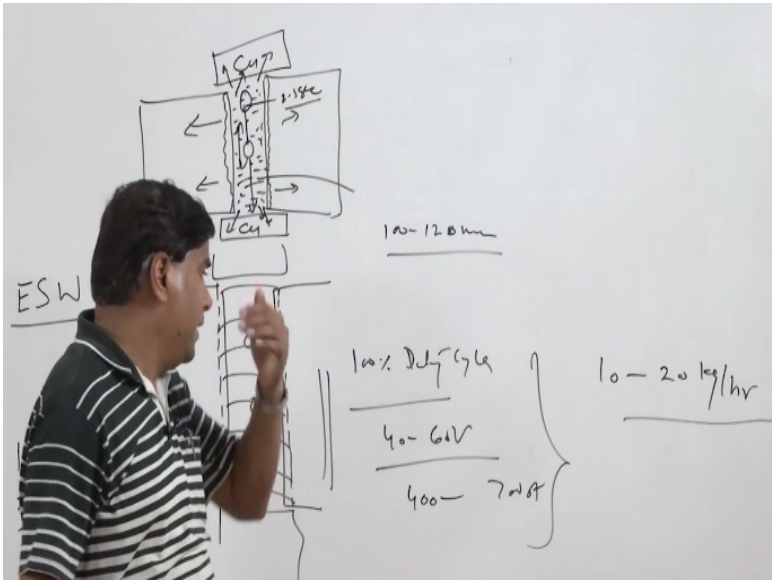

It is common that 42 to 60-volt current, arc volt is used and in this case also the normal current rating maybe 400 to 700 Ampere and whenever the electrode depending upon the electrode diameter we may get the deposition rate from 10 to 20 KG per hour which is pretty on the higher side and similar to that of the submerged arc welding process.

As I have said there are 2 electrodes there maybe 1, 2 or 3 depending upon the thickness of the plates to be welded but these electrodes will be passing through the gap between the plates during the welding.

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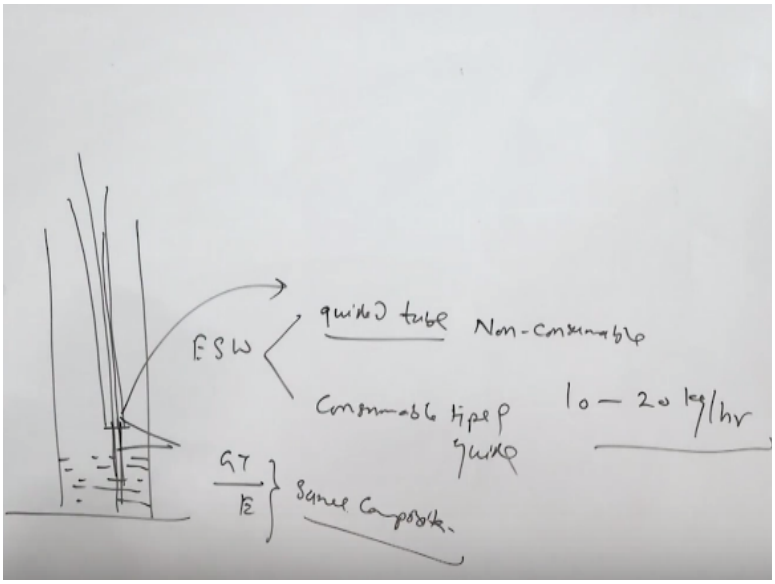

So if the gap is really if the height of the plate to be welded is really very large then the long electrode must be fed through the guided tubes. So these, there are 2 variants in this process, electro-slag welding come with the welding process come with the 2 variants, one is where guided tube or guiding tube which guides or fits the electrode in particular path it is a non-consumable kind, it is not consumed.

And another one is consumable kind of where consumable type of the guide. So this entire, in one case it will be kept away the bath and it is it will be feeding the electrode only and while in other case and it will be kept away from the surface of the molten bath, So, this is the non-consumable kind and in case of the consumable kind the electrode along with the guide will be dipping into the bath.

