Finite Element Modeling of Welding Processes

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Module – 01
Introduction to welding processes
Lecture – 02
Fusion welding – 1

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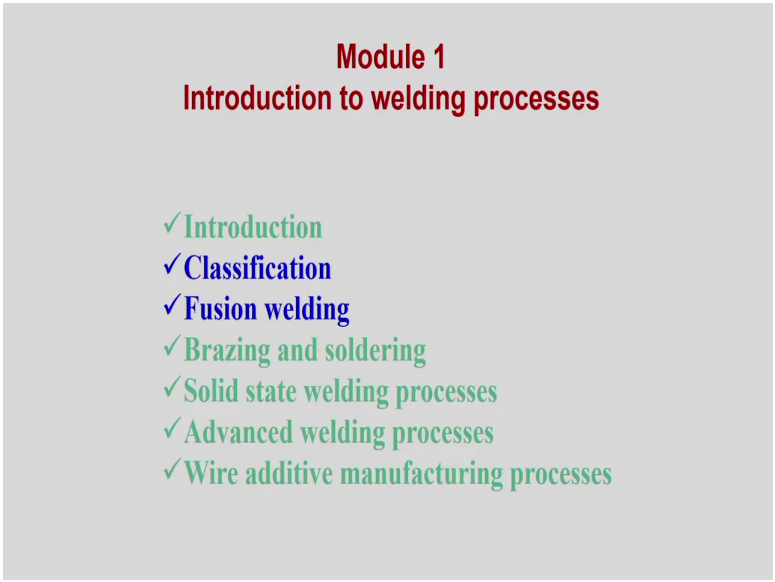

Hello, everybody. Now, we will discuss part 2 of the module 1. Basically I have already explained this thing the introduction; that means, we explained the different type of the material properties, the basics which is required to develop a one finite element model in particular to manufacturing process or in particular the fusion welding processes.

So, the different processes, materials that we have discussed now we will try to look into the different welding processes, what way we can classify them and specifically to do we will discuss only on the different fusion welding processes. But, the objective here is not to explain in details, objective the practical aspect all these things not like that, rather I will try to focus the know about the basics of these different types of the fusion welding process is which normally we use in most of the applications.

And, we will try to get some overview of this different type of the fusion welding processes and from there we will see what way we can develop the model; that means, we try to understand the basics physics behind this fusion welding processes that is the main objective of this particular lecture.

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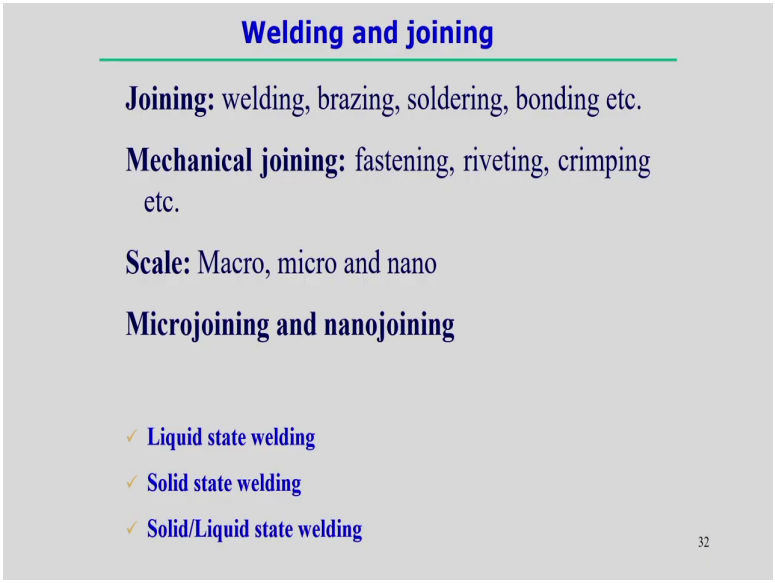

Now, we start with this thing welding and joining. If we look into that over all we can always say that it is a kind of welding and joining processes not only welding or not only joining processes because in some part you can categorize these joining processes something like that it is includes all these processes welding, brazing, soldering, even bonding.

And, sometimes it includes the mechanical joining processes as well. That is why in general we say that different welding and joining processes, but our focus is not into the mechanical joining or other joining processes rather I can say the only fusion welding processes is the focus of this course.

Now, mechanical joining process the fastening riveting that is also joining crimping etcetera that is also joining processes and the two material two components can be joined by some mechanical means simply we can join the permanent join or semi permanent join can be done using some kind of the mechanical means.

So, that is not our scope of discussing in this part particular. But, overall the different welding processes or we can say the joining processes we can divide into two different scale maybe we can say micro and nano scale. Actually normally macro scale and the micro scale these are the basic divisions of the different welding and joining process over which we can analyze the different processes.

But, nowadays the nano joining is basically gradually developing this particular the very nano sized components. They are also on nano devices or micro devices also there may be necessary to join two different components and that is the part of this nano joining technology. But, that is not in the scope of discussion, but till that area is basically evolving nowadays.

So, micro joining and nano joining is other. It is a simply we can say that scaling down of the welding processes; that means, we know the conventional welding processes, the existing welding processes, but depending upon the application miniature of the components there is need some micro scale application of the welding processes. So, that is called we can say the

micro scale it is basically nothing, but the difference from the conventional in the form of a scale.

And, similarly in nano joining processes has also been developed or it is a further reduce the scale analyze all these processes the mechanism of the joining then we can that is comes under the nano joining processes. So, micro joining processes can also be possible to develop under the microscope also and that may be required in kind of some micro devices, memes structure, there you can get a lots of application of the micro joining processes.

Even some medical devices and medical component if you want to develop there also we can find out the a lots of application of the micro joining processes. We will discuss on that the one part is there the micro joining processes, the advancement of this micro joining process we will discuss on the particular thing.

But, broadly the welding processes can be classified in this way maybe we can say the liquid state welding, solid state welding and solid or liquid state welding. So, liquid state welding means the joining may happens it is necessary to raise the temperature the of these components of these materials above the melting point temperature. Then after that if you allow solidification, then two components can be joined that is called the liquid state welding.

But, solid state welding processes also the joining of the two components can also happen below the melting point temperature, but it is almost close to the melting point temperature that is the solid state welding processes. That means, in principle solid state welding process it will never cross the melting point of a particular component in a particular joining system and then solid and liquid state welding process means we are not joining two different components.

For example, brazing and soldering process in this case maybe parent material not necessary to melt, but the filler material has to be melted and then two materials can be joined together. So, one metal is in the solid state and may be all other metals maybe necessary to liquid state.

So, that is why the brazing and soldering its this joining technology is comes under the solid and liquid state welding process.

So, these are the three different categorization of the welding processes we can say, but there are so many welding techniques following this kind of the principle. For example, liquid state welding process there are so many welding technology has been developed and similarly solid state welding process there are so many welding processes has been developed.

We will discuss, few of them we will discuss and then of course, solid and liquid state welding also we can say this brazing and soldering is the one kind of this processes.

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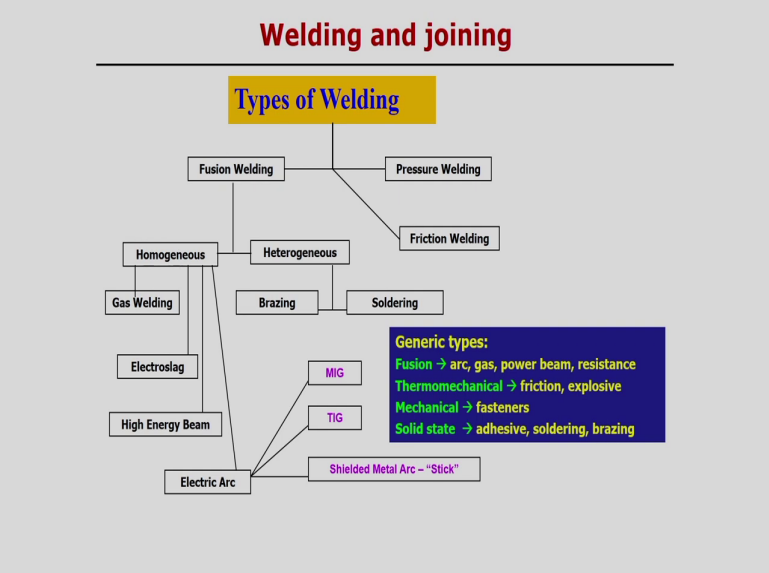

Now, if we do further classification look into the what are the different welding and joining processes so, types of welding maybe we can look into that. Fusion welding maybe this is the

one category is that things; then pressure welding is the another category, that means, application of the force is required and friction welding also, that friction welding comes under this category of that. Some frictional heat generation is there and that is responsible to join up the two components.

So, in broadly these three types of the welding processes: fusion, pressure and friction welding processes. Now, welding processes fusion welding processes might be homogeneous process and heterogeneous weld fusion welding process in homogenous. Fusion welding process comes under this processes; that means, gas welding, electro slag welding, high energy beam welding and electric arc welding. These alls are homogeneous fusion welding process.

So, in homogenous welding process two parent materials are joined and that means, they can be either melted most both of the materials can be melted and even if we use the filler material also then that filler material also mix with this molten material and make a homogeneous structure. That is why its come under the homogeneous welding process.

