Joining Technologies of Commercial Importance
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Lecture - 12
Gas Metal Arc Welding

Hello. I welcome you all in this presentation related to the subject joining technologies for the metals. In this presentation mainly I will be talking about one unique variant of the gas metal arc welding process. Since earlier I have not talked much about the gas metal arc welding process. So, I will linger on first the gas metal arc welding process before talking about the cold metal transfer welding process.

Because this is one variant of the GMW process. I will see if we take the help of this diagram in this process we use one the continuous electrode which is fed through the contact tube.

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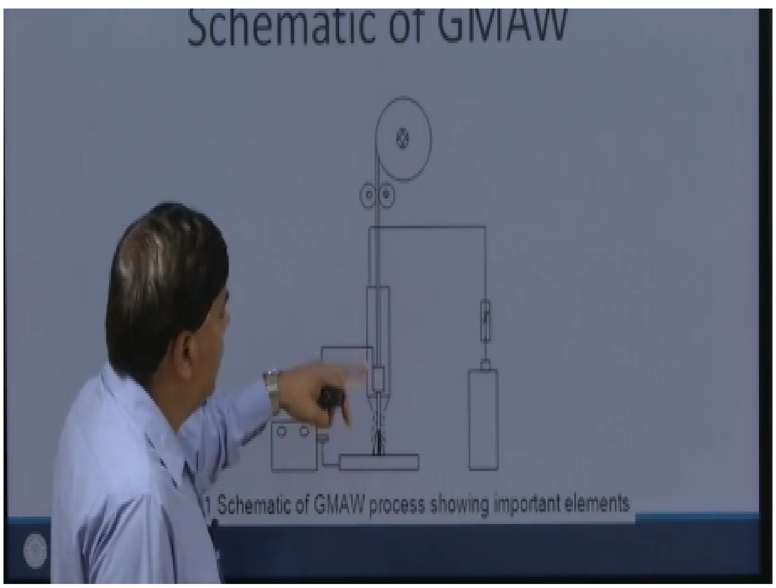

And the contact tube is connected to the power supply and power supply one terminal which is normally positive is connected to the electrode and the negative terminal is connected to the work piece. Arc is struck between the electrode and work piece and the heat of the arc is used for melting of the base metal as well as melting of the electrode.

And to protect the welding arc as well as to protect the weld pool inert gas or the inactive gases like Co2 or inert gases like helium and argon can be used. They are fed through the nozzle of the welding torch which will be surrounding the weld pool as well as the welding arc to protect the weld pool from the atmospheric gases. So the contamination of the weld pool from the atmospheric gases is protected through the inert or inactive gases.

So, this is one typical variant of the –there are various variant of the GMAWA process the one variant is the cold metal transfer arc welding. So, here in this process but additionally if you talk of the cold metal transfer welding.

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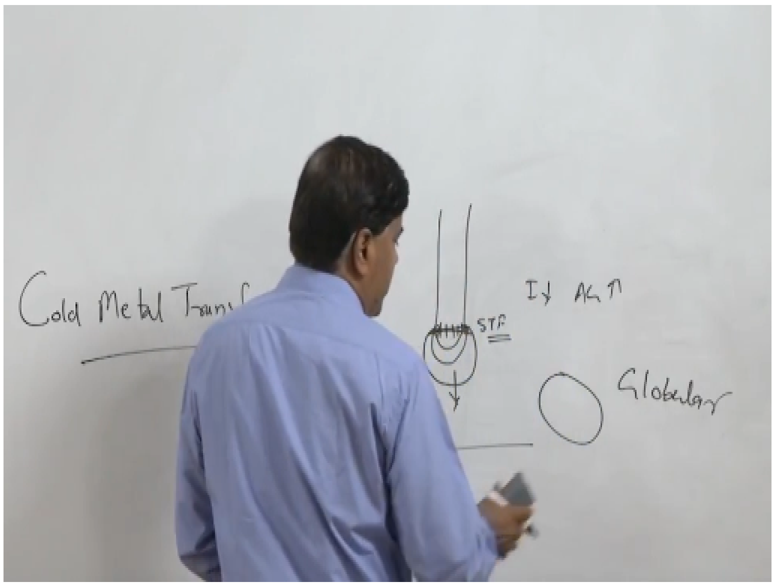

So, here to understand the process principle it is necessary to see that in a typical gas metal arc welding process arc is struck between the electrode and work piece and electrode is connected to the suitable power supply whose positive terminal is normally connected to the electrode and negative terminal is connected to the work piece and the DC RP or the reverse polarity is used and in association with constant voltage power source in order to have the advantage of the self-regulating arc.