And in this process, the electrode as well as the guide tube both will melt and will form the part of the weld so the guide tube and the electrode both must be of the same composition, so

that they do not create a problem well metal chemistry modification due to the melting of the guide tube. Now, we will talk about the positives and the negatives of the process.

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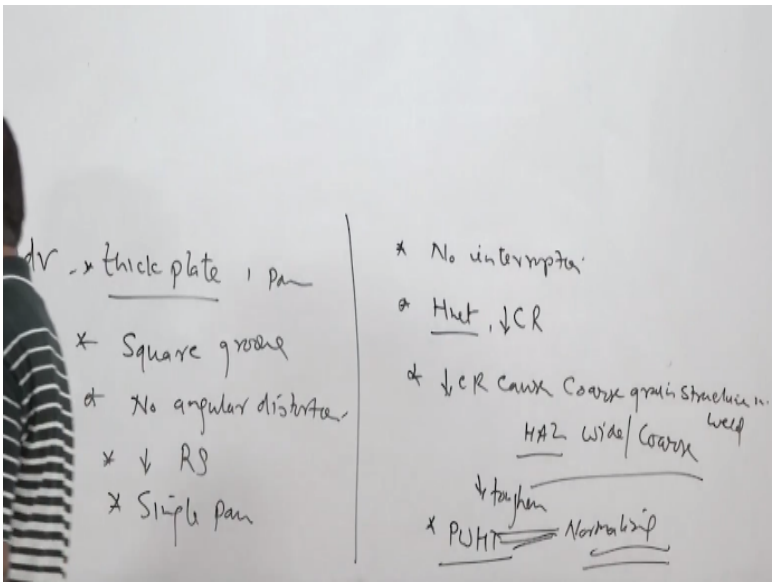

As far as this process is concerned advantage is very thick plates can be welded in one pass. Second, square group no edge preparation is needed square groups are used by the process and no angular distortion residual stress magnitude is very less or the magnitude of the residual stress is reduced when this process is used its a single pass process so even very heavy thick plates can be welded in one go.

And on the other hand the negative sides like it is single pass, so no interruptions are permitted. If the interruption due to any reason takes place then it will result in the discontinuities and defect in the weld metal and another is H-net with the process is high, so high heat input results in the lower cooling rate. This is good especially in case of the hardenable steel which show tendency for cracking.

But otherwise this low cooling rate, reduced cooling rate causes coarse grained structure in weld, this is one. And also XZ is very wide as well as coarse. So, very wide coarse XZ in case of this steel say coarse martensitic structure results in the reduced toughness. So, reduced toughness or embrittlement of the heat affected joint takes place, so the reduced toughness this advanced effect in case of hardenable steels must be eliminated.

And for that purpose post weld heat treatment is mandatory and which is done primarily in form of the normalizing operation or normalizing heat treatment process. So, the same now

we can see using the diagram or the photograph which is there in the presentation. I will just for the sake of clarity, I will use that to describe each and everything related with this electro slag welding process.

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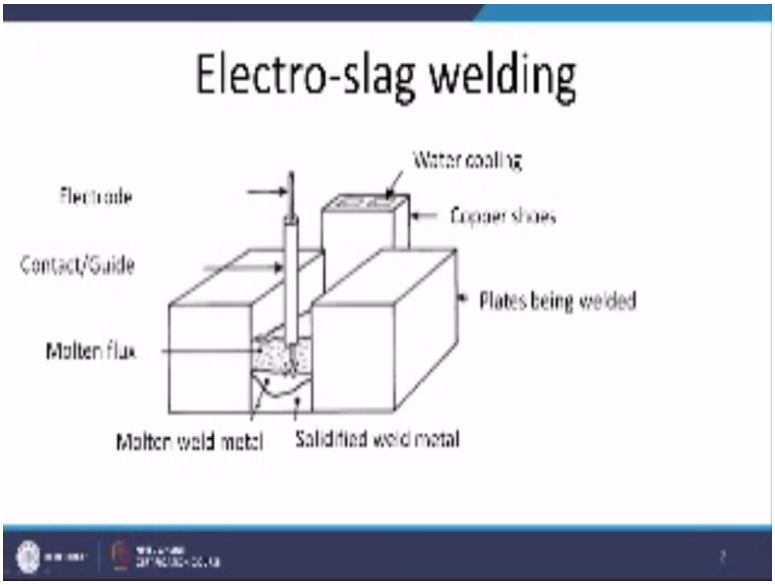

