Welding Engineering

Prof. Dr. D. K. Dwivedi
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

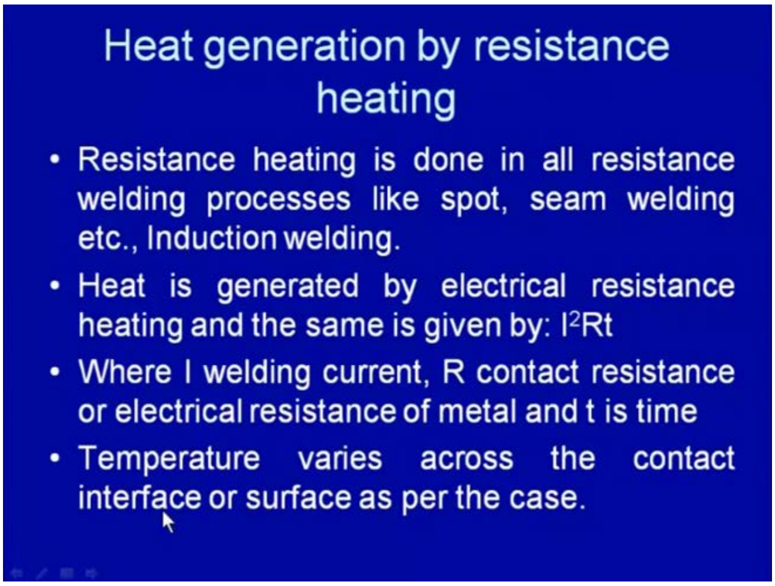
Module - 1
Introduction
Lecture - 4
Sources of Heat and Protection of Weld pool

So, we have seen that for developing the weld joints, we can use the different processes in which heat can be used or even without application of the heat just by using the pressure joints can be developed. But for the fusion welding process heat is invariably applied for melting the faying surfaces, and thereafter solidification of the weld metal gives the metallic continuity to produce the sound weld joint.

So, in the previous lecture we have seen that there are different sources which can be used for generating the heat, so that either the softening of the faying surfaces can be done or they can be brought to molten state by generating the heat using various approaches. The application of the chemical reactions to generate heat in case of the thermite welding you have described in the last lecture. And also the heat generation by the arc between the electrode whether it is of consumable or non consumable type and the base metal.

So, the heat generation by the arc and the various vectors affecting the heat generation by the arc were also discussed. In this presentation first of all we will take up the two approaches, which are used for generation of the heat for either melting of the faying surfaces or for softening the surfaces to be joined using the frictional effect or using the electrical resistances the heating.

(Refer Slide Time: 02:12)



So, here the first of all we will see that the how heat is generated by the electrical resistance heating approach and what are the various factors that affect the heat generation by electrical resistance heating. This approach is mainly used for developing the weld joint using the resistance welding processes like spot welding, seam welding, flash butt welding, stud welding, etcetera. In the resistance heating process or in this approach the faying surface is mainly heated by the flow of current which is allowed to pass through the components to be joined.

So, because of the high contact resistance at the interface the flow of current results in the severe and high electrical resistance heating. This resistance heating is done in all welding processes which are mainly resistance heating based like spot, seam welding. And in induction welding also the induced current causes the resistance heating and the heat generated is used for either melting of the faying surfaces or for thermal softening. The heat generated by the electrical resistance heating is governed by the equation typical equation known as I square R T where I stands for the welding current being passed through the components to be joined and R is the contact resistance at the interface and T is the time for which current is allowed to pass through.

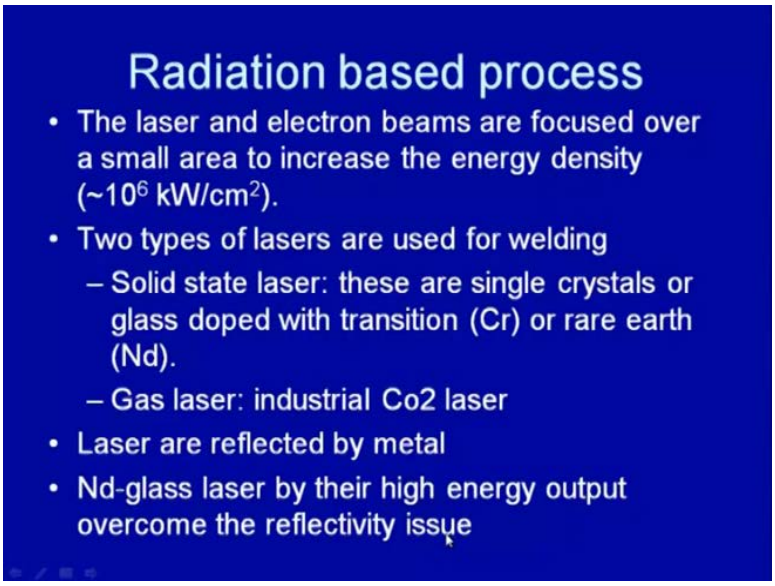
So, this is what has been mentioned here welding current in Amperes, contact resistance in Ohm and the time in seconds. And when the current is passed lot of heat is generated by the electrical resistance heating in the base metal also and at the contact interface.

However the heat generation in the base metal found lower because of the better conductivity of the metal systems. And while in case of the contact interface the high contact resistance at the interface results in the higher electrical resistance heating.

And which in turn results in the greater interfacial temperature which is required for the softening and partial melting of the faying surface is being joined by the electrical resistance welding processes. And accordingly the temperature varies across the contact interface and it is found maximum at the interface and then it keeps on decreasing in the base metal.

And then again the temperature is found slightly higher at the contact interface between the electrode and the work piece surface in both the sides. So, the temperature that is why varies in case of the electrical resistance welding processes, which are based on the electrical resistance heating generation. And this temperature variation is an integral part of the resistance heating processing in case of the resistance welding processes.

(Refer Slide Time: 05:26)



Heat can also be generated for developing the weld joints by melting the base materials using the radiations. And there are two commonly used form of the radiations like laser beam and the electron beam for melting the base material to develop the weld joint. Both these kind of the radiation can be focused over a very small area to deliver high energy density, are so that the melt small amount of heat can be used for melting the base material, and the weld joint can be made.

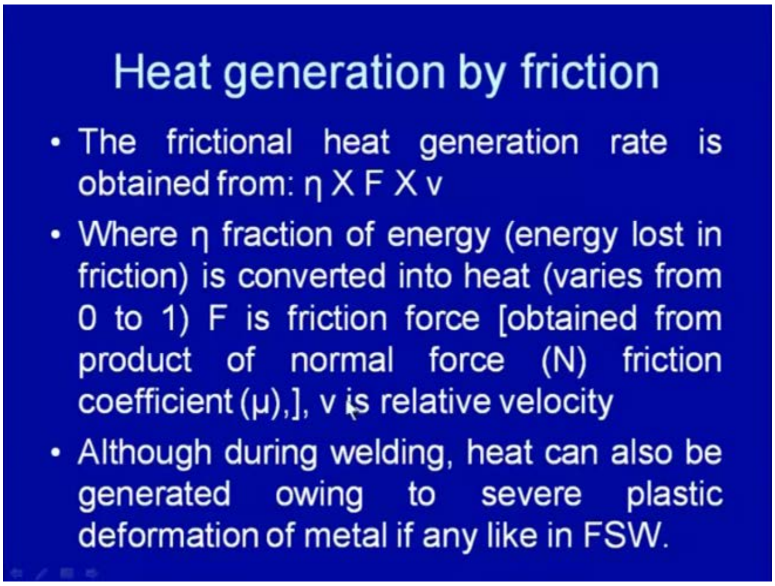
So, if we see here laser and electron beams are can be focussed over a small area so as to deliver the high energy density. This energy density can be as high as the ten to the power six kilo Watt per centimetre square or even higher. And this can be effectively used for melting as well as the ablation for the controlled removal of the material in case of the machined processes. But in case of the welding the somewhat lower amount of the energy density, lower energy density is used.