Self-regulating arc helps to maintain the arc gap when the electrode is feed at a constant speed. So, in case of the constant speed fed electrodes and use of the constant voltage power source with the DCRP we typically get the self-regulating arc which means the arc length is automatically adjusted by governing the melting rate through the regulation of the welding current.

So, in this case the metal transfer means the electrode melts and the molten metal drop is formed at the tip of the electrode and when it attains the large size enough it gets transferred to the pool. So, the transfer of the molten metal from the consumable electrode to the weld pool can take place in different ways. So, there are different ways by which this transfer can take place. This is the pool so the transfer of the molten metal from the electrode tip to the pool can take place through the different modes.

And there are four modes of metal transfer which are very commonly used one is short circuiting transfer. In case of the short circuiting mode of the metal transfer the gap between the electrode and the work piece is very less and the current value is low arc gap is less so the current drop grows gradually and as soon as it grows large size enough it touches to the pool and by the surface tension effect the drop gets transferred to the pool.

So, this is called short circuit transfer. In this case, the welding current is very low and the arc gap is also very less so when the drop grows it touches to the pool and the drop gets transferred to the pool. In this process the heat because of the low current heat input is very less, less heat input means the temperature of the molten metal is less surface tension is high fluidity of the molten metal is less and we will see that the elemental transfer efficiency is high.

Because the high temperature, heat applied is limited and the temperature generated is also very limited there for the losses inform of the losses of the element in course of the transfer from the electrode to the pool is very limited. But on the other hand there are other modes of the transfer also like the globular mode.

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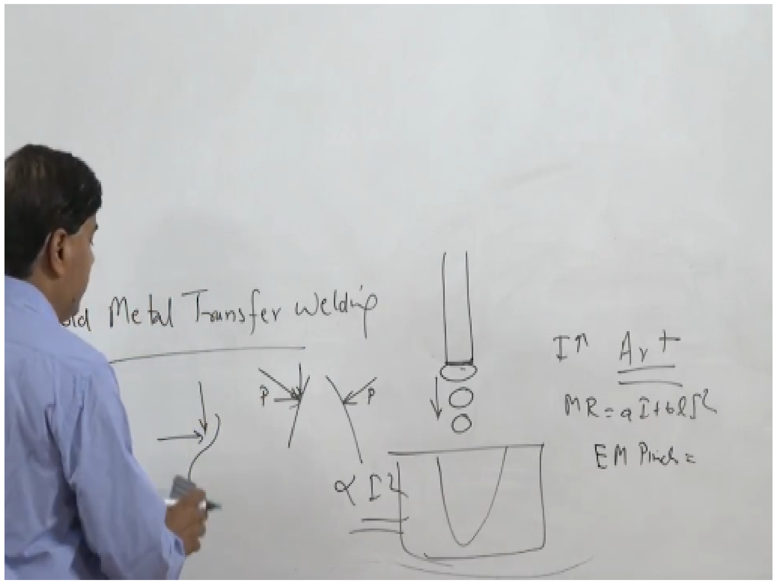

It is observed when the gap between the electrode and work piece is large enough current is less but the arc gap is large. So in this case the drop will be growing gradually and it may grow as large as 1.5 times to the 2 times of the electrode diameter and once it attains large size enough. So, the forces holding the drop surface tension forces, holding the drop at the tip gets reduced to such an extent that the surface tension forces holding its magnitude becomes less than the gravitational force due to the weight of the drop then the drop gets detached.

So, the size of the drop becomes large enough means very large and that is why it is called globular transfer. It is normally observed when the gap is large and the current value is less and then we will see that when the current is high and the shielding gas specially in case of use of argon in that case high current causes the faster melting and because the melting rate is found function of the aI + bl I square.

So, in case of the small diameter electrodes large electrode extension and high electrical resistivity all these factors play big role. In all this cases the second factor plays a big role so specially when the current is high melting rate is significantly influenced by the welding current and then I will that the drops are formed very quickly at the tip. At the same time the pinch force also found electromagnetic pinch force that acts at the tip like this about perpendicular to this surface of the drop.