But, heterogeneous process brazing and soldering comes under this category because, brazing and soldering process it is a one parent metal not necessary to the melt, but suppose two metals we want to join, but by using some kind of the liquid metal in between.

So, then this is comes at the heterogeneous processes because state of welding, state of material state or in this cases the different in these cases one cross the melting point remaining can be in the solid state also. That is why brazing soldering we can say the heterogeneous welding processes.

Now, it is a most commonly used welding processes; that means, we can say the electric arc that comes under the MIG welding process we know the metal inert gas welding process a gas metal arc welding processes, then TIG welding process, shielded metal arc welding process, then we simply we use the stick, sometimes it is called stick welding process. So, this

welding processes some idea we have because somewhere we have seen this widely wide application of this processes and that this type of welding processes.

Now, the generic types you can say that fusion welding process definitely the melting of the materials is required. So, then arc welding process the electric arc can be created, then gas welding the process the gas can be used as electric source heat generation is responsible for the generation of the heat on the using the some gas. Then power beam for example, laser and electro beam that also comes the under fusion welding category and resistance spot welding or resistance welding comes under the fusion welding category.

So, these are the different see all are fusion welding processes, but we use the different type of the sources – one is electric arc, another is a simply gas, another is the laser source we use the different different sources we can use it. Then thermomechanical is another type of the welding process that would come for example, friction welding then frictional heat generation is there.

And, explosive welding that also comes under the thermo mechanical processes; that means, the joining is responsible for the thermal some temperature development is there at the same time by means of some mechanical forces is also required. So, in these cases we can say the it is the kind of thermo mechanical processes friction welding, then explosive welding.

Then purely mechanical and this fasteners we join the two using some nut and bolt that is also joining process, but its comes under the mechanical welding process or joining processes then also. But, solid state welding process, we can say that is the adhesive soldering, brazing and other friction state welding process that comes under the solid state welding process.

And, this comes under the solid state welding process because in this case the adhesives also there are liquid state, but the joints comes under the generic type of solid state. Even soldering, brazing also the base material basically which we use the some component which is melt and then that melting material is fill the gap between the two parent material.

So, then that parent material does not melt in this cases. That is why its comes under the generic type of the solid state welding processes. So, these are the overall the different classification or categorization of the different types of the welding and joining process and these things. But of course, there are so many other welding processes may be involved, but I think that is not required to analyze all these things because that is not the objective in this course. Rather we try to look into the overall basic features phenomena happens in the welding processes, that is the part of the analysis in this particular lecture.

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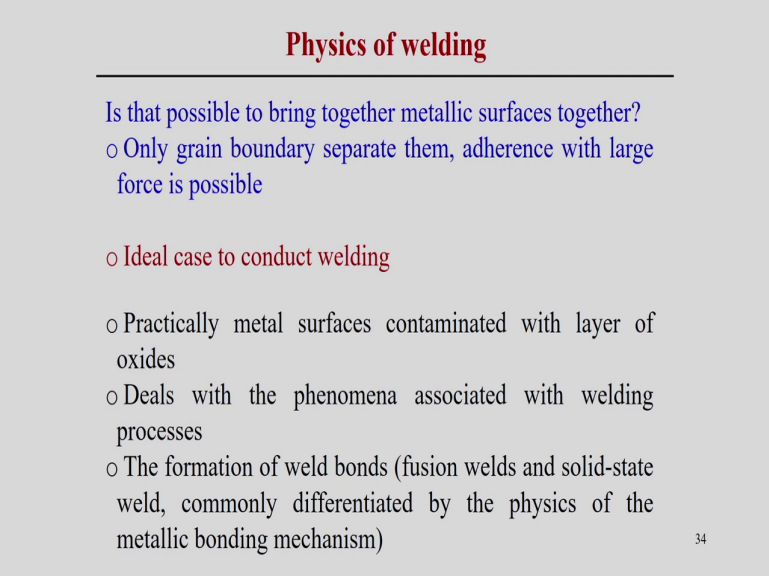

Now, I stick with the fusion welding process then we comes that under the what are the physics of welding process. So, physics of welding process we start under this basic how the welding processes has been developed in this from the which principle we can give some idea

that how different components can be joined. For example, is that are possible to bring together the metallic surfaces such that it can be joined in the state?

That means, if you characterize the one of them any kind of metallic surfaces its basically most of the cases we will find the some contaminated layer on the surface and then next layer maybe some oxide layer and then we can go to the pure metal. In that form we normally get the any kind of the engineering material.

And, that is why if we want to remove these oxides and contaminated layer, then we need to apply some kind of the heat or some kind of the energy is required in the either heat energy; that means, simply heating supplying the heating to the substrate or some by means some by mechanical means, we can remove these things.

So, by application of the mechanical energy we can remove the metallic surfaces. Then, after removing of the oxide layer and the contaminated layer, then if it is possible to bring to atomic surfaces in the atomic scale if we look together this with the atomically they are flat surface, then these two components can be joined. In principle these two components can be joined without application of the any kind of the external heating or external energy in these cases.

But, why there is a need to look into join when we are joining two components there is a need of application of some amount of the energy? Because it is only because we want to remove the necessary the oxides layer and this thing and then come in contact the two pure metal, then that is why we need some amount of the energy.

So, only grain boundary separate them; that means, the polycrystalline material if you pure polycrystalline metal without any kind of the contaminated layer then the only grain boundary separate these things. Then adherence with the large force is possible; that means, only grain boundary separate the surface existence on this particular surface. And, then if it is possible to reduce the surface energy and then two materials can be in contact, then simply application of the force then two material two components can be joined.

But, the condition is that the surface would be free from any kind of the contaminated or oxide layer. So, that is the very ideal situation for the joining of the two components to conduct the welding process, but practically this metal surface contaminate with the layer of oxides and basically in this cases which deals with the phenomena associated with the welding processes.

That means, since practically all kind of the metallic surfaces having some kind of the oxide layers. So, therefore, it is necessary to remove these layers and there is a deed of this application of the some amount of the energy and based on the application of the energy or different from the different sources the different welding processes has been developed.

Now, the formation of the weld bond; that means, bonding between these two components fusion welds and the solid state both, commonly differentiated by the physics of the metallic bonding mechanism. So, actually in terms of the whether it is fusion welding process and solid state welding process the bonding mechanism are different in these two cases.

But, in principle these two components can be joined using both following the principle of the fusion welding process, but at the same time we are following the solid state welding processes, both is possible.

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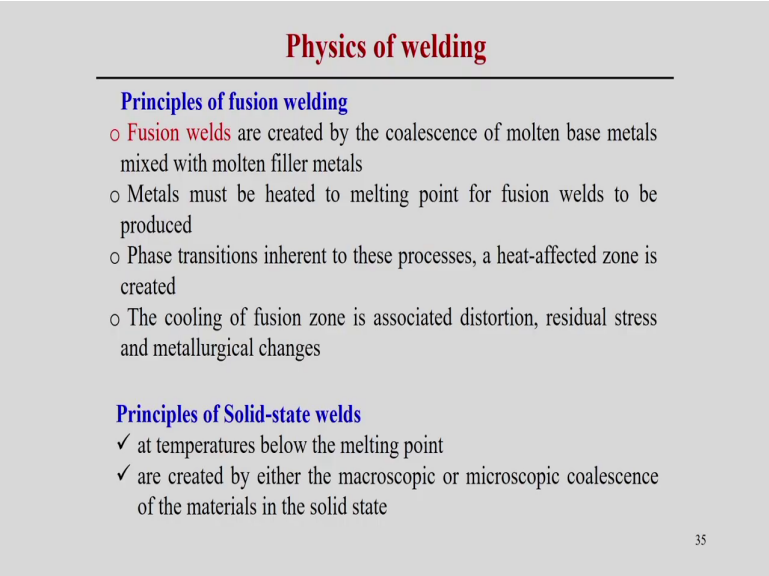

Now, principle of the fusion welding process we can see that fusion welding means their application of the heat such that it creates at least reach the melting point temperature and the coalescences by these two component base metals and sometimes mixed with the filler materials, but it is not necessary you have to use the filler materials autogenous fusion welding is also possible.

So, therefore, metals must be reach the melting point temperatures such that fusion welding process can be proceed and that process because wants two components with the application of the heat, melt the material and then two components can be joined.

And, then after mixing these things these twos in the liquid state then falling the solidification process then the structure coalescences of these two metals can happen in this particular

fusion welding process. So, definitely it is must associated with some kind of the phase transition from the liquid phase to solid phase during the solidification process.

And, then it will create some kind of the heat affected zone as fusion zone depending upon the temperature reaches in particular zone then we can differentiate what which one is the fusion zone and which one is the heat affected zone in a fusion welding process. But, even after joining these two components the one of the main issue on the fusion welding process is the even after cooling there may be some amount of the residual stress generation within the structure.

And, of course, it is associated with some amount of the distortion because the non-uniform heating and cooling processes basically this produce the some kind of the strain micro structural changes also happen the structural happen. So, may dilution may also happen, even different phases also – that introduce some amount of the distortion and residual stress in a fusion welded structure.

Now, principle of the solid state welding process – definitely temperature below the melting point temperature in principle, then join can be created either the macroscopic or microscopic coalescences between the materials, but it at the solid state solid state means that in principle the temperature should be below the melting point temperature in this case.