There are two types of lasers which are commonly used for the welding purpose like solid state lasers. These use single, they are single crystal or the glass doped with the transition elements like Chromium or the rare earth elements like Neodymium. And the gas lasers are used like the C o 2 laser which is very commonly used for industrial applications for welding as well as the machining purposes. But there is one problem associated with the laser that these are reflected by the shining materials like Aluminium.

So, to develop the weld joints of the Aluminium we need a extra care and additional steps to reduce this reflection of the lasers. But they still which shows somewhat lower reflectivity for these. The radiations are lasers they can be welded effectively, using the laser welding process. And the neodymium glass laser by their high energy output helps to overcome the reflectivity related issues.

So, because of this relation amount of the energy, which is actually used for melting the faying surface of the base material for developing the weld joint. This is somewhat adversely affects the speed of the welding. So, if somehow this reflection of the laser falling on the surface of the base material can be reduced, then this will help in increasing the welding speed. Another approach is the heat generation by the friction. And heat generation by the friction is commonly used in the solid state welding processes. Where mainly, the contact interfaces are made to move under the high normal force to have the higher frictional effect and then the higher relative velocity between the melting components to be joined, generates lot of heat.

(Refer Slide Time: 08:56)



So, the heat generation by the frictional effect can be given by this eta multiplied by the F, that is friction force and v is the relative velocity. Here eta is corresponding to the fraction of the energy that is converted into the heat. So, here eta the fraction of energy which is being consumed to overcome the friction or energy lost in overcoming the friction is converted into the heat and it varies from 0 to 1. And F is the friction force at the interface obtained from the normal force being applied, and the friction coefficient mu. And v is the relative velocity between the components to be joined.

Here this eta is an important component as it varies from 0 to 1. And if the most of the heat most of the frictional energy, energy being consumed in overcoming the friction is consumed, is converted into the heat than the eta value becomes closer to 1. And if that fraction is found to be very low means the fraction of the energy being consumed in overcoming the frictional effect then this eta value is found to be significantly lower.

So, depending upon the fraction of the energy consumed in overcoming the fraction which is converted into the heat then the eta value is governed by. So, further if we see this equation, if we can increase he frictional force in order to increase the frictional heat generation then it will help in the softening of the faying surface is easily. And to increase the frictional force we can increase the normal force.

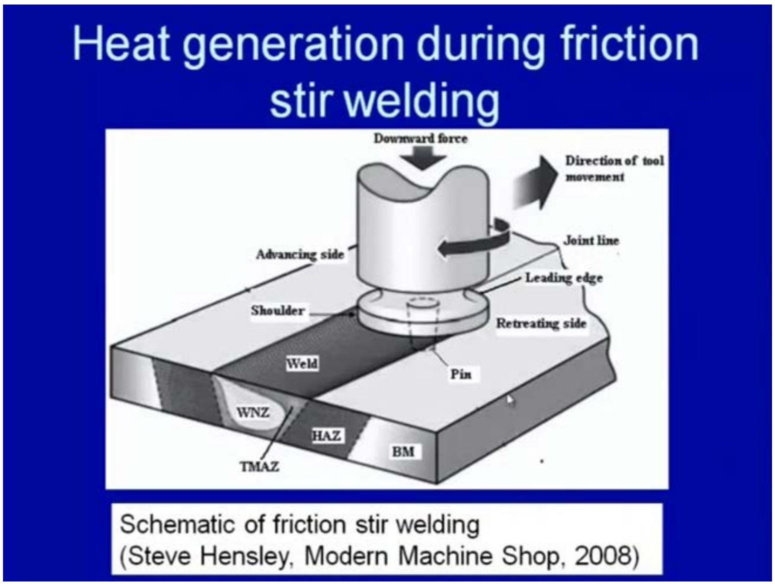
And at the same time increase in relative velocity will further help in localising the heat generated by the friction effect. And that is why all those processes, welding processes in which heat is generated heat generated by the friction is used for the softening of the faying surfaces. Usually high normal surface and the higher relative velocity is used. And like for example, frictional heating is very effectively used in friction welding processes of friction. Friction stir welding process and linear friction welding process, where the very high rotational speed is used to, rotational speed is used between the friction components or between the tool and the work piece being joined.

So, that if the frictional heat being generated can be localised significantly and as a thermal softening can be done, although during the welding heat can also be generated due to the plastic deformation of the metals. So, the heat generated in the processes like in friction stir welding also includes the heat generation by the plastic deformation. Because we know that in this welding process even high contact normal forces applied and the relative under the high relative velocity conditions some interfacial plastic deformation takes place.

So, apart from the frictional heat generation in the welding processes like linear friction welding and the friction stir welding the plastic deformation will be inevitable. And whenever they there is a plastic deformation of the metal some heat is always generated. So, this heat generation due to the plastic deformation, in addition to the heat generation by the frictional effect. Both are taken into account while considering the effect of the frictional heat generation in the welding processes like friction stir welding and which help in the softening of the faying surfaces to develop the weld joint.

So, these are the two other approaches which are used for the generation of the heat one by the frictional effect and another was that we have discussed today. So, we have seen that in this presentation that apart from the heat generation by the arc and by the chemical reactions. The heat generation by the friction and electrical resistance heating or the other approaches, which can be used for the softening of the faying surfaces or for melting of the faying surfaces so as to develop the weld joint. But there is another new process in which the frictional heat apart from the frictional heat the severe plastic deformation is also used for making the weld joints. And this is called the friction stir welding process.