So, here this component like say this is the drop which is hanging at the tip so one force acting perpendicular to the surface of the drop. So, this pinch force can be resolved into the two components one is vertically and another is horizontal. So, horizontal component tries to press the drop by reducing its cross section and the vertical component tries to push it down and tries to detach.

So, when the welding current is high the drop even when it is of small size action of the heavy pinch force which is proportional to the square of the current helps to detach the drop even when it is of very small size. So what we will see high current will be melting the drops at the faster rate and detaching them even when they are of the smaller size. So, there will be continuous movement of the drop from direct towards tip towards the weld pool and giving the feeling like a spray.

So, this kind of the transfer is called spray transfer. Spray transfer is observed when the current is high and so at high current level the higher pitch force and high melting rate faciliate the faster melting and pinching of the drops ever when they are of the smaller size giving the transfer in form of the spray.

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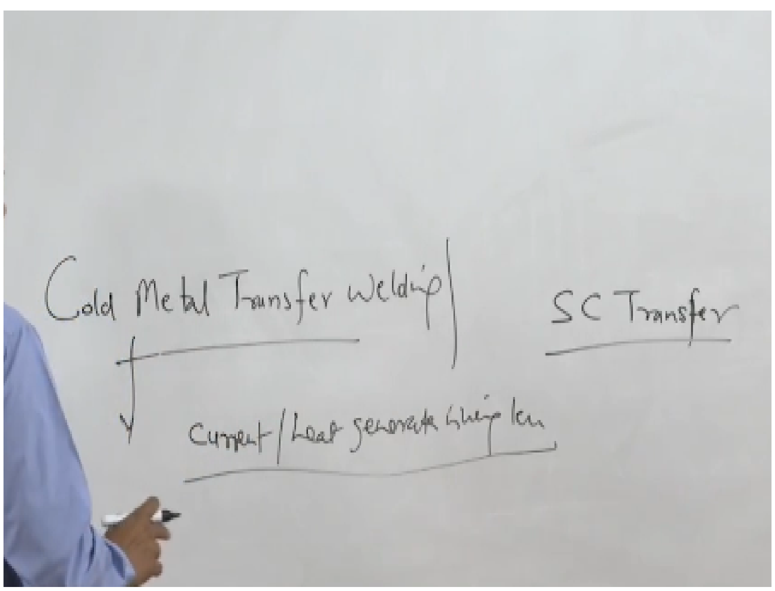

Another is the rotational transfer in case of the rotational transfer current is too high so high current causes I square Rt heating making the electrode tip and specially when the electrode extension is large making the electrode soft and specially near the tip of the electrode. So your tip starts moving or rotating so the transfer specially the tip starts rotating under the electromagnetic forces.

So the transfer of the molten metal is less controlled and we will see that it has not as directed towards the well pool as desired but the placement of the molten metal starts at the places where it is not desired. So, rotational transfer is avoided because in this case we lose the control over the transfer of the molten metal and it is placed at the places where it is not desired. So, what is cold transfer here?

So, there are three or four types of the transfers what we have seen but we did not see the cold metal transfer what it is and what is the meaning of this? You know it is a one typical situation of the short circuit transfer which is achieved in case of the cold transfer actually this is not cold. But meaning of the cold is that the movement when transfer takes place the current value is less. The current and the heat generation is very less.

So, this situation with respect to the other arc welding processes has been defined or termed as the cold one but actually it is not cold. The heat generated and the current conditions used for this kid of the transfer or this kind of the welding process is very as compared to the other process that is why it is called cold transfer. But this process is also combines the some benefits of the another variant of the GMAW.

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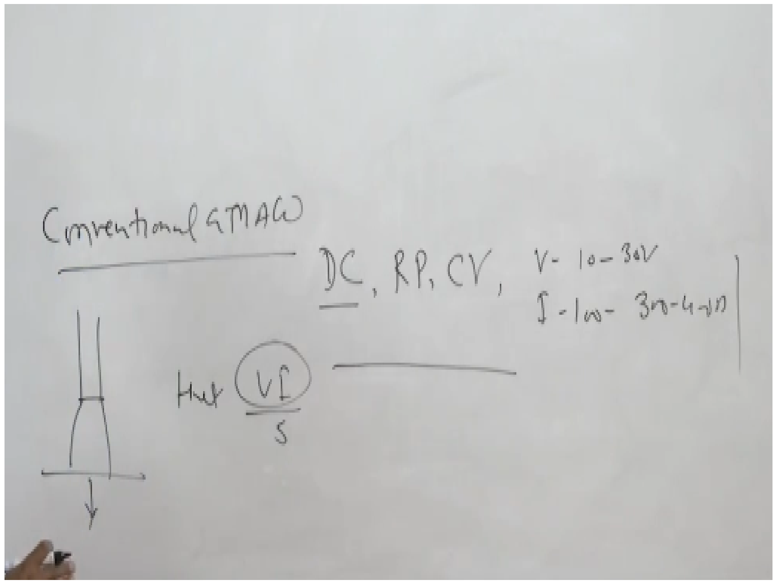