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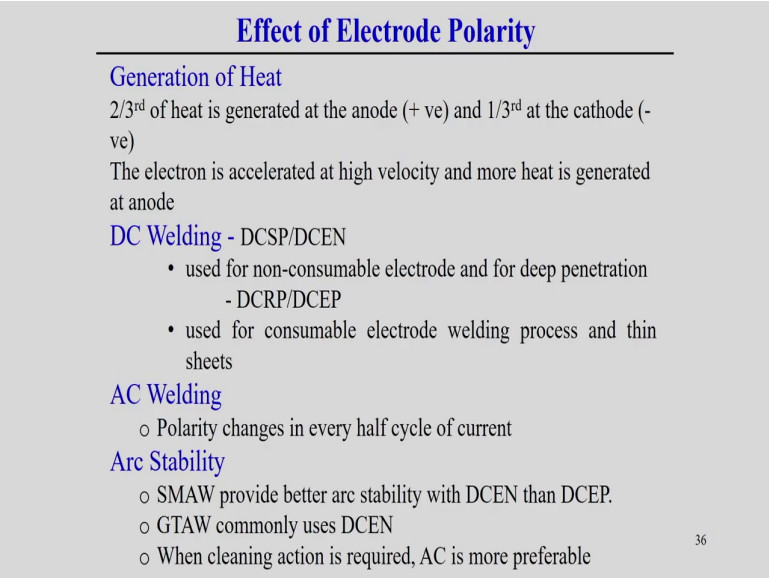

Now, effect of electrode polarity that means, we use some kind of the if you look into some welding machines and sometimes there is a necessary in welding machines. So, we have to set the current and voltage I am talking about the arc welding process. So, in this case there is a need of the current and voltage set and that application of the current. And, then of course, certain amount of the current and certain amount of the voltage or potential dependencies is also required to join the two components.

And, in principle the welding machine also in arc welding machines they are they basically they are same in this situation that the application of the current as well as the voltage is required and between the two electrode and then such that it will making a complete circuit the passage of the current.

And then this sufficient amount of the current and voltage will try to generate some amount of the heat, then coalescences of the melt the material and coalescences of the material happens and after solidification the joining also happen.

This is the in principle this follow the in arc welding process. But, if we look into the we have seen the different arc welding processes then we normally has to decide that what should be the polarity in this case; that means, what should be the if we both direct current and alternative current can be used in a welding process.

But polarity; that means, which one is the positive polarity positive terminal, which should be negative terminal has to be decided in before performing the welding process. That we will try to look into that what way we can decide the polarity.

Basics of that the when there is a passage of the current and the within the electric arc there is a flow of the electron happens. So, flow of the electron is the electron is basically negatively charged. So, flow of the electron happens from a negative to the positive side. So, in this case that if we attach the workpiece as a positive terminal and electrode as a negative terminal; that means, in the same flow of the electrons from electric to the workpiece; that means, positive terminal.

But, at high velocity will comes there and release the kinetic energy and then heat is generated on the workpiece surface. So, in that sense that almost two third of the heat generator at the anode that means, positive terminal and around one third of the cathode heat is generated at the negative terminal; that means, in the cathode. Now, how it happens? Because the electron is accelerated at very high velocity and the more heat is generated at the anode.

So, at very high velocity then it will be always be attracted to the positive side more even there is a flow of the electron. Of course, there is other effects also because with the shielding gas also during, so, shielding gas also having some effect also. So, in this case that maximum heat is generated for the workpiece if we workpiece is attached with the positive terminal.

Now, in DC welding we can say that direct current electron negative or direct current state polarity. This terminology we normally use to understand that in DC welding process DCEN polarity, simply understanding that electron negative and workpiece should be the positive. So, in this case this kind of polarity is normally we used non-consumable electrode.

So, in and for the deep penetration electrode because the maximum heat will be generated at the workpiece material and minimum amount of the heat will be generated at the electrode.

So, when we using the non-consumable electrode and if we want to produce the depth of penetration because that is the most desirable to want to join the in two components so, as much as possible the heat the multi engine can be fully penetrate fully full depth of penetration can achieve. So, from that sense we it is necessary to use the direct current electron negative polarity in case of the non consumable electrode, but for consumable electrode it happens this consumable electrode the reverse may happens.

Because in case of consumable electrode means for example: gas metal arc welding process or we can the stick welding process. So, in this case it is necessary to consume the electrode more during this process then. So, electrode is a consumable electrode should be the positive terminal and workpiece can be the negative terminal such that the positive terminal maximum amount of the heat generation.

So, material deposition will be more from that sense we can say that when the consumable electrode we can using we normally use the DCEP polarity direct current electrode positive polarity or it is also called direct current reversed polarity normally used.

But, in case of the AC welding process its polarity changes every half cycle; that means, there is a change of the polarity. In this case the low melting point having the high affinity to form the oxides. So, in this case for example, aluminum the aluminum the aluminum or the oxide layer as mostly most stable oxide layer is formed on the aluminum.

So, in this case it is necessary to remove this oxide layer. So, then in that sense that AC welding is most suitable for the welding of the aluminum or aluminum alloy in this case because the more cleaning action is required. So, that means, most oxide has to be removed during the welding process. So, has to be break during the welding process. So, in this case the AC welding is most suitable.

But, arc stability if you look into from that point of view the stability of the arc then shielded metal arc welding – shielded metal arc welding provides better arc stability with a DCEN polarity than DC electrode positive polarity. So, from that point of view also we can choose the different kind of the polarity.

But, GTAW commonly use the DCEN polarity. And all the shielded metal arc welding process in this case there may be some metal deposition maybe there, but till we can use the DCEN polarity because of the arc stability is better in this case DCEN polarity. But, when cleaning action is required then AC is more preferable that is why I have explained in the (Refer Time: 23:08) that for example, aluminum or aluminum alloy we can use the AC current for the welding of the aluminum.

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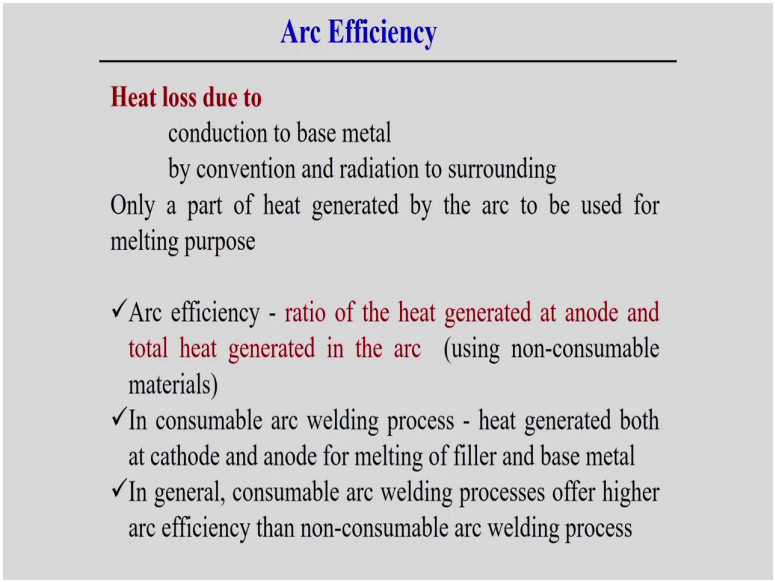

Now, we can look into the other terminology arc efficiency; arc efficiency can be defined because the workpiece between the workpiece and electrode there is a gap within the gap the arc is created. So, then when there is arc is created and with the application of the certain current and voltage, but it is not necessarily all amount of the energy will be generating the heat energy and that is responsible to melt the workpiece material.

So, by creation of the arc when it is shielded by the shielding gas also there must be some amount of the heat loss. There by mostly maximum by radiation so, convection and radiation heat loss must be there. So, based on that if we count this heat loss, then we can estimate the arc efficiency.

So, heat loss due to the conduction to the base material; so, that means, can be this thing one of this part is that the conduction to the base material this means effort from the arc (Refer

Time: 24:09) what is the amount of the energy is transport to the workpiece material from the workpiece material and the heat will be conducted to the boundary and from the boundary there may be heat loss by convection and radiation; both heat loss will be there to the surrounding.

So, that loss is also accounted, but only a part of the heat generated by the arc can be used for the melting purposes. It means that what are the heat generated by the arc is not exactly utilized all the amount for the melting of the substrate material. So, there we can define the arc efficiency in that way the ratio of the heat generated at the anode and total heat generated in the arc using the non-consumable electrode.

So, what is the total heat generated in the arc? That ratio is basically indicates the arc efficiency of a particular this thing. But, that means, when you try to estimate the efficiency we have to account the what is the what are the losses normally happens during this process, but in consumable arc welding process heat generated from both the cathode as well as the anode for melting of the filler and the base material has to be accounted to estimate the arc efficiency.

In general, the consumable arc efficiency that consumable arc welding process offer the higher arc efficiency definitively than the non consumable arc welding process because non-consumable electrode process the only the heating of the workpiece and then melt these things. But, non-consumable electrode process it is melting happens from both side; that means anode and cathode both the cases we will be getting the melting.

So, in that cases the utilization of the heat generated by the arc is more in case of the consumable electrode. That is why arc efficiency will be more when we are using the consumable electrode as compared to the non consumable electrode. So, this is the way we can just analyze what maybe the arc efficiency of a particular arc welding process.