(Refer Slide Time: 14:16)

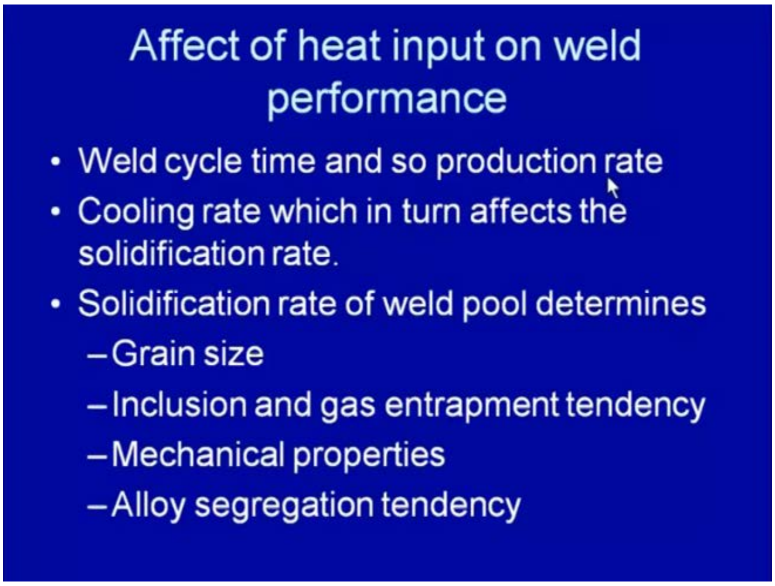


In this friction stir welding process the heat generated by the friction as well as the heat generated by the deformation both are effectively used for making the weld joints by softening the material. So, this is schematic diagram shows the scheme of the friction is stir welding process. Where the plates to be joined are kept in butting position with each other and then they are held firmly. And then tool having this shoulder and the pin are first the, that the pin is plunged when the tool is rotating. And once the plunging is over in this position the shoulder and the pin will be in contact of the base materials.

So, this relative motion between tool and the work piece develops the frictional heat. At the same due to this heat material is softened and it is deformed. Because of this deformation also heat is generated. So, combination of the frictional heat and the deformation heat softens the material, and by the extrusion and the forging action. So, material is transported from one zone to another developing the metallic weld joint. And this process is able to perform or develop the weld joints in the solid state without need of the melting and lot of work is being done on this process.

Now a days even efforts and being used for developing the weld joints of the high temperature materials like steel and titanium using the friction is stir welding process. Now, we will see that if the heat generation is less or more? Then how it can affect the performance of the weld joints? So, look into the way by which heat generation can effect performance of the weld joint. We need to see that what are the ways through which can effects?

(Refer Slide Time: 16:19)



Like if the heat generation is more during the welding like A infusion welding processes. Then more heat generation and application of the more heat will increase the time required to supply the welding current first. And the time required to solidify, the weld metal which in turn increased total weld cycle time.

So, because total weld cycle time includes the time during which the current is supplied, and the N after solidification cooling down to the room temperature. And if more heat is applied then it will increase the time required to complete a weld cycle. And the longer weld cycle time will increase, will decrease the production rate or the number of way the units that can be produced or the length of the weld that can be made.

So, longer weld cycle time and decreased production rates are the things that are affected by the higher heat generation like in the fusion welding processes. And heat generation also effects the rate at which the weld metal will be cooling. Since if the heat generation and the heat application is more in case of the fusion welding processes that it will be, then it will be decreasing the cooling rate. And decreasing the cooling rate will be increasing the time required to solidify.

So, solidification rate will be decreasing and the decreased solidification rate effects the soundness of the weld joint in number of ways like say, the solidification rate of the weld pool determines the grain size, inclusions in the gas, entrapment tendency, the mechanical properties and the alloy segregation. So, the heat generation in the weld pool effects one the weld cycle time. And so the production rate and weld heat generation also effects the cooling rate which is experienced by the weld pool and the heat affected zone during the welding. And effect of the cooling rate in the weld pool directly affects the solidification rate and which in turn effects the grain size.

For example, higher the cooling rate higher will be the solidification rate, lesser will be the time required to solidify and which in turn will decrease the grain sizes. Because the each micro constraint will not be getting enough time to grow to the large extent and which in turn will decrease the grain size. However the inclusion and the gas entrapment tendency increase the with the increase of solidification rate, because increase in solidification rate due to the high cooling rate decreases the time required for solidification of the weld metal.

And therefore if at all any inclusion is present or gases in the dissolved state are present in the molten weld metal then these inclusions and gases will not be able to come up to the surface of the weld pool. And that is why they will show the greater tendency for entrapment in to the weld pool. So, the lower heat input higher cooling rate and the higher solidification rate. And higher solidification rate will be increasing the inclusion and the gas entrapment tendency and if we see these two things are just opposite to each other. It is always desirable to have the finer grain size to have better mechanical properties while they increased an entrapment tendencies for inclusions and the gases will adversely affect the mechanical property.

So, if somehow we can avoid the inclusion and presence of the inclusions and gases in the weld pool, then it will always be favourable to have the finer grain size using the higher solidification rate. And which can be achieved by heat input to the weld pool. So, if the finer grain size can be produced free in the weld which is free from the inclusions and the gas entrapment, then the mechanical property is will certainly improved while in case of the, when the inclusions and the gases are entrapped in the weld pool.

So, despite of having the finer grain size mechanical properties can deteriorate significantly. Especially the notch toughness fortic performance, where these sides act as a high, as a location of high stress concentration, which in turn will be decreasing their mechanical properties in respect of the fortic and notch toughness. The another important point is that the heat input also effects the alloy segregation tendency, because the greater higher heat input reduces the solidification rate. Decreasing solidification rate increase the solidification time and this in turn will lead to the greater alloy segregation tendency.

While in case of the high cooling rate, less time is available for the solidification and the low melting point will not get low melting point. Phases will not be getting enough time to get distribute and that is why low melting point elements. And the phases will not be getting enough time to segregate and that is why high cooling rate will result in the lesser segregation tendency.

And that is why if we see the weld joints which are made using the low heat input process like the tig welding and the plasma arc welding. They show the lesser segregation tendency as compared to the joints which are made using the submerged arc welding or the electro-slag welding where the high heat input facilitates the lower cooling rate and so the higher segregation tendency.

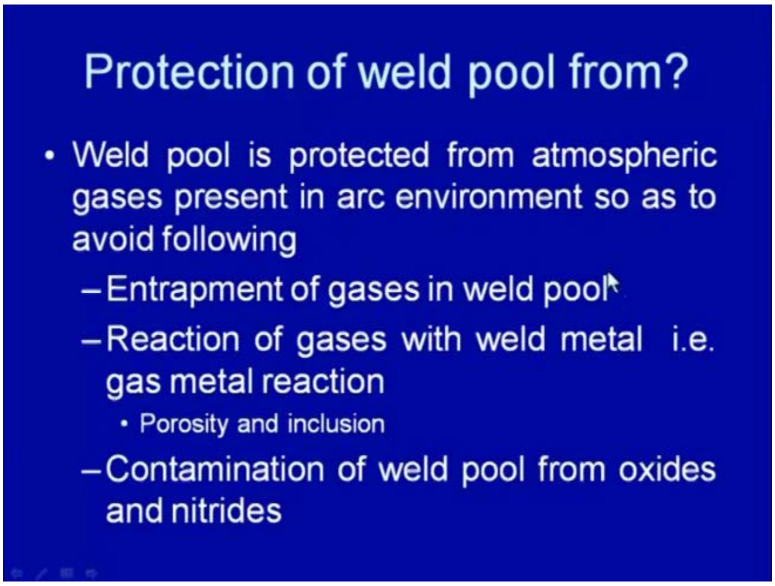
If we see that the heat generated and applied to weld pool developing weld joint can affect the production rate because of the effect on the weld cycle time. And it can also affect the cooling rate. So, the cooling rate indirectly affects the solidification rate and the solidification rate dictates the grain size inclusion in the gas entrapment tendency mechanical properties and the low segregation tendency.