The conventional GMAW uses certain things. Like DC power, reverse polarity, constant voltage power source and say the voltage ranging say 30 volt or the current may vary say 100 to 300 to 400 ampere like this. So, in conventional it is current largely remains constant. So, it is easier to calculate the heat input from the VI by S. Heat generation by the arc and S is the speed. So, net heat input we can easily obtain in this case.

Heat being delivered by the welding arc to the base is fixed in this case and that we can obtain from the VI by S. But in some cases when we intentionally want that heat delivered to the work place is limited in order to avoid it is related adverse effects then the processes modified intentionally. And in that case we do not deliver the cost and current like CS but the current magnitude is controlled in a particular manner and for that we use the pulse GMAW.

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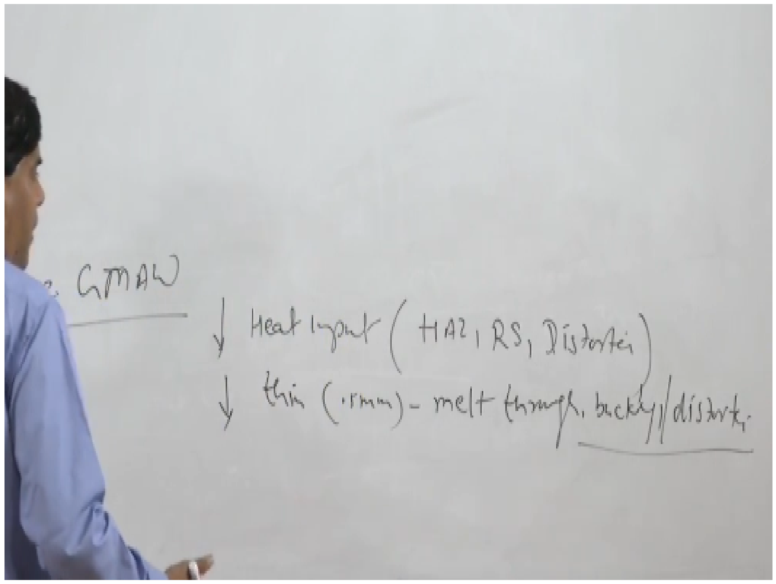

The purpose of using this is somehow let us reduce the heat input to the work piece. So, that the related adverse effects in terms of the heat effected zone, residual stresses, distortion etcetera unfavorable metallurgical transformation all that can be reduced. That is the main purpose. Another alternative may be we want to join extremely thin sheets like say .5 mm or .33 mm or less than 1 mm in that case two high heat input will immediately cause the melt through situation and will not be able to control the molten metal.

So in case of the welding of the thin sheets the melt through kind of situation will be there and then there will be bucking or distortion on achieving the shape which is not desired means rapping and buckling or distortion of the sheets will lead to the development of the joints which will not solve the purpose due to the change in size. So, this is what we will conventionally we getting in case of the conventional welding.

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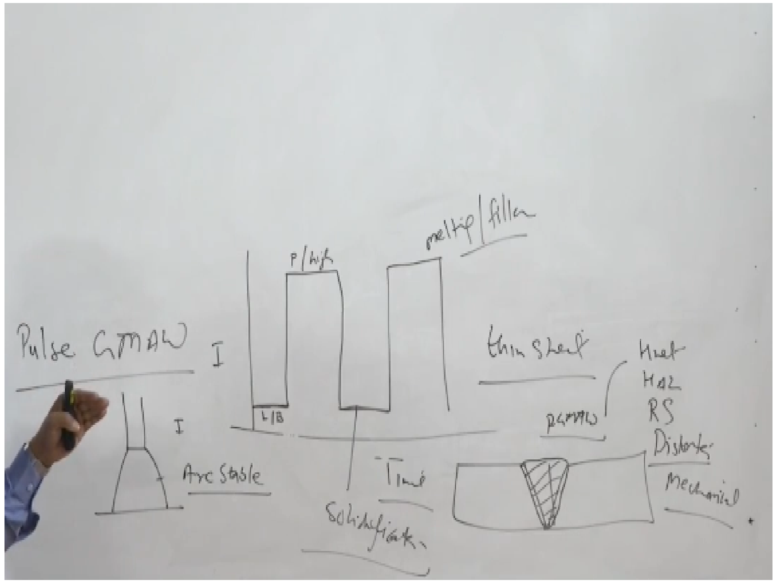