So, here if we see this is the process. This is electrode fed which is, electrode which is fed through the automatic roller feeders normally constantly speed kind of speed drives systems are used in this case the electrode is fed and it is fed through the contact tube or guide tube. This guide tube will be feeding the electrode down to the bottom. These are the two plates is one another plate but this is the front view you can see and these will give us the top view.

So, the front means this shows the gap between the plates to be welded and this is the width and this is the height of the plate and the length of the, means height of the plate will determine the length of the weld to be made. Here this is the solidified weld metal, here molten weld metal, here molten flux and then this is the molten metal being transferred from the electrode to the work piece. In this case contact tube has been dipped into the bath.

So, this is the consumable guide type of the contact tube arrangement and here we will see this is the contact tube and the copper shoes are placed both the sides like this, other side and similarly it is kept this side also, so that there is no flow of the molten metal and outside the plates been welded and it acts a mold.

This center cavity in between the copper shoes acts as a mold and to maintain the temperature since the temperature of the molten metal is much higher like say the temperature of the

molten flux is around 1,900 degree centigrade. This is of 1,650 degree centigrade and this molten metal is of the temperature. So, molten flux is of the temperature of 1,650 degree centigrade and 1,950 for the molten metal the temperature.

And the copper shoes are in contact with the molten flux as well as the molten metal and since the copper melts around 1,050 or 1,060 degree centigrade so in order to maintain the temperature of the copper shoes within the safe limit these are the water cool. So, this is how the process once the solidification takes place the entire arrangement is just like welding head is moved up.

So that this process progresses in one direction from the bottom to the upward. So, in this case one more additional thing which is that the process follows the directional solidification.

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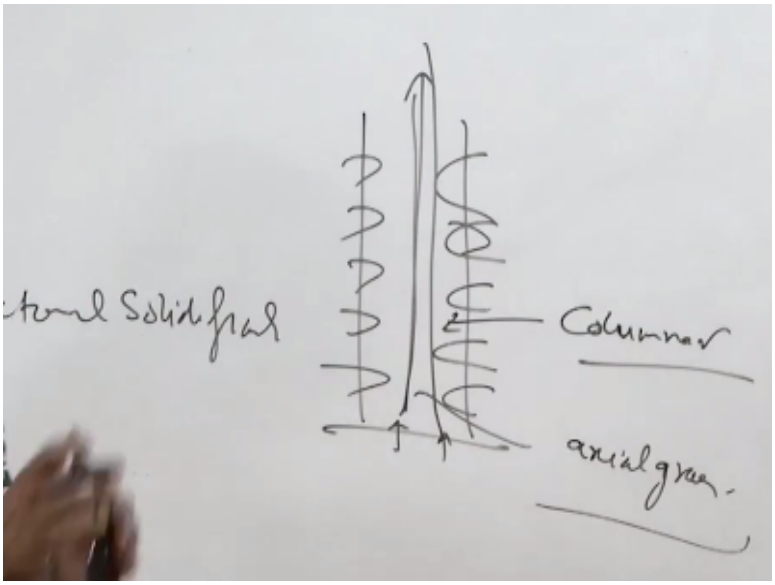

Directional solidification means the process like it starts from one end and then it completes at another end. Of course the columnar grain structure appears from both the sides of the plates being welded but sometimes axial grains are also observed running along the weld line. So, there are two types of the grain structures are normally observed one is the columnar grain structure which will be perpendicular to the faying surfaces of the base metal and another are the axial grain structure.