So, once the heat is generated and it is applied to faying surface, so depending upon the process either melting of the faying surfaces can take place or they can be softened to the greater extent, where application of the forging pressure or required force to get the metallic continuity and get the weld joint.

(Refer Slide Time: 24:14)

But in those processes where the fusion of the faying surfaces take place it becomes important to protect the molten weld pool which is being generated along the edges of the plates to be welded. Because the molten weld pool becomes very active in respect of the their reaction with the surrounding gases their ability to absorb the gases from the atmosphere. And these activities means this increased activity of the molten weld metal in the weld pool makes the weld pool sensitive to have the impurities and undesirable the constituents which can adversely affect the performance of the weld joint. That is why it becomes mandatory to protect the weld pool using the suitable approaches.

(Refer Slide Time: 25:11)

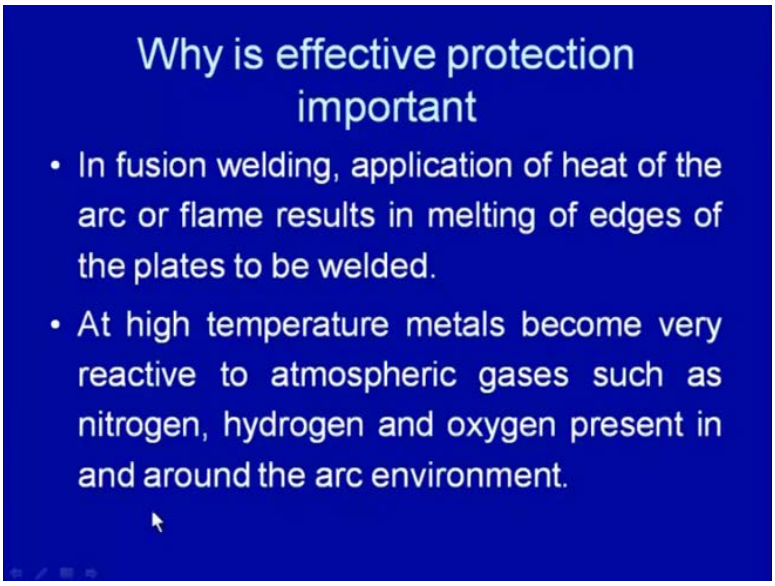


We will see in detail that what is the need of protecting the weld pool? And what are the various approach being used for protecting the weld pool. And how the each approach is found to be effective or is found to be found to have the different effectiveness as compared to the other welding processes. So, if we see that what is the need to protect the weld pool from the atmospheric contamination? It is important that weld pool is protected from the atmospheric gases present in the arc environment so as to avoid the entrapment of the gases in the weld pool.

The atmospheric gases which are present in the arc environment if they are not taken care of properly then under the high solidification rate, conditions of the weld pool these gases can entrapped and can lead to the gaseous defects in form of blow holes and the porosities. Further these gases can also react with the molten weld metal and reaction of the molten these gases present in the arc environment can lead to the development of the undesirable reactions in form of the gas metal reactions. This may result in the formation of the oxides, nitrides and the dissolution of these gases with the molten metal, which can produce the porosity and inclusions and further the contamination of the weld pool from the oxides and nitrides. And these can lead to have very adverse effect in the mechanical performance of the weld joint.

So, if we see that if the atmospheric gases present in the arc environment lead to their entrapment resulting in the porosity and the inclusions. And further these gases reacting with the weld metal can form variety of oxides and nitrides. And which can lead to have the undesirable micro constituents in the weld pool. So, if these micro constituents present in the weld pool in the solid state they are not separated from the weld pool, then these will be present in the form of inclusions which will act as a side for weakness and increase stress concentration which will deteriorate the mechanical performance as well as corrosion resistance of the weld joints. That is why it becomes mandatory and important to protect the weld pool from the atmospheric contamination.

(Refer Slide Time: 28:14)



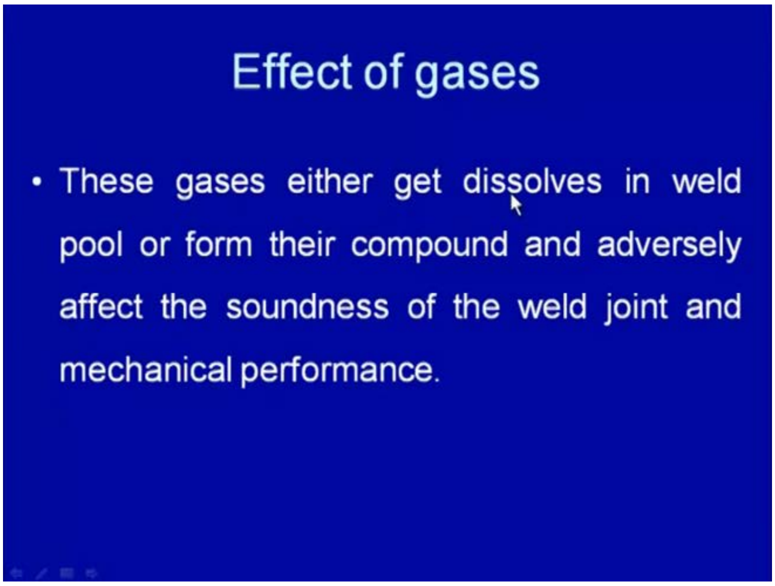
Further if we look into why we should protect the weld pool especially in the fusion welding processes. Because when we apply lot of heat, so with the help of either arc or using suitable flame, so as to melt a faying surfaces the molten metal of the faying surface obtained from the faying surfaces in the weld pool or the molten metal coming from the electrode tip after the fusion of the electrode and becomes very active at the high temperature to the atmospheric gases.

And these gases can react very rapidly with the metals like aluminium, titanium, magnesium. And even in case of stainless steel the chromium can react with these gases very rapidly to form those oxides and nitrides which will not either dissolve rapidly or they will remain present in the weld pool in inclusions because of the similar density like the base metal or the weld metal.

So, at high temperature because of the high reactivity of the molten weld pool with the atmospheric gases such as nitrogen, hydrogen and oxygen which are present in the arc environment. If the proper protection is not given to the weld pool then these gases will react and will form their oxides an nitrides and hydrides which will act as a inclusions. And these inclusions will deteriorate the mechanical performance to the weld joint. Also they will decrease the soundness of the weld joint.

That is why especially in case of fusion welding process processes the protection of the weld pool becomes very important. This protection may not be important that much in the case of resistance welding processes or the solid state welding processes where the faying surfaces are heated mainly to achieve the softened state. So, that there yield strength can be reduced and the melting is not achieved in those processes.