So to avoid that the GMAW process is modified in a particular way where in the value of current is regulated as a function of time. So, what is done in case like here we have current and the current value initially we will keep the current value less like say this is the welding current, also this welding arc and current is fed. So, the value of current is regulated. The first like say the low level of current or you can say background current like this.

Background current will be just enough to maintain the arc stable that is the only purpose of maintaining the background current arc just we made stable. Its purpose is not to develop the heat. So we maintain the background current then the current is increased this increase may be at different rate say it may be like this or it may be like so there can be differ rates and the different kind of the waves which can be generated as per the requirement.

So, normally they if the square wave like this is generated where after reaching a particular background current period the current is increased to the high value. So, this is called peak current or the high current value. So, the peak current will generate the required heat for the melting of the faying surfaces and of the base metal and then again it is brought to the background current level.

So this is how the cycle is kept on maintaining background current, high current. So this is what we can say the current is pulsated between the background current level and the high current level, low peak current. So, when the current level is peak or melting of the base metal as well as filler is facilitated and when there is background current in this case the solidification is facilitated.

So, this is especially useful for the cases like when we are working with very thin sheets so the pulse will come it will melt the small amount of the metal of the edges of the faying surfaces of the sheets and then solidification will be followed. So, the pulses will be supplied at the different intervals as per the choose frequency so we may have this is the weld line what we will see one pulse will come here.

Another pulse will come here, another will here and at certain interval of time so one pulse will develop one pool melt through thickness will take place then it is solidification will take place then another pulse will come after sometime. In mean time, we expect that the solidification of the pool will proceed. So, especially this is useful especially in two case when very thin sheets are to be welded or when very heat sensitive metal is to be welded.

We want that even if the sheets are not very thin but the metal which is being welded is very sensitive to the heat. So, the heat delivery to the base is very less and very little melting of the base metal take place for development of the joint. In this case also the pulse GMAW helps a lot because it effectively reduces the heat being delivered for the melting of the faying surfaces and development of the weld joints.

So, whenever pulse GMAW is used it effectively reduces the heat input. It reduces the HAZ size, reduces the residue, it reduces the distortion. It refines the grain structure so better mechanical properties are also obtained in case of the pulse GMAW. So, this is one step ahead of the conventional GMAW. In conventional GMAW, we supplied only the constant current and the constant voltage for a constant current value for the development of the welding arc.

And heat delivered was also constant during the welding but in case of the pulse GMAW the value of the current was regulated between the peak current and the background current levels so that the melting and the solidification can proceed sequentially step by step.

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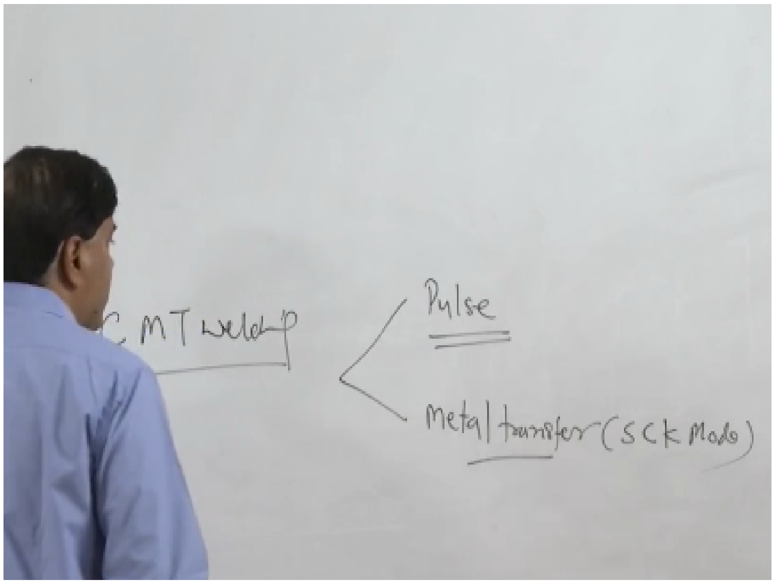

With respect to the cold metal transfer welding, it incorporates the two aspects. One is the pulsing means the pulse feature and another is efforts are made to regulate the metal transfer in a very controlled way through short circuiting mode. So, these two things are clubbed in case of the cold metal transfer welding. How it is realized for this using the electronics and the controlled movement of the electrode what is done in this case?