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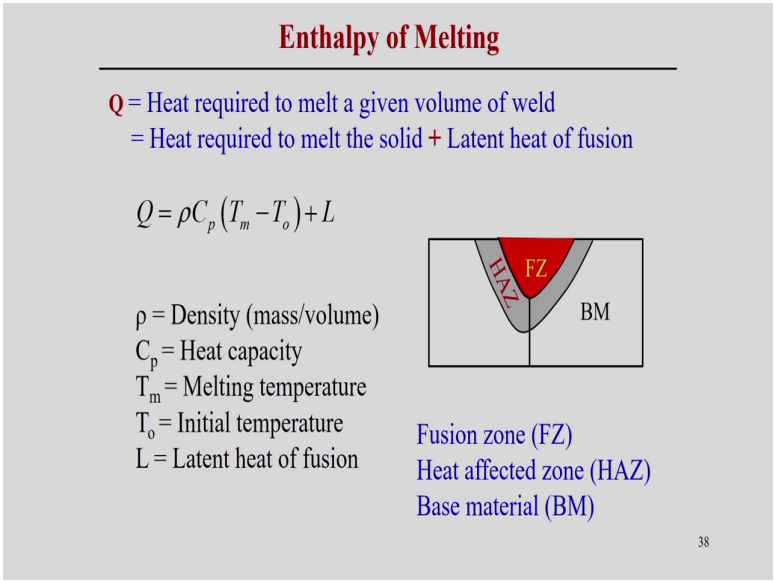

Now, enthalpy of melting because it is necessary to understand what we can say the what is the enthalpy of melting; that means, basically heat content in a particular welding process what we can estimate that may be helpful for the development of the model and that we will see also later on, but here we can see the enthalpy of melting heat required to melt a given volume of the weld.

So, heat required to melt a given volume of the weld its basically heat required to melt the solid; that means, the solid initial temperature ambient temperature, that solid application of the heat, the solid is transformed to the liquid state. That means reach to the melting point temperature and just melting point temperature.

Apart from that there is a latent heat of fusion also; that means, phase change from solid phase to liquid phase and melting point temperature. So, both the amount of the heat has to be

counted has to be estimated or it necessary to estimate these two amount of the heat which is indicates the what is the enthalpy of melting. It means that one particular solid material, what is the amount of the heat required to just melt it.

So, that is counted is that Q can be estimated like that the specific heat the rho C p we know the C p is a specific of this particular material and T m minus T 0; that means, leads to the melting point temperature and T 0 is the ambient temperatures from it raise the temperature from T 0 to T m. T m is the melting point temperature and plus the L, is the latent heat of fusion.

So, I have not shown the it is balance of this thing equation, but a latent if the fusion has to be dimensionally has to be balanced here do counting on these things maybe density or maybe mass, maybe require in this cases to account make the balance this equation.

So, from ambient temperature to the melting point that accounts the specific heat the C p is the main parameter here and rho and then other is the L; that means, it is a phase change basically from liquid phase to solid phase and melting point temperature what is the amount of the latent heat of fusion is required in this case. This total heat count the enthalpy of melting in a particular zone.

Now, if we look into that typical cross-section of a weld joint, we can find out that in weld joint if you see the red zone is shows that it indicates the fusion zone and then it creates the heat affected zone and at the unaffected base material by temperature. So, all this zone has been defined simply by the temperature isotherm that fusion zone is defined the melting point isotherm.

And, then heat effected zone is particular phase change basically one phase to another phase change component, but it is depends on the different type of the material. So, that define what are the changes of the phase that zone is basically define different temperature isotherm that particular temperature isotherm is decides the what is the heat affected zone in case of particular material in a particular welding process.

Now, base material is basically indicates that which zone is not affected by the temperature; that means, even small rise of the temperature does not account any kind of the phase transformation normally in this base material. So, this is the integration. So, all this zone is defined based on the as in the what is the temperature is reach is a particular domain or a particular zone in that case accordingly we can define the different zone.

Because this fusion zone heat affected zone and base material these all the common terminology normally used for the development of the numerical model or to analyze the model to understand this any physical mechanism of the welding process. So, it is necessary to understand at this point of view.

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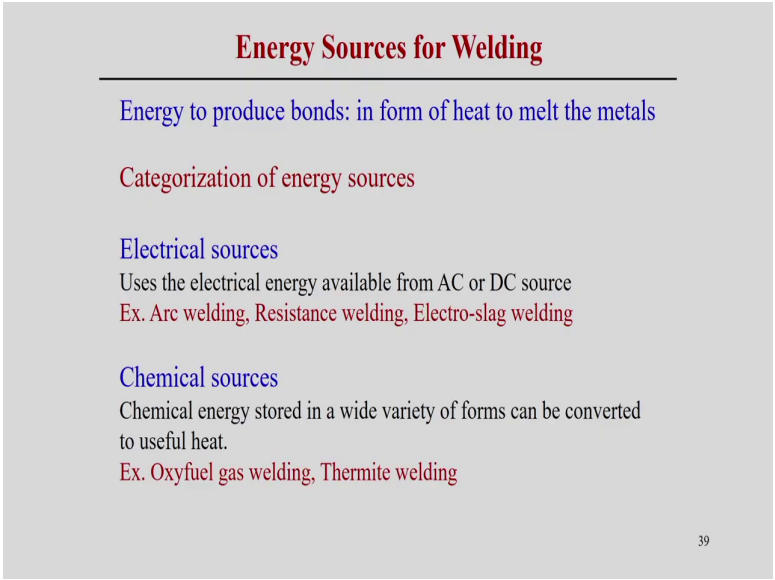

Now, we see the basics of the different kind of the energy sources. At the very beginning I already mentioned that the in principle it is a liquid state welding process, but there are so

many technology has been welding technology has been developed depending upon the heat source of the heat can be different.

So, here we see that energy to produce the bond basically in the form of a heat to melt the metals, but different way we can melt the metals. For example, see the categorization of the different energy sources – first is the electrical sources. So, in electrical sources we can see uses the electrical energy available from AC or DC source.

So, AC or DC current we can count this as a electrical sources to melt this material. So, AC current or DC current. For example, the arc welding process, resistance wielding process, even electro-slag welding process all these cases we can use the electrical source as a for the generation of the heat to raise the melting point temperature of a substrate material.

Similarly, chemical sources also; that means, chemical energy stored in a wide variety of forms can be converted to the heat. One is the oxyfuel gas welding process we can use particular fuel mix with the oxygen and then using that we can generate the amount of the heat. So, heat source is different in these cases. And, thermite welding also we can use the different source of the energy to melt the substrate material. So, that is the source or the chemical sources is used in this case.

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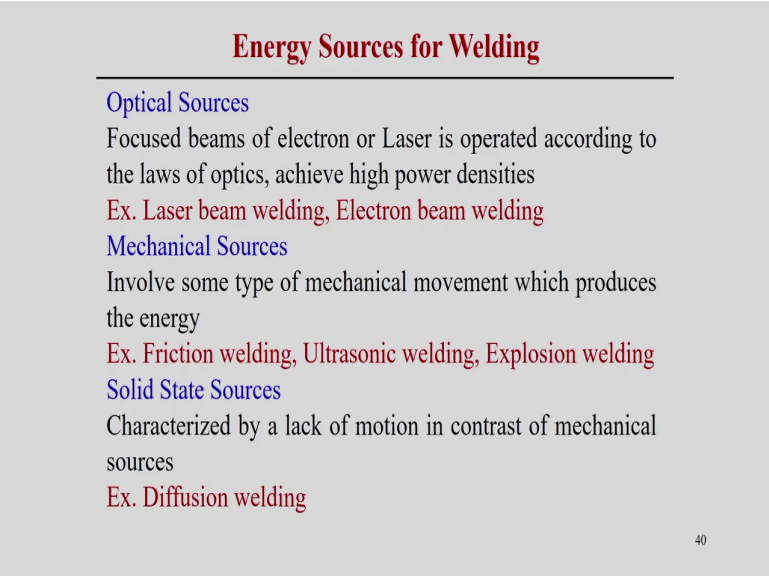

Now, energy sources for welding other also optical sources. For example, the optical focused beams of the electron laser operated according to the laws of the optics. So, that is how we can say these are the optical sources of the energy. So, that means, laser and electron beam welding process they use these kind of the source of the energy for the welding purpose.

Additionally, that mechanical sources can also be used some kind of the mechanical involved some type of the mechanical movement; that means, which produces the energy; that means, friction. So, some relative motion between this work piece and the some tool is required such that frictional heat generation will be there.

So, that means, in principle some mechanical movement will be there such that it is converted to the it generate the amount of the heat which is sufficient to melt the substrate material that

is called that one type that type of the welding processes has been developed is friction welding process.

Even ultrasonic welding process also because ultrasonic welding process some ultrasonic vibration. So, vibration energy is required in these cases to localize to melt the particular material. As similarly explosion welding that can also be comes under the mechanical source of the energy utilized for the development of the deep welding processes. Solid state sources – solid state sources means characterized by lack of motion in case of in contrast of the mechanical sourcing because mechanical sources normally utilize some movement or mechanical movement of the material is required, but in case of the solid state sources it is a without movement also the two components can be joined.

For one example is the diffusion welding process. In case of diffusion welding process two very clean surface come in contact, keep this for a long time with the application of the static application of the load. Even sometimes we can aided by the temperature then two different components can be joined, but success of the diffusion welding entirely depend on the surface preparation of the particular component.