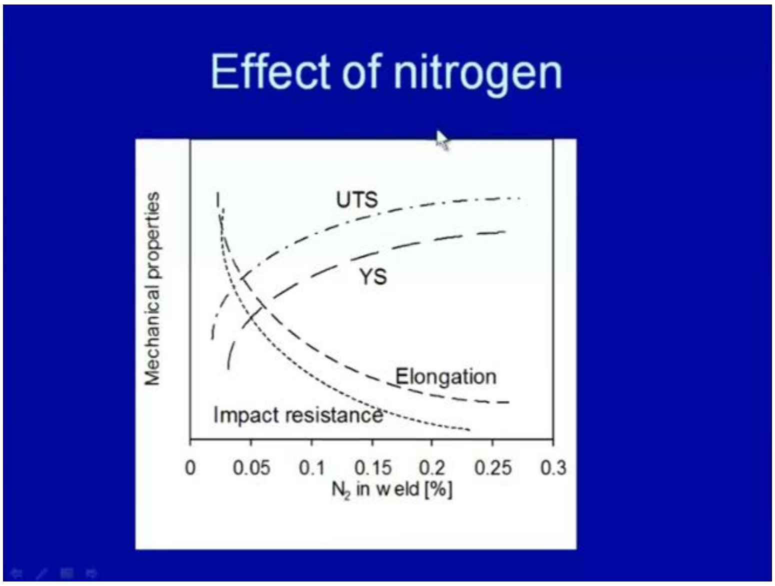
(Refer Slide Time: 30:43)



So, when these gases present in the arc environment they can work in different ways. The one common way is that these gases because of their high solubility with the molten metal they get dissolve in weld pool. And if not enough time is given for these gases to come out of the weld pool during the solidification then these can get entrapped in the weld pool and produce that gaseous defect in the weld joint. And another way by which these gaseous can work is that they can form the compounds.

And these compounds if are having the density similar to that of the weld metal then these will remain with the weld pool and will be there even after solidification in the weld joint. And if these will remain there with the weld joint then they will adversely affect the soundness of the weld joint and which in turn will decrease mechanical performance. So, these gases therefore must be expelled or these gases should not be allowed to be there in the arc environment. And for this purpose the different approaches have been developed and are being used.

(Refer Slide Time: 32:16)



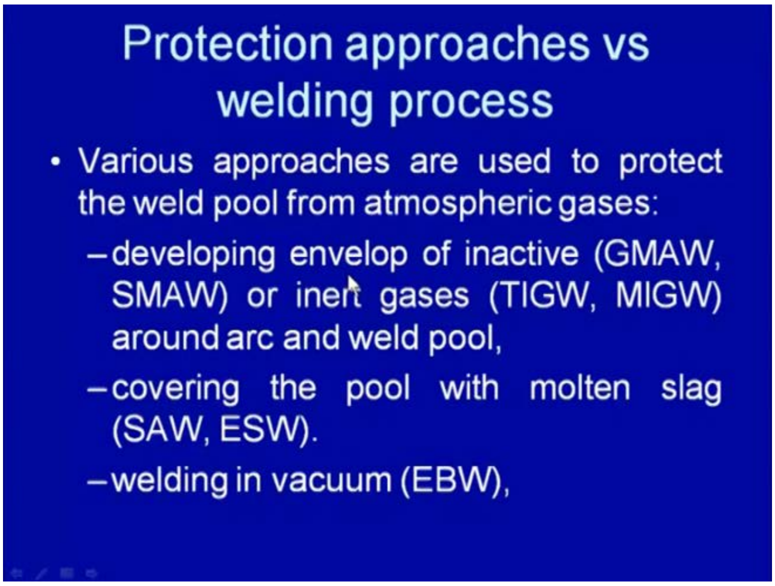
Just for an example if we see that if the nitrogen is present in the arc environment it can easily react with the iron and can form iron nitrides. Formation of iron nitrides in form of the needle shape is a very hard and brittle micro constituents adversely effects the mechanical properties. If we see that if nitrogen is increased in the weld meant because of the atmospheric contamination ranging from very small magnitude to the higher level. Than it is adversely effects the impact resistance and the elongation while tensile strength and the yield strength increase.

And this variation mainly attributed this increase in strength and the hardness increase in tensile strength and the yield strength is mainly attributed for the formation of the hard and the brittle needle, shaped iron nitrides and the decrease in elongation. And the impact resistance is because of these hard and brittle needle shaped iron nitrides which provide easy site for nucleation of the voids. And nucleation of the crack at the needle and the iron matrix interface especially at the tip of these needles promote the easy nucleation and the crack. And this in turn decreases the elongation and similarly higher presence of iron nitride hard and brittle iron nitride needle also decreases the impact resistance.

So, it is not desirable to have the lower impact resistance and the elongation because most of the engineering components and the weld joints are subjected to the impact loading and fortic loading during the surveys and the actual service conditions. So, if the impact resistance is very poor then the weld joint will not be able to survive during the engineering application or during the service. So, it is not desirable to have the nitrogen in the large quantity unless the steel itself is designed to have the higher yield strength and the tensile strength with the great compromise over the toughness and elongation for those applications, where the impact resistance and the fortic loading is not expected to take place during the service.

So, similarly the oxygen and the hydrogen also adversely affect the performance of the weld joint and its soundness. Because the presence of the excessive presence of the oxygen forms the oxides, iron oxides and oxides of aluminium, chromium, magnesium depending upon the kind of elements which are present in the metal being welded. And these are oxides act as a inclusion and deteriorate the mechanical performance of the weld joint.

(Refer Slide Time: 35:26)



Similarly, if the presence of the hydrogen in the arc environment can effect the soundness of the weld joint in two ways; one is it can get dissolved with the weld metal and produce the hydrogen induced porosity and other porosities distributed in the weld. And another way is that especially in case of the harden able steel weld joints the presence of the hydrogen in the arc environment can lead to the cold cracking or hydrogen induced cracking.

So, increased tendency for the cracking of the weld joint especially from the heat effected zone is promoted by the presence of the hydrogen in the weld joint. That is why it becomes important to protect the weld pool from the presence of the atmospheric gases such as oxygen, nitrogen and the hydrogen from the arc environment. And therefore, various approaches are used for protecting the weld pool from the atmospheric gases so that the sound weld joint and the better mechanical properties of the weld joint can be obtained. For this purpose various approaches are used to protect the weld pool from the atmospheric contamination.

They are three main approaches for protecting the weld pool for avoiding the atmospheric. One is developing an envelope or shield of the inactive gases. Inactive gases includes the carbon dioxide or the mixture of the organ and the carbon dioxide in the different proportions. And these envelope or shielding of the inactive gases is mainly used in the welding processes like the gas metal arc welding process or shielded metal arc welding process.

So, these inactive gases are formed all around the arc zone and that helps to protect the weld pool. Similarly, the inert gases helium and argon can be used to protect the weld pool from the atmospheric contamination. And this is mainly done by supplying a jet of the inert gases like helium and argon around the arc through the nozzle. So, this approach is mainly used in the tungsten inert gas welding process and the gas inert gas of metal inert gas welding process.

There is no major difference in the GMAW and the mig welding except the difference is of the shielding gas which is used in case of the metal inert gas welding process, inert gases is used. While in GMAW process mainly the inactive gases are used to protect the weld pool, another approach apart from developing a shield or cover or envelope of inactive gases or inert gases to protect the weld pool. The second approach is to cover the weld pool using molten slag. This molten slag is formed during the arc welding process itself where heat of the arc melts the flux, which is present either in form of the granular material or with the or in form of coding around the electrode.