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Like say this is an electrode I will make four diagrams like this so let us start here. This is the arc so when there is arc means the current value is like this when there is arc so this is the arc position one case one. Case one when there is arc the heat will be generating the molten metal at the tip of the electrode. In this course the melting will be facilitated as a function of time and this is current.

So, the melting is facilitated. So once the sufficient melting has taken place and the drop has been formed then next step the electrode is moved forward. So once there was arc, arc developed the molten metal, drop of the molten metal at the electrode tip. And once the tip is generated of those large size enough the electrode is advanced. As the electrode is advanced the drop will be toughing to the pool so this is the case when drop will touch to the pool.

So, here as soon as the drop touches to the pool like say this is the drop hanging at the tip and it just touches to the pool there was arc like this. So, as soon as it touches to the pool the drop will get transferred in this case short circuiting will take place. So the transfer is just by touching to the pool, the circuit is completed between the electrode and the pool. So, short circuiting takes place but at this stage very low current is ensured.

So, the transfer is very smooth because current magnitude is reduced. So at this stage current is lowered. At the stage of short circuiting current is lowered and this is the short circuiting. Once the drop is transferred after touching this electrode is retracted so the electrode is brought back. So, once first it is advanced once the sufficient drop size is developed and then it touches to the pool so short circuiting takes place. The third, it is retracted or it is withdrawal.

So again the gap is established. So once the gap is established, arc is there and this arc will again have the current value corresponding to the peak currents. So, this is one where there was a peak current, drop was developed at the tip and then electrode was advanced and as soon as it touches the pool drop is transferred at the short circuiting stage. So, this is the short circuiting stage and then it is retracted, and they are retracted the gap is established arc is again initiated.

And heat is generated again the melting is started. So, what we will see the back and forth movement. If we will see there is simple back and forth movement when the electrode is back there is arc, drop is developed and as soon as drop is developed it touches to the pool. So short circuiting takes place so once it touches the transfer of the molten metal to the pool takes place.

At this moment current value is very less. So very limited current facilitates spatter less transfer.

So, here the unique feature is spatter less transfer. And the condition when the transfer takes place current is very low. So here you can say it is very cold kind of situation, no heat generation and whenever there is heat generation the electrode is away from the pool. The peak current helps to develop the heat and so the drop is formed and once the drop of large sizes enough is formed again the electrode advances.

So this is the sequence of which is normally repeated and it is synchronized according to the pulse between the peak and the background current level. So here short circuiting takes place and this I the peak current level. So one current one pulse means one drop one pulse kind of synchronization is achieved for the CMT process where in after each cycle there will be transfer of the one drop.

The unique feature of this since the pulsing helps to reduce the heat input and touching, transfer in the short circuiting wave and the current value is very less the transfer is very spatter free very smooth.

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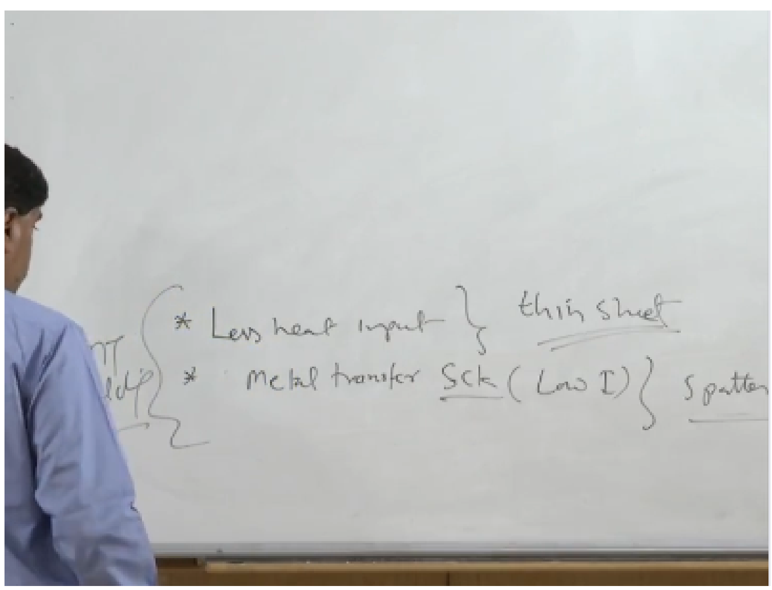