So, that is way different energy sources can be used or in the different welding processes or I can say using the different source of the energy different welding technology has been developed.

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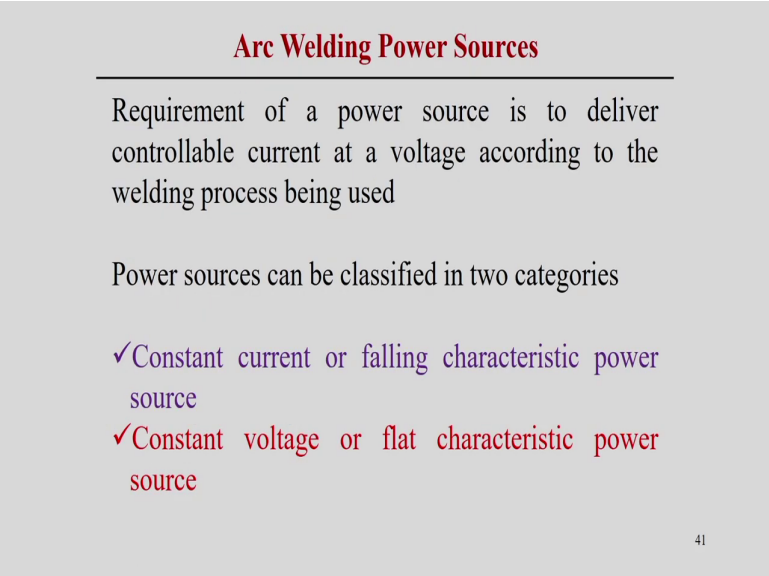

Now, what now we can discuss the one of the most important topic that is on arc welding power sources. So, we use the arc welding process which the welding machines that there are which the current and voltage, but what way we can regulate the current and voltage because so many of the arc stability all these things is there.

And, maybe if we use some manual arc welding process, some automatic arc semi-automatic arc welding process, what type of the relation between the voltage current is required, what we can control the change of the current or voltage that is called the characteristic of the power source which is required to understand the welding process in the common welding process.

So, therefore, power sources can be classified into the two categories specific to the welding process; one is the constant current or falling characteristic power source. We use the this

terminology constant current or falling characteristic of the power source, another one is the constant voltage or flat characteristic of the power source both can be used we see what are the two different type of the power sources normally used in case of the welding process.

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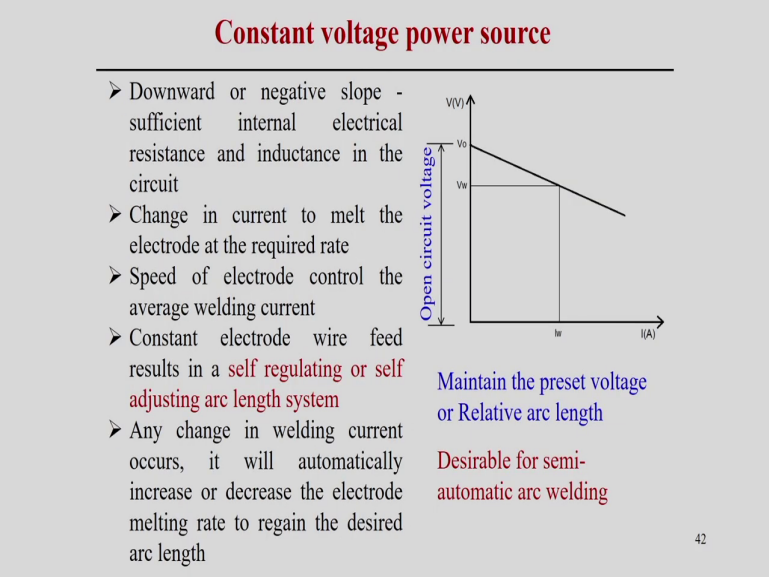

One is the constant voltage power source. In this case constant voltage is maintain the preset voltage or relative arc length. Basically the in arc welding process the arc voltage is very much relevant to the voltage is basically set relevant to the arc length. So, it is very much sensitive to the arc length.

So, we can say that if we preset the voltage in a particular process, so, then arc length can be more or less can be fixed for a particular voltage or potential difference we can get the particular arc length.

See if there is a change of the voltage, then arc length will change or vice versa also if there is a change of the arc length then voltage can be changed. But, if we keep constant voltage power source that means, if you keep voltage remains more or less constant then arc length remains more or less constant in this particular situation.

So, it is basically desirable for semiautomatic arc welding process because in automatic arc welding process that if we try to maintain due to the welding process the constant arc length so, requirement of the voltage is more or less constant, but if there is a small changes arc length happens the what way it responds the what way the voltage changes.

So, with the increment of the current how this voltage basically, because for example, we set particular voltage and which is related to the arc length also. So, if we preset some particular voltage and there is a requirement in a if we look into the machine there is a requirement of particular current. Now, if there is a change of the current so, gradually there may be the necessary to change of the voltage. So, how it responds these things we can see from this figure that its a certainly it is a gradual dropping characteristic we can see.

If you see first on that constant voltage or flat characteristic of power source that there is a gradual decrement of the voltage we can see which starting with the open circuit voltage. Before start of the welding process the what are the potential voltage is available there that indicates the open circuit voltage.

So, from the open circuit voltage this is gradual decrement of the voltage is required even we increase the current. So, this kind of the characteristics means power characteristics required for the semi-automatic welding. We see that how to what way we can define this constant voltage power source.

Downward negative slope is there, but sufficient internal electric resistance and it inductions in the circuits is available there. Change in the current to melt the electrode at the required rate; that means, if the change in the current is there accordingly it will try to melt the

electrode at the required rate. That means, change of the current is automatically the melting rate will be affected in this case.

Speed of the electrode control the average welding current. At the same time speed of the electrode; that means, what way we moving the electrode to melt this thing that also influenced by the control the average welding current also. Now, constant electrode wire feed rate. So, feed rate is wire feed rate is constant result in the self regulating or self adjusting arc length system because we see the preset the arc voltage. So, automatically with the depending upon the arc voltage the self regulating means to maintain the particular arc length the melting of the electrode will be maintained accordingly.

So, any change in the welding current occurs during this process then it will automatically increase or decrease the electrode melting rate. So, melting rate will automatically adjusted in this case to regain the desired arc length. So, it is always try to any change happens in these cases it will try to reach the preset value of the arc length because and that is the when preset value of the arc length we can say indirectly the preset value of the arc voltage will try to maintain these things.

So, that means, we are keeping the voltage fixed, any changes happens in between it will try to adjust, such that it will try to reach the preset values of the arc length because arc length is more influence more related to the voltage of a particular circuit in this particular power source. So, that is why these type of characteristics very much suitable for the semiautomatic arc welding process.

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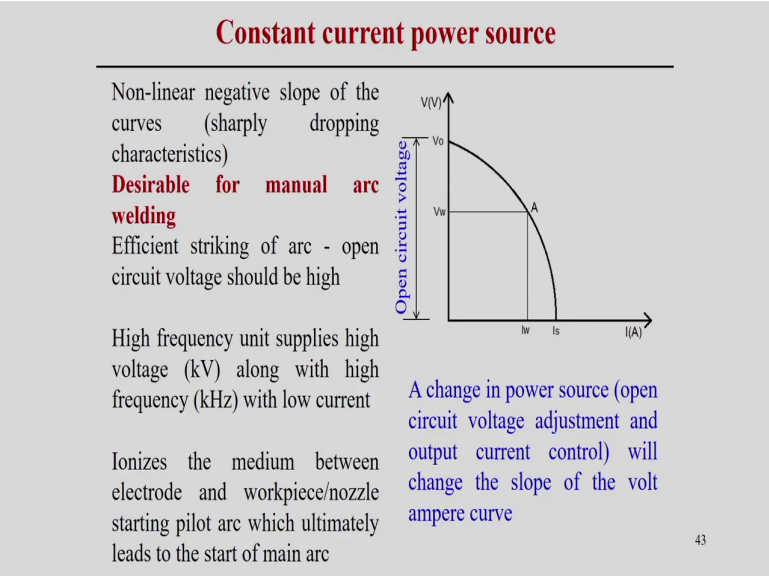

Now, other look if the if you see the that is called the sharply constant current or falling characteristic of the power source. You can see the figure indicates the open circuit voltage, but there is a sharply dropping characteristic of the current is there. So, non-liner negative slope of the curve sharply dropping characteristics normally follow in case of constant current power source in this case desirable for the manual arc welding process.

So, that means, in this case manual arc welding process what happens practically manual arc welding process if there is a moment of the arc; that means, welding torch also these is a quite possible it is very typical to maintain the constant length of the arc. So, it is quite possible there is a change of the arc length in between. So, how we can adjust the change of the arc length such that it will adjust the other parameters to mention the welding process the

stability of the arc has to be maintained in this case. So, if it is very much sensitive to this thing.

Length of the charge is automatically adjusted, but it is a quickly adjust such that it follow this kind of the curve not very linear or gradual decrement of the current or voltage maybe in this case there are sharply decrement of the current is required in this case. So, a change in power source open circle bottle adjustment and output current control we start with the very high open circuit voltage will change the slope of the volt ampere curve.