So, this molten flux forms the cover along the weld pool and avoids the entry of the atmospheric gases in the arc environment. And this approach is mainly used in submerged arc welding and electro-slag welding. In case of submerged arc welding whole of the electrode is burred or submerged under the cover of the flux or the pool of the flux.

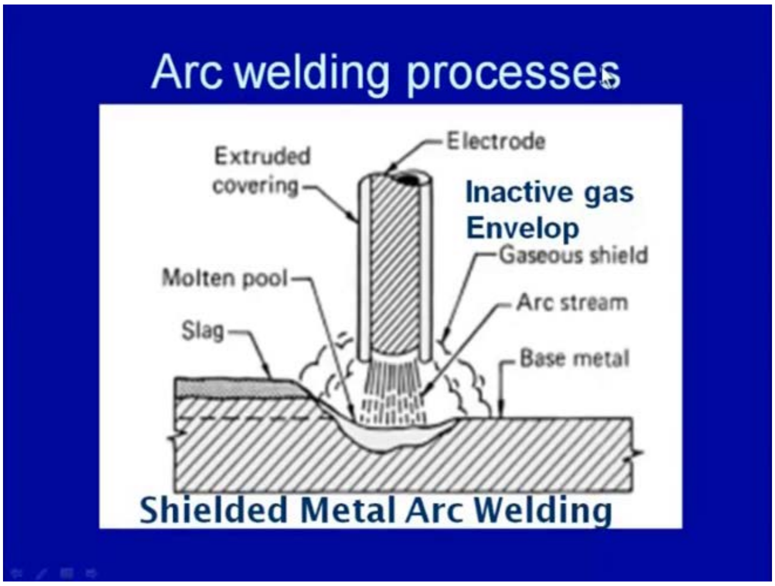
So, when arc is established that flux melts and form the shield of the molten slag and molten flux around the arc and so protects the weld pool from the atmospheric contamination. Similarly, the first in lector-slag welding, the first huge pool of huge the pool of or the amount of the the flux is made first and then initially the arc is ignited. That arc melts the flux and then when lot of flux is brought to the molten state supply of the current causes the electrical resistance heating and the heat generated causes the melting of the faying surfaces.

So, formation of the molten flux pool protects the molten metal coming from the electrode and coming from the Baye's metal. So, the molten flux and molten slag approach is used to protect the weld pool in case of the submerged arc welding and electro-slag welding process. Another approach is the welding in vacuum like the metal systems which are highly active to the atmospheric gases.

This and for those applications where high quality weld joints are required like the titanium weld joints for aerospace applications are for the nuclear reactor components. The welding of stainless steel, magnesium alloys, titanium alloys and the nickel alloys for critical applications are welded in vacuum, so that any sort of atmospheric contamination can be avoided. And this approach is mainly used in the electron beam welding processes.

So, here we can see to protect the weld pool. There different approaches available and each welding process uses the different approach for protecting the weld pool. And these are mainly like shielding the weld pool using the inert gas or inactive gases covering the weld pool with the help of molten flux or molten slag and performing the welding in vacuum itself so that all the atmospheric gases can be taken out, and so as to avoid their entry in the arc region. If we see that the different approaches how the different approaches are being used in the different welding processes.

(Refer Slide Time: 42:48)

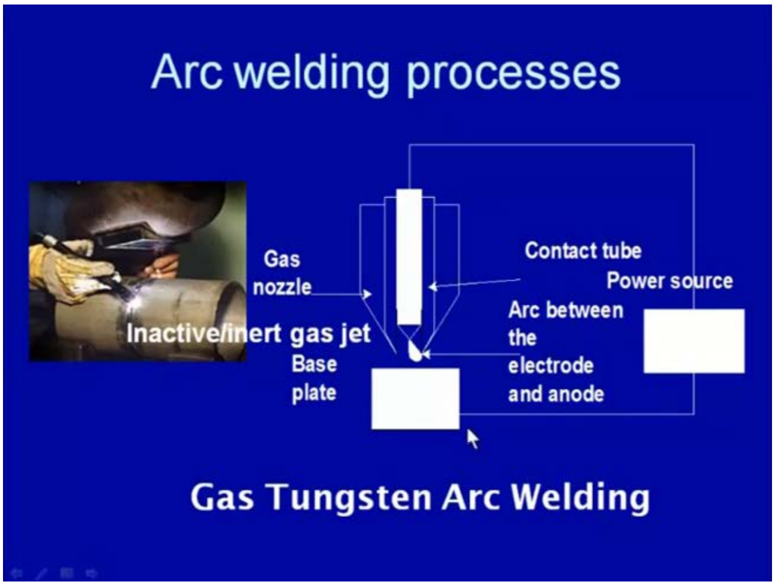


Say for example, in case of shielded metal arc welding process it uses the consumable electrode. And this consumable electrode mainly has a covering of the flux all around it. And this covering of the flux is decomposed with the help of a heat generate by the arc between the electrode and the base metal.

So, these when heat generated by the arc decomposes the flux covering present all around the electrode it generates lot of inactive gases all around the weld pool and thus forms the shielding of the inactive gases. Mainly these are the carbon dioxide and carbon monoxide and nitrogen are said related gases. And these gases forms a cover all around the arc and the weld pool so as to correct it from the atmospheric contamination. But this kind of shielding is not found to be very effective, because the heat these gases generated form the cover on their own and there is no specific deriving force to form a complete cover or shielding all around the weld pool.

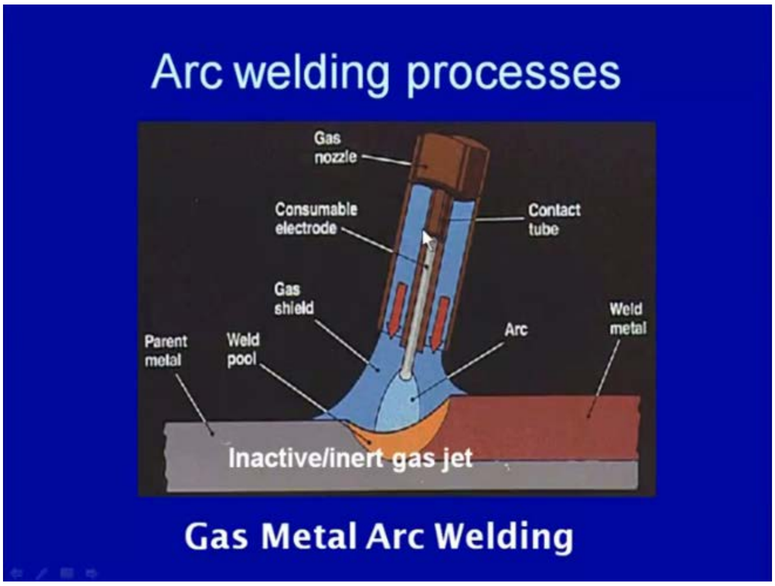
And that is why there is always some possibility for atmospheric gases to be present in case of in weld pool. And that is why the quality of the weld joint produced by the shielded metal arc welding process is not that good, because this approach although helps in protecting the weld pool from the atmospheric contamination to some extent. But not all the atmospheric gases are not eliminated by this approach, and their entry is not completely restricted. And that is why for better quality and the higher quality weld joints this lead metal arc welding process is not used.