So this feature facilitates two things like very less heat input that is one and metal transfer in short circuiting way specially when current is very low. Low I or nil current. It is actually not nil current value. Value is very low so the molten metal is cold in that way. So because of this feature it is spatter free and the low heat input will facilitate the melting of the welding of the thin sheets.

So, this is what is called these are the two key features related with the cold metal transfer welding. If we will see it combines the positives of the pulse GMAW as well as additionally it uses the unique movement of the back and forth movement of the electrode which facilitates the touching of the molten metal drop to the pool for smooth transfer to the pool so that the weld joint can be –as the metal is transferred in a spatter free using the freeway, using the very low heat input.

Now, we will see some of the diagrams of their which are related with this transfer.

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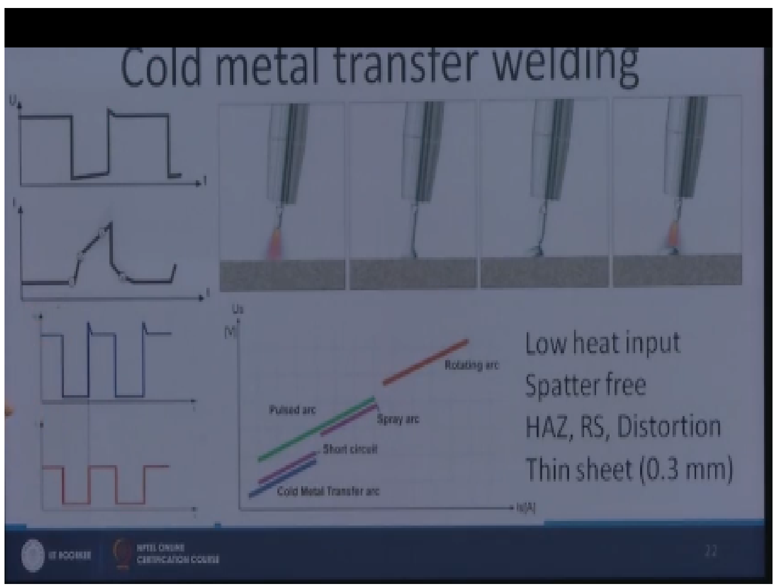

So, cold metal transfer welding. The current value is regulated as per the requirement and accordingly the voltage will also be changing when there is arc the voltage is high and once the gap is closed the voltage drops because in the short circuiting stage again as the drop is transferred again voltage jumps up. So, similarly when there is short circuiting current value is also less and then gradually it is increased.

So, now we will see these are the four diagrams we will be showing that this is the stage when there is welding arc and this stage the melting of the electrode tip will be facilitated once the drop is formed the electrode is advanced and then it touches to the pool or the base metal and once it is transferred by the short circuiting way then this electrode is retracted and the gap is created once again and the arc is stablished.

So, this cycle is kept on repeating. The conditions which are achieved for like where does this cold metal transfer arc welding exists so it is further lower then this is for short circuiting transfer. This is pulse arc. This is spray rotation arc. This is cold transfer arc. As far as the welding current and the speed and the voltage is concerned. So it works with very low voltage and very low current conditions and as far as advantage is concerned this process of very low heat input, spatter free.

And because of these two it offers very limited heat input, the heat affected zone, reduced residual stress and distortion and it is capable to weld very thin sheets that is what we can see here is one typical experimentation which was used for developing the joints of like say half mm thin sheet and the joint was made using the see empty process. However, it shows some of the pores and the blowholes.

So, nose here all the pores are of very science may be say 50 to 60 micrometer. But it is very isolated. So, here now we will conclude this presentation in this presentation I have talked about that how the CMT exploit the positives of the pulse GMAW and the conventional GMAW process and how it offers the good control over the heat in put good control over the metal transfer. So, that it becomes useful for joining of the thin sheets. Thank you for your attention.