So, it is the relation between the volt and ampere curve that is changes with respect to that if there is a change of the arc length during the manual arc welding process. But, efficient striking of the arc open circuit voltage should be very high. So, in this manual arc welding process we start with this thing there is a striking of the to create the arc we just strike the electrode on the surface and then we maintain the gap. So, in for this purpose it is an it is a efficient striking of the arc open circuit voltage should be very high in this case.

High frequency unit supplies the high voltage. Definitely, along with the high frequency with the low current this kind of the power characteristic we find out we may be desirable in the constant current power source. While the ionization is the medium between the electrode the workpiece nozzle and starting pilot arc which ultimately leads to the start of the main arc. So, in this case we understand that constant current power source means in this case the in the machines we normally keep the current as a constant.

So, preset the current value as a constant, but during the welding process there may be the change of the arc. So, if there is a change of the arc length happens then that will be adjusted by the change of the voltage because arc length is more relevant to the more associated with the change of the voltage. So, when there is a arc length change voltage will be changed quickly accordingly, but current can be remains more or less constant. So, this type of power source is also available in the welding, but this type of process is very much suitable for the manual arc welding process.

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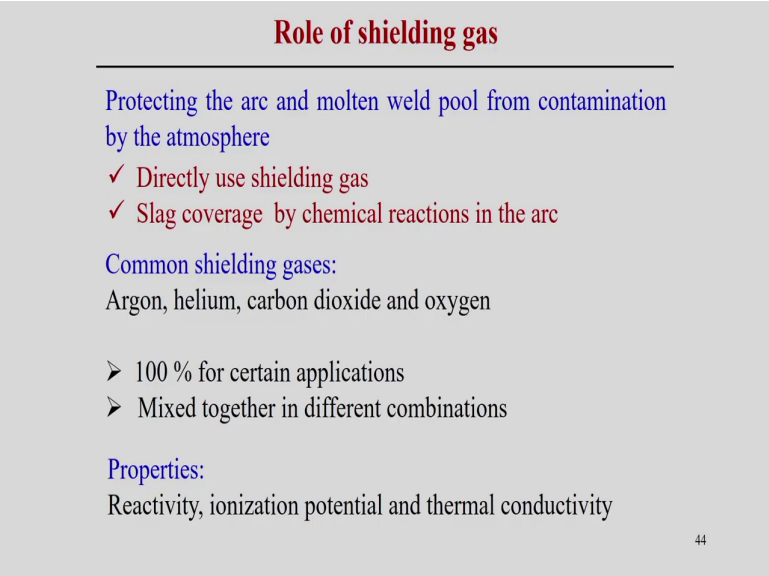

Now, definitely shielding gas also used in a case of the welding process. So, what is the role of the shielding gas. So, basically shielding gas protect the arc during the because molten pool and from the contamination by the outside atmosphere that is the main purpose of using the shielding gas.

But, directly shielding gas can be used from the torch or nozzle. The coaxial nozzle you can use and through the nozzle you can pass the shielding gas also it is possible or sometimes we use the slag we cover the zone by the slag coverage by the chemical reaction in the arc therefore, the solid form of the slag. So, we create the arc melt it then that actually cover the molten arc or during this welding process.

So, that is why common shielding gas we can use; for example: argon, helium, carbon dioxide and oxygen and mixing up that with a certain proportion, but of course, the stability

of the arc quality of the joint is too much up to certain extent they influenced by the choice of the shielding gas. And of course, it depends on what type of material and what type of welding process we are using all these factors.

So, therefore, having certain role of the shielding gas in a weld joint quality, but 100 percent for the certain application we can use 100 percent on particular shielding gas and mixed together with a different combination that is also possible depending on the application, depending upon the stability of the arc with this particular shielding gas.

And they are because different shielding gas having the different characteristic, different properties also there. And, but which properties are important of shielding gas? The reactivity ionization potential and the thermal conductivity of the shielding gas because, that is that particular properties are influence to the stability of the welding or welding arc this process or to produce the good quality of the weld in from the different perspective.

So, point is that shielding gas is also one important these things one important aspect in the welding processes and the main role of the shielding gas is simply protect the molten pool, but it inference the weld quality or may be welding process also.

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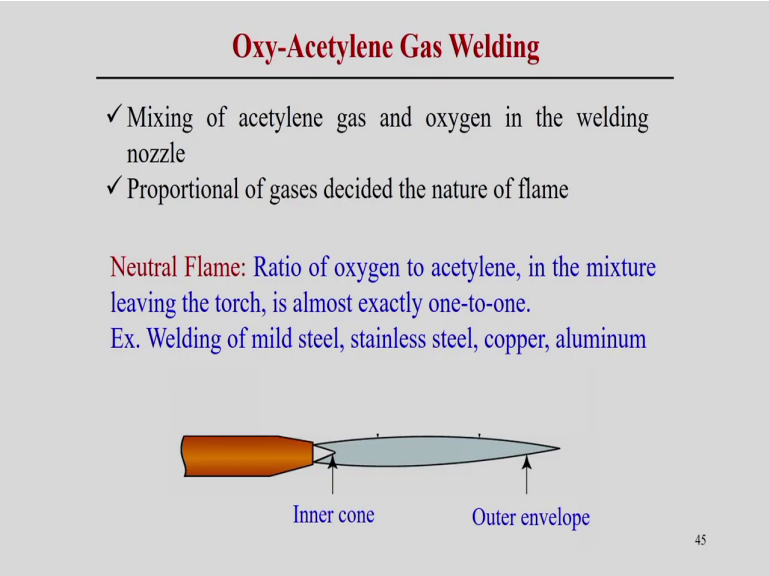

Now, I come to the different welding processes we can start that oxy acetylene gas welding process. Now, I come to this point the different fusion welding process one is the oxy acetylene gas welding process simply mixing of the acetylene gas and oxygen in particular ratio in the wielding purposes.

And, then from the nozzle this gases passes through this and create the arc and then it creates the particular kind of flame is been created see there is a inner core and the outer envelope if you look into this figure. These are the typical characteristics of the flame.

So, inner core the we can get the inner core the maximum temperature. So, that part is basically focused on the workpiece and the to melt the workpiece material, but the outer

envelope is simply protect this workpiece from the outside atmosphere it is a simply play the role of the shielding gas in this particular process.

Now, different kind of the flame can be used depending upon the ratio of the oxygen and acetylene for example, if the ratio of the oxygen acetylene in the mixer leaving the torch is almost exactly one to one; that means, one to one in this case the natural neutral flame will be created.

So, in this case the welding of the mild steel stainless steel copper aluminum will be more preferred using this neutral flame because this flame depending if you create the different kind of the flame so, the temperature maximum temperature can be different. We see this thing also.

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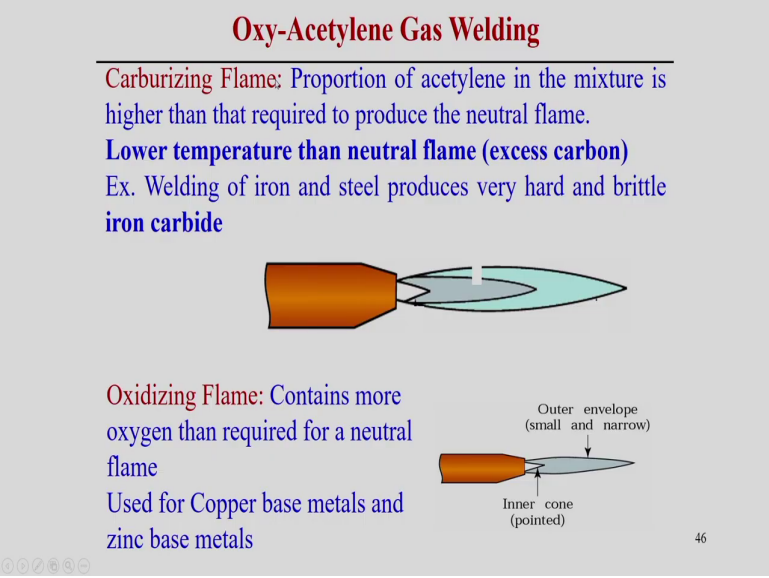

Apart from the neutral flame carburizing flame can also be created, but in this case definitely acetylene ratio of acetylene percentage will be more in this case. So, proportion of the acetylene in the mixer is higher than that of the required to produce the neutral flame. So, in this cases lower temperature than neutral flame because of the formation of the excess carbon.

So, that is why welding of the iron and steel produces the very hard and the brittle iron carbide phases because the excess carbon will be create because the proportion of the acetylene is more with respect to this thing it creates the carburizing flame. And, that carbon becomes part of the iron an iron when melting the welding of the iron.

So, iron carbide is can be created in this particular in particular flame and then such that iron carbide is very hard and brittle material. So, this kind of flame is very much suitable for the welding of the pure iron and the steel.

Similarly oxidizing flame also; oxidizing flame contains more oxygen as compared to the acetylene in this case required for the with respect to the neutral flame. So, in this case when there is a oxidizing flame the temperature generation the maximum temperature is more as compared to the neutral flame. So, in this case it is most suitable for the joining of the copper based metals and zinc base metal.

And, if you see because copper is having very high thermal conductivity, so, maximum temperature can be very much much more as compared to the welding of the steel or other components. So, that is why oxidizing flame is more suitable for the joining of the copper. So, these are the three different types of the flame in case of the oxy acetylene gas welding process.