(Refer Slide Time: 45:05)



And the arc welding processes like the gas tungsten arc welding process where the heat is generated by arc which is established between the tungsten electrode and the work piece. And this arc is found to be have very short in length, very short arc length. And it is completely shielded by jet of the inert gases like helium or argon and forms very sound cover around the weld pool. And the formation of inert gas jet cover by the inert gases provides very effective shielding in case of gas tungsten arc welding. Further a shorter arc length and the use of non consumable electrode further helps in protecting the weld pool by this jet of the inert gases in case of the tungsten arc welding processes.

(Refer Slide Time: 46:13)

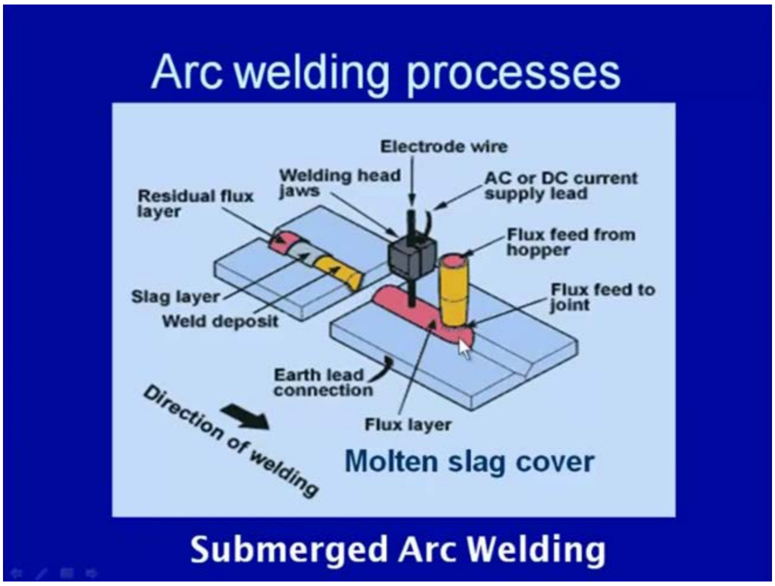


The mig welding is the another gas metal arc welding process another process where consumable electrode is used. And the arc established between the consumable electrode and the base metal and for protecting the weld pool from the atmospheric contamination. A jet of the shielding gas either inert or inactive gas can be used for the gas metal arc welding process. So, here one jet of the shielding gas is used to protect the weld pool and avoid the atmospheric contamination. But the application of the consumable electrode somewhat larger arc length in associated with these process reduce the effectiveness of the shielding being provided by the inert gases and the inactive gases application.

So, therefore the gas metal arc welding process despite of using the jet of the shielding gases in form of inert gas or inactive gases do not provide that much shielding from the atmospheric contamination. And that is why the soundness of the weld joint in respect of the inclusions and the porosity in which are produced by the gas metal arc welding process are not that sound, as that can be produced by the gas tungsten arc welding process.

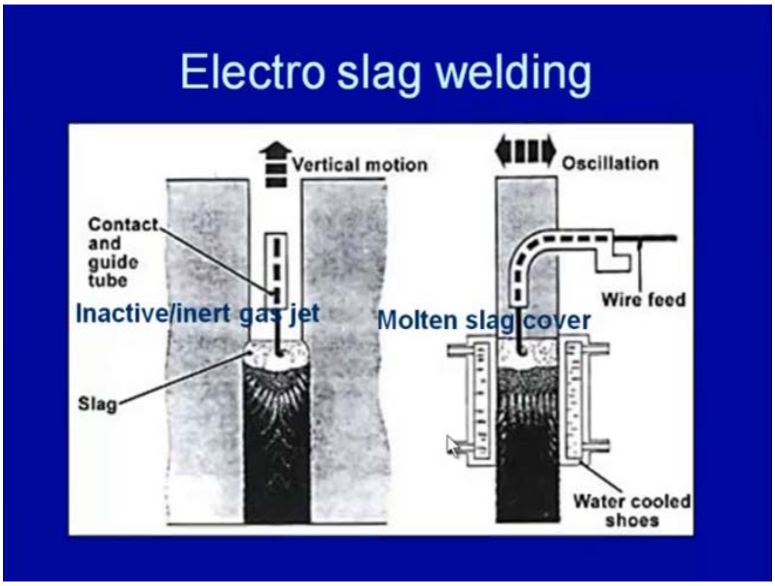
So, the quality of the weld joints produced by gas tungsten arc welding process is found to be better than the gas metal arc welding process, because use of the larger arc length and the use of the consumable electrode decreases the effectiveness of the gas metal arc welding process. Despite of using the jet of the shielding gas all around the arc the submerged arc welding process is the another one way where production of the weld pool is carried out by supplying with the help of the molten slag.

(Refer Slide Time: 48:18)



Here the electrode is submerged under the flux and the arc is established between the electrode and the base metal heat generated by the arc melts the flux cover and the molten flux further forms cover all around the arc and that is how it is protects weld pool from atmospheric contamination. So, here molten slag and molten flux cover around the arc helps to protect the weld pool from the atmospheric contamination.

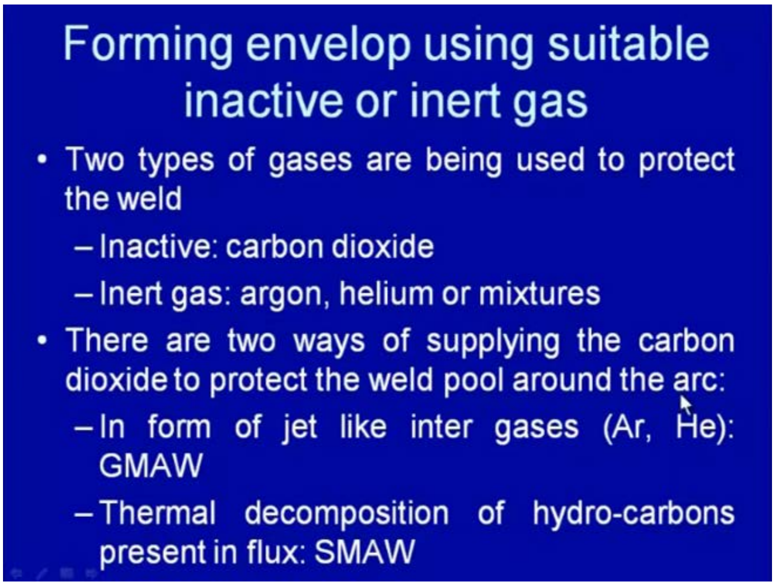
(Refer Slide Time: 49:08)



Similarly, in case of the electro-slag and the electro gas welding processes also the first the arc is established. And then in case of the electro-gas welding process the arc is established. And here the slag and the molten flux is protected either with the help of the inert gas which is supplied all around it. In case of the electro-gas welding process the inert gas supply or inactive gas supply is made to protect the weld pool. While in case of the electro-slag welding process, the molten slag helps to protect the molten weld pool from the atmospheric contamination.