Axial grain structure is normally observed in case of very thick plates, very wide gap and very slow cooling conditions are there. So, in that case, so this is the directional solidification which is normally observed in case of the electrode slag welding process. Now, we will talk

about the electro gas welding process. Electro gas welding process is the schematic wise, the infrastructure wise, the component wise all are same but there is very little difference as far as this process is concerned.

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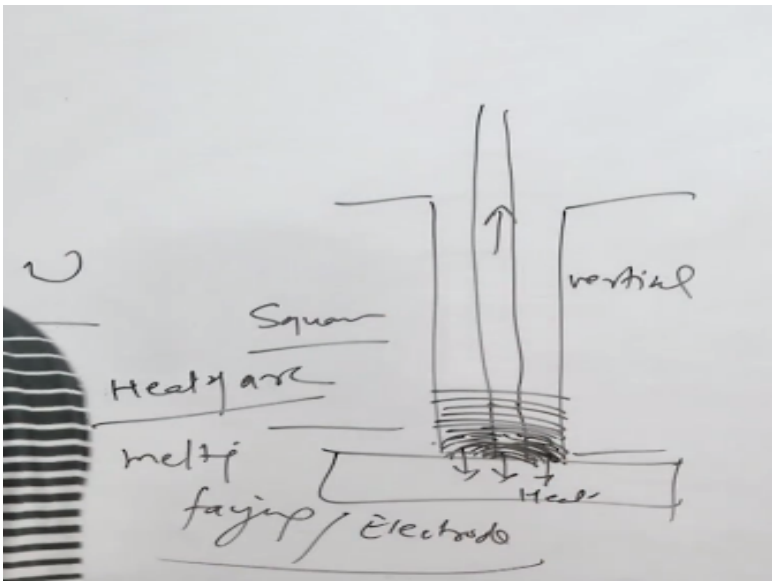

This process is called electro gas welding. We have seen in electro slag welding process is starts with the arc thereafter further electrical resistance heating is responsible for melting of the base material as well as electrode but here in this case only arc is generated. In earlier case protection was there from the molten flux and the flux molten slag was covering the weld metal.

But here in this case a separate shielding gas is provided which may be Argon or Helium or Carbon dioxide as per the kind of the quality which is needed and kind of metal to be welded. In electro-slag welding normally like the similar kind of arrangement it starts with the back inflate the two plates to be welded.

It is also the vertical uphill, square groove, single pass all the things are same as that of the electro-slag welding except that here the electrode which is being fed to the contact tube its strikes the arc with the backing plate and melts the electrode and this is how, now if you have to really distribute the heat all along this then oscillation of the electrode is needed.

So, movement of the electrode between the plates is important for uniform distribution of the heat. Basically heat of arc is used for melting of faying surfaces of the base metal as well as melting of the electrode and whatever melting takes places that fills in the gap between the

plates being welded and once the gap is fulfilled the solidification continues, solidification with the extraction of heat will result in the progression of the solidification as the weld is completed between the plates being welded.

The welding head will keep on moving up and so that is how the joint is made. So in electro-slag welding, this is arrangement wise it is same as that of the electro-slag welding means, electro-gas welding is similar to that of the electro-slag welding except that here heat of the arc is used for melting of the electrode a well as of the faying surfaces of the base metal.

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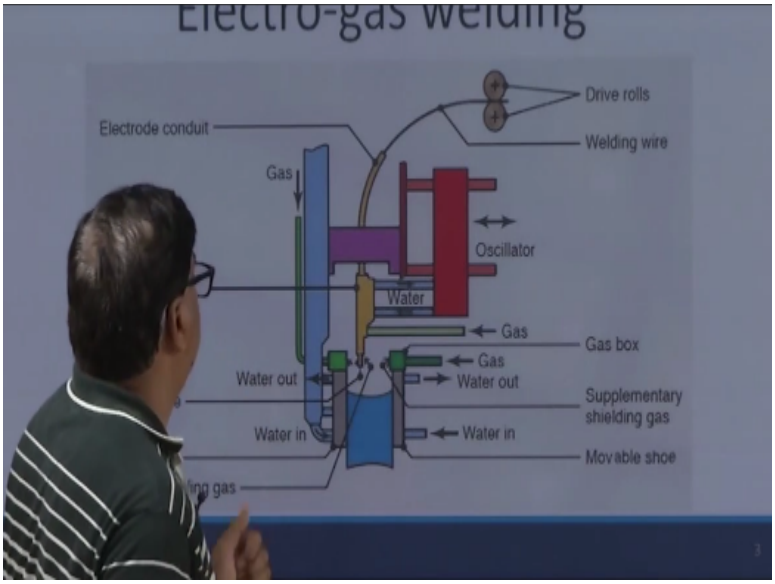