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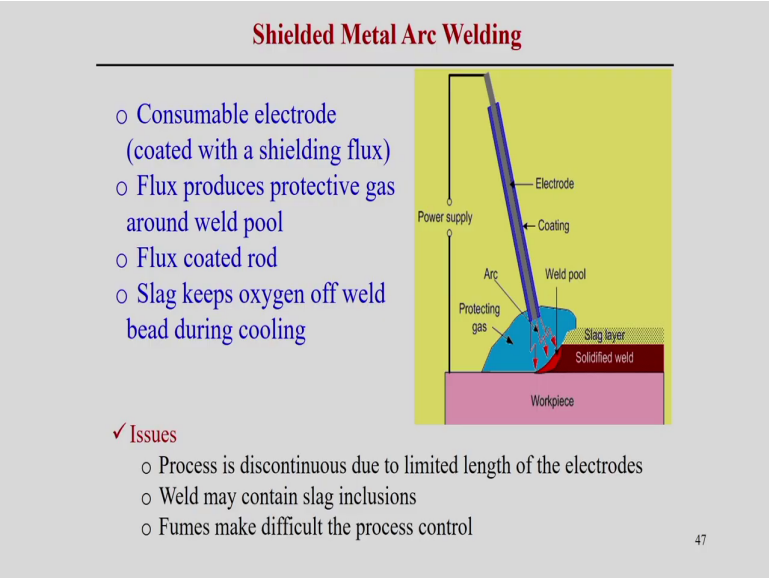

Now, we will look into the different other welding processes. The shielded metal arc welding process shielded metal arc welding process we can see that we can use the consumable electrode and coated with a shielding flux. So, electrode is coated with the flux from this figure and arc is created.

So, inside the material is been deposited at the same time it is melting the workpiece then solidified metal is formed and the slag is basically from the top because slag is the lighter in weight. It comes under the top and this is basically protect the material from the outside contamination. So, instead of using the shielding gas we can use this kind of the we try to promote the slag formation also that helps to the to protect the molten zone to some extent.

So, flux produces a protective gas around the weld pool and flux coated rod we normally coated rod we use a flux coated rod we can use and a slag gives the oxygen of weld of weld

bead during the cooling period. Definitely slag is basically protect the this weld solidified zone basically. But, issues is that in case of the shielded metal arc welding process we use the stick kind of this.

Process is discontinuous. It is not as a continuous because once the stick is over then we have change we have to attach on another stick. So, the process is discontinuous so, therefore, due to the limited length of the electrodes. But, weld may contain the slag inclusion, but some the although there is a slag formation its protect the molten material from the outside atmosphere, but sometimes it can be a part of the weld joint.

So, slag inclusion is maybe one the solidified metal is one of the issues associated with this particular process. Fumes make difficult process control if it. So, I think if you observe this kind of the process also there is a lots of fumes normally generate in this arc welding process. So, because of that, it is sometimes difficult to capture the data and make the automated process using this shielded material arc welding process.

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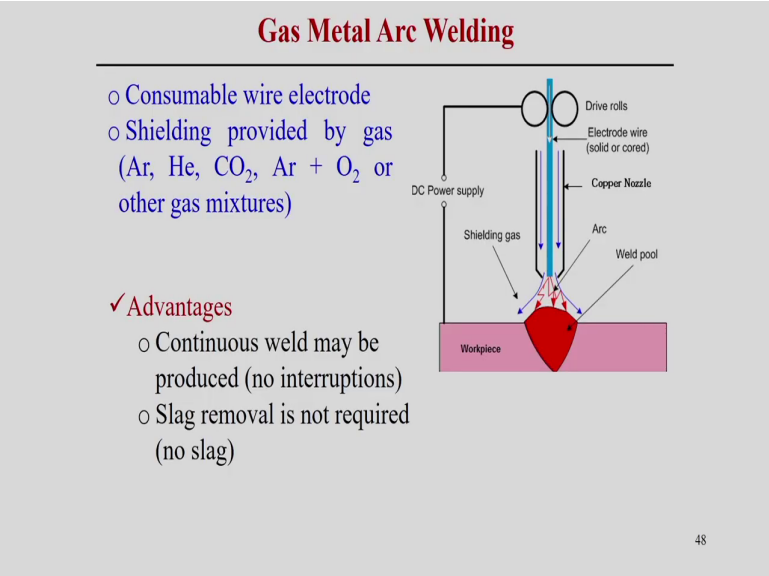

But, I will look into the gas metal arc welding process use the similar principle, but in this case there is a continuous supply of the wire is required. So, consumable wire electrode: so, from the pool of the wire there is a continuous supply of the wire is there.

So, shielding provided by the shielding gas in this cases we do not use this kind of slag formation rather we use the shielding gas. Shielding gas argon, helium, carbon dioxide and combination argon oxygen can be used or any other mixer. If we look into this principle there is a continuous supply of the electrode wire through the copper nozzle.

And, then inside there is a shielding gas is there. Firstly, the shielding gas is there and arc is created and then molten metal has been created using the consumable electrode from the wire. And, then in this case the shielding metal helps to protect the weld zone and the two metals can be joined. So, this is called this is the gas metal arc welding process. Advantages

continuous weld may be produced no interaction is required and slag removal is not required in this case also since we are using the shielding gas.

So, after welding it is not necessary to remove the slag that is that was associate with the previous process, but it is not associated with this process.

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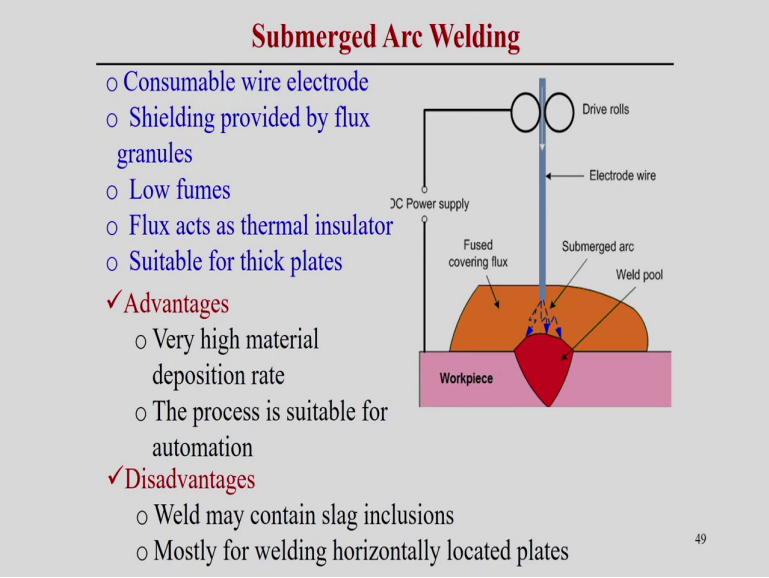

Now, submerged arc welding process: submerged arc welding process also use a similar kind of different from the gas metal arc welding process. Here also electrode wire is used, but instead of shielding gas it is used the fused covering flux, the total weld zone is covered with the fused covering flux and arc is created under the flux and weld pool is created. But, how it is different from the other process?

So, what are the different advantage of this process submerged arc wielding process? It is a very high metal deposition. Normally, very heavy thickness very high thickness material, heavy structure we can use the submerged arc welding process and this process is very much suitable for automation.

And, the arc efficiency is very high because in this case almost loss of the heat what is happens for the other welding processes because its a completely covered with a granular kind of the flux the total zone. That is why arc efficiency is very high in this case.

Disadvantage: weld may contain the slag inclusion. This is the common disadvantage it may have that is the common kind of defects or normally we found in case of shielded submerged arc welding and shielded metal arc welding structure and mostly for welding horizontally located plates. So, its very difficult to develop this process for the other orientation, but mostly this application for the horizontally located plates we use the submerged arc welding process.

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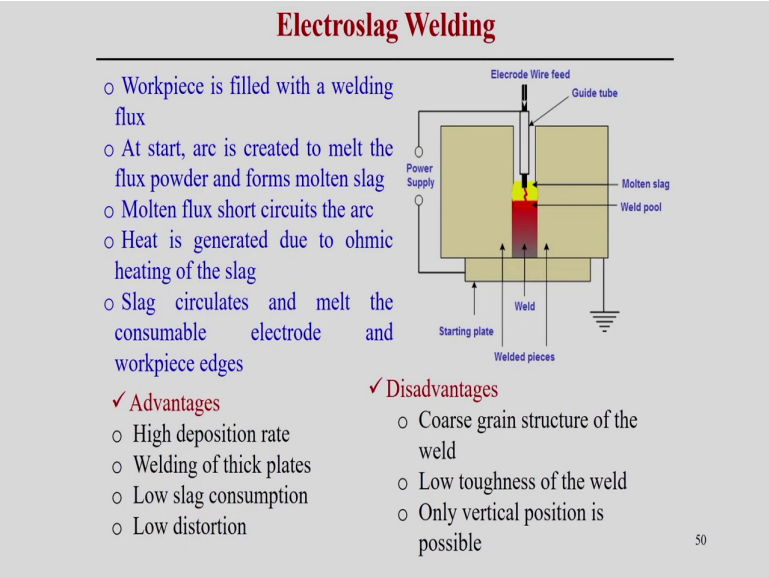

Similarly, electro slag welding process in this case the workpiece is filled with a welding flux. These two workpiece are there in between the gap is filled with the welding flux. Then at start, arc is created to the melt the flux powder and the forms molten slag.