So, these are the two approaches which are used in electro-slag and electro gas welding processes. In case of electro gas welding process the jet of the inert or inactive gases supplied to protect the weld pool while in case of electro-slag welding process the molten slag covers the weld pool and it protects it from the atmospheric contamination. Now we will see that if we use the approach of forming a cover or shield around the welding arc to protect the weld pool from atmospheric contamination, what are the various important factors that should be looked into and the factors that can effect the effectiveness of this approach?

(Refer Slide Time: 50:43)

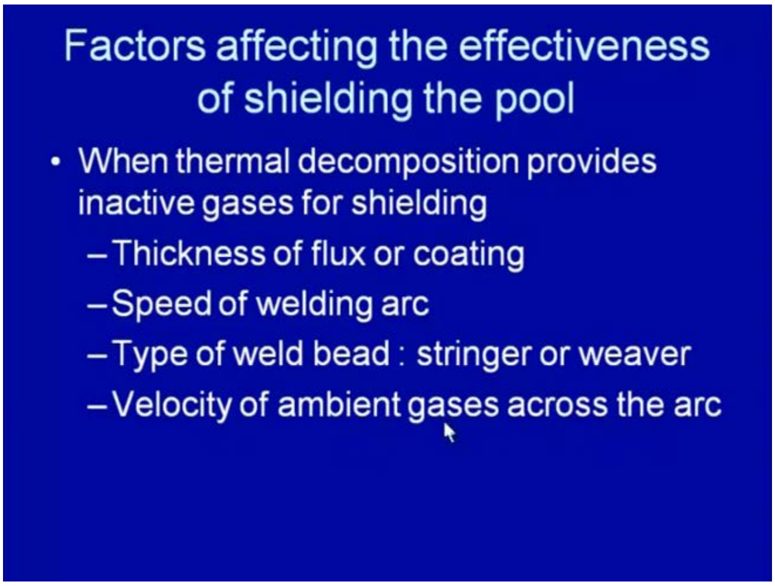


So, the forming envelope using the suitable inert, and active gases using this approach. If we see what we can use for protecting the weld pool from a atmospheric contamination. There are two types of gases which can be used. One is inactive gas like the carbon dioxide. If this gas does not react easily with the molten weld metal in the arc environment however some amount of the decomposition of the carbon dioxide takes place and that releases the oxygen and leads to the contamination of the weld pool from the oxygen.

But reasonably good quality of the weld joints are produced in case when the carbon dioxide is used as a shielding gas. When the inert gases like helium or argon or mixture of argon and helium is used we get very good quality weld joint. But these gases are costlier then the carbon dioxide. And if we see here there are two ways of supplying shielding or forming an envelope around the weld pool to protect it from the atmospheric contamination. One is we can form a jet like of the inert gas like argon and helium in case of the gas metal arc welding or in tungsten arc welding.

So, one approach is like forming a jet all with the help of jet a cover is formed around the arc. And another is that the using the flux or the coating material having the large percentage of the hydrocarbons. These are decomposed and their decomposition results in the formation of the inactive gases around the arc, like in case of shielded metal arc welding. So, these are the two ways through which the inert or inactive gases can be used to form a cover around the weld pool to protect it from atmospheric contamination, so forming a jet and the thermal decomposition of the hydrocarbons present in the fluxes.

(Refer Slide Time: 53:09)



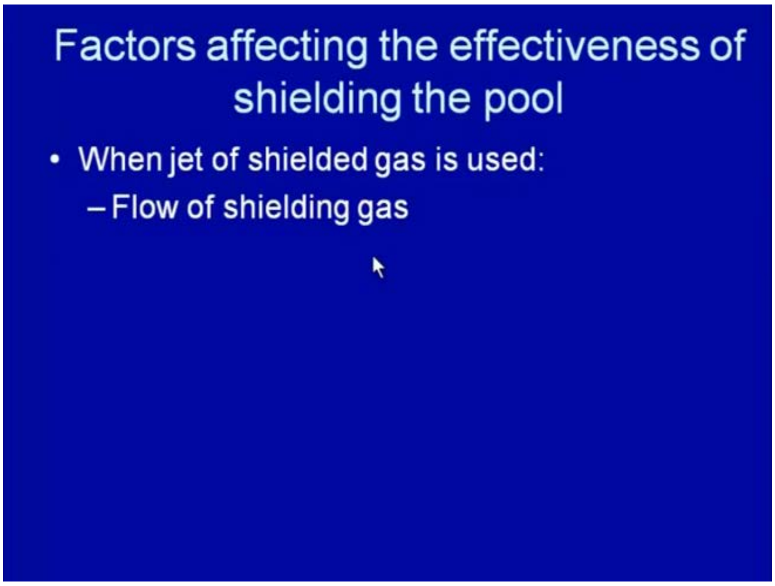
So, here if we see that what are the factors that affect the effectiveness of this approach where shielding is done of the weld pool inactive or inert gases. When we use the thermal decomposition approach like in shielding metal arc welding, where heat of the arc is used to decompose the hydrocarbons and develop the inactive gases for the shielding gases. The amount of the flux which is present in the consumable electrode, more is the amount of flux more will be the decomposition of the these. The hydrocarbon and greater will be the amount of the inactive gases that will be generated to provide the effective shielding.

So, this the thickness of the flux is important when this approach is used. If the flux coating is a flux or the coating thickness is very less than inefficient amount of the shielding gases around the arc will further decrease the effectiveness of this method. Another factor that can affect the effectiveness of the if this approach of shielding is the welding speed. If the arc is moved slowly then the gaseous environment around the arc will not be disturbed much.

While welding at high speed increases the relative speed between the arc and the atmospheric gases all around it. And which in turn decreases the effectiveness of the shielding by this method. By low welding speed helps to provide the better shielding then the high speed and the type of the weld bead is the another factor effect the effectiveness of the shielding. By this approach in case of the stranger bead the shielding cover will be disturbed less and we will form a continuous cover to protect the weld pool. While in case of the viewer bead the arc case viewed and moved very randomly in different paths.

So, the protection of the weld pool by this approach adversely affected the stranger bead in that way offers the better shielding is compared to the viewer bead. Another factor is the velocity of the ambient gases across the arc. If the velocity of the ambient gases across the arc is more than all inactive gases being formed by the thermal decomposition. It will be taken away or moved away by the ambient gases and which in turn will decrease the effectiveness of the shielding. And therefore, the higher ambient higher velocity of the ambient gases should be avoided and the proper protection to the arc is given.

(Refer Slide Time: 56:23)



So, another factor is that the factors affecting the effectiveness shielding gases. Effectiveness of the shielding by the pool is in case of the, in case when jet is used that like what is the flow rate of this shielding gas is higher flow rate or the lower flow rate. High flow rate is desired to have the effectiveness effective shielding all around the arc. So, in this presentation we have seen that the two approaches of the generating heat for developing the weld joint.

One was the electrical resistance heating and another was the frictional heating. Apart from that we have also seen that what is the importance to protect the weld pool and various approaches to protect the weld pool, we will see the things in detail about other approaches which are effecting the effectiveness of the protecting weld pool by the different methods.

So, thank you for your attention.