So, that is what we will see here. In this arrangement here like say these are the plates to be weld, these are the copper shoes and here we see copper shoes fed with the water. Water comes and gets into the copper shoes and then it comes out and this is where the weld is being, this is weld metal and will see that is this is the spool where from the, this wire feed drive system and the wire is fed through the spool.

And wire feeding system will feeding the electrode through this guided tube or electrode continued pipe and this will effect directly in the gap between the electrode and work piece. Here it will be striking the arc and providing the molten metal for uniform distribution of the heat between the plates and in uniform distribution of the weld metal between the plates. This is oscillated.

So, oscillator is provided so that it uniformly delivers the amount of heat which is needed and the molten metal which is required and the gases are also fed for the purpose of protection of

the weld metal and the arc to avoid the contamination of the weld metal from the atmospheric gases. And for this purpose we use, we can use either Carbon dioxide or the Argon or the Helium as per the requirement or as per the quality of the weld metal which is needed.

Since, in this case the heat generation is by the welding arc for the purpose of melting of the faying surfaces as well as the electrode, so the cooling rate experienced by the weld metal as well as the heat effect as well as the base metal is high and that in turn results in the higher cooling rate and higher cooling rate will lowers the heat affected joints.

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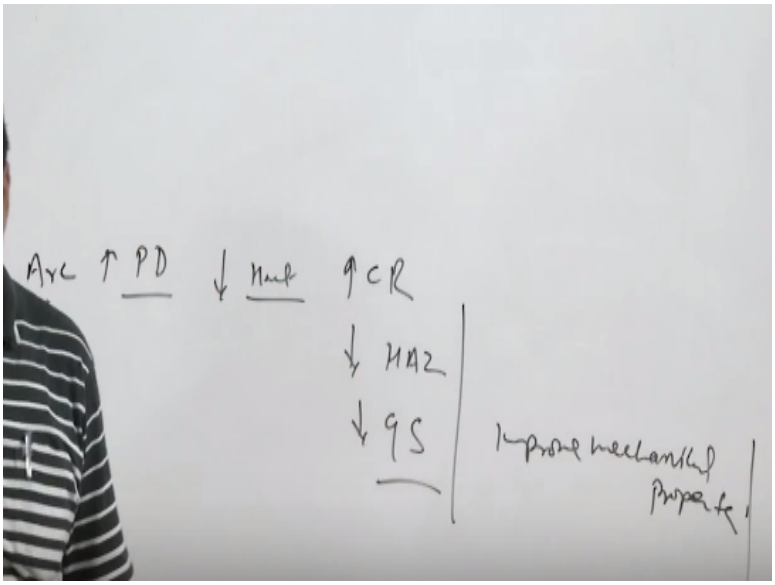

So the plus side is, since the arc offers the higher power density or energy density so which in turn reduces the H-net and reduced heat input increases the cooling rate decreases the heat affected joint width refines the grain structure and these in turn improves the mechanical properties. So this is, so if we compared the electro-slag welding with the electro-gas welding then you will find that electro-gas welding offers the much better mechanical properties as compared to that of the electro-slag welding.

So, now I will conclude this presentation. In this presentation, primarily I had talked about the way by which the electro-slag welding and electro-gas welding process work what are the things important related with, what are the positives and negatives related with these two processes and how the two processes can be compared as far as the performance of the weld joint is concerned. Thank you for your attention.