So, flux powder is created then molten slag is normally created. So, molten flux short circuit the arc and then heat is generated due to the Ohmic heating of the slag the heat is generated and then the molten slag is basically try to melt the surrounding material these two components of the material then weld pool is created.

And, it is gradually keep on filling form the bottom to the upper side. So, slag circulates and the melt the consumable electrodes and the workpiece edges also. So, in this cases also electrode wire feed is there. So, that consumable electrode melt it and the protect the molten

slag is in contact and then this vertically it is goes upward direction and, but gradually holding these two components in the big structure.

Advantage – high deposition rate welding of the very thick plate can be joined, but slag consumption is very low in this cases as compared to other processes and distortion can be very low. Disadvantage – coarse grain structure of the weld can be possible low toughness of the material and only vertical position is possible so, by this particular process.

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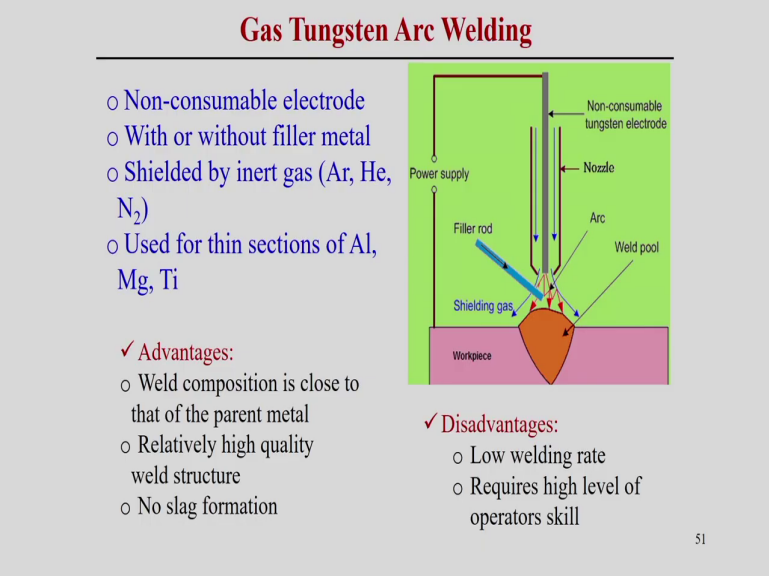

Now, gas Tungsten's arc welding process. In these cases we use the non consumable electrode and sometimes if necessary we can use the some filler rod externally. Same principle non-consumable electrode; so, if a current is pass electrical circuit is if you can see between the electrode and the workpiece and the weld pool has been created, arc has been

created between the non-consumable electrode to the workpiece and the weld metal can be joined.

So, in this case we can use with or without filler material shielding gas for example, argon, helium, nitrogen can be used as a shielding gas and this is normally used for the very thin section. For aluminum, magnesium, titanium very thin section can be joined because in this case mostly you do not use in the autogenius mode we use this welding process we do not use the filler material most of the cases.

Advantage: weld composition is close to that of the parent metal because we are not using. There is no deposition of the material is required in this case in principle and relatively very high good quality of welded structure and no slag formation because in this case we use the shielding gas.

But, low welding rate; so, welding rate is very low in this cases and require high level of operator skill to operate this kind of material this kind of welding process because age preparation all these thing because normally do not use the any kind of non consumable electrode.

So, there is no material deposition from the electrode. So, high scale of the operators is required to get a good joint at the same time it is in this particular process it is necessary to handle the very thin sheet also.

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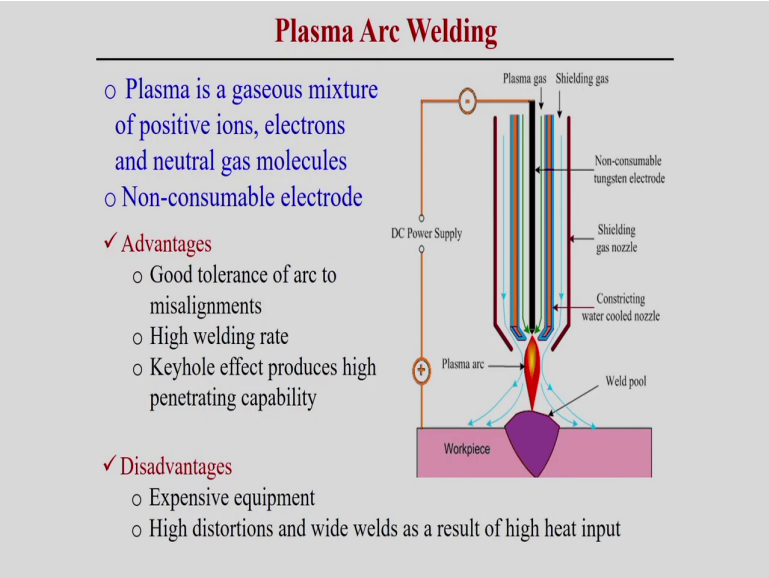

Now, if you can look in to the plasma arc welding plasma is a mixture of the positive ions electrons and neutral gas molecules, but in this cases the plasma arc welding process which is different from the gas metal arc welding process. In this case there is a two source of the gas is required.

One is the shielding gas another is the plasma gas, but both plasma gas shielding gas can be same also. Here also we can use the non-consumable electrode, tungsten electrode and then there is a plasma gas create the arc which the help of the non-consumable electrode.

And, this one advantages is that the position of the water cooled nozzle, but of course, cooling channel is there is such that the constitute arc can be possible as compared to the

open arc in case of gas metal arc welding process. So, this very high depth of penetration and control arc can be possible using the plasma arc welding process.

In this case, good tolerance of the arc on to misalignments; so, basically there is a misalignment then that can be tolerance of the arc is very good in this particular plasma arc welding process. High welding rate, but keyhole mode can also be created by the high penetrating capability.

So, that is a sometimes we can use although plasma arc welding is very the machines is very cost is low as compared to the laser sometimes we take the certain and advantage plasma arc welding process and we can compare with respect to the laser welding process because in the plasma arc cooling process it is possible to generate the keyhole.

Disadvantage: expensive equipment, but this expensive equipment in the sense that as compared to the simple other welding processes, but its the equipment cost is low as compared to the laser welding process. High distortion and wide welds as a result of high heat input. So, these are the typical disadvantage this particular plasma arc welding process.

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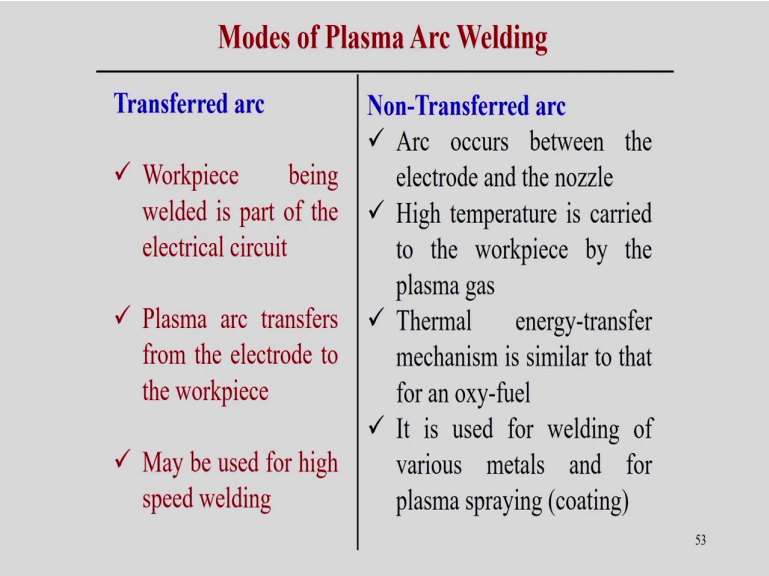

We can see the modes of the plasma arc welding process it can be either transferred or non-transferred arc, because transferred arc we can see the workpiece being the part of system electrical circuit in this case transferred arc, but non-transferred arc are occurs between the electrode and not the workpiece between the electrode and the nozzle. So, between that the arc is actually created.

So, transferred arc the plasma arc transferred from the electrode to the workpiece. So, arc is created between the electrode to the workpiece and maybe used for the high speed welding processes. So, then joining of the two components normally the transferred arc mode we can use, but non-transferred arc we can see the high temperature is carried to the workpiece by the plasma gas in this case.

So, thermal energy transfer mechanism is similar to the for an oxy fuel weld; that means, when there is a creating the arc between the electrode and the nozzle and it is between these two. So, heat can be that heat generated heat can be transferred to the workpiece.

And, that this water we can transport to the we can heat the using the oxy fuel gas welding process because oxy fuel gas welding process which I heat the workpiece material, but we cannot we do not create the electrical circuit; that means, we just simply heat from this source by chemical source. That means, the heat is generated by this oxygen and fuel bonding of this oxygen and fuel ratio, but in this case and then heat is transferred to the workpiece.

So, same also heat is transferred to the workpiece if we create the non transferred arc mode in case of the plasma arc welding process. But, this kind of the most more suitable various metals and the plasma spring basically for coating purpose this mode of the non-transferred arc mode of the plasma arc welding is most suitable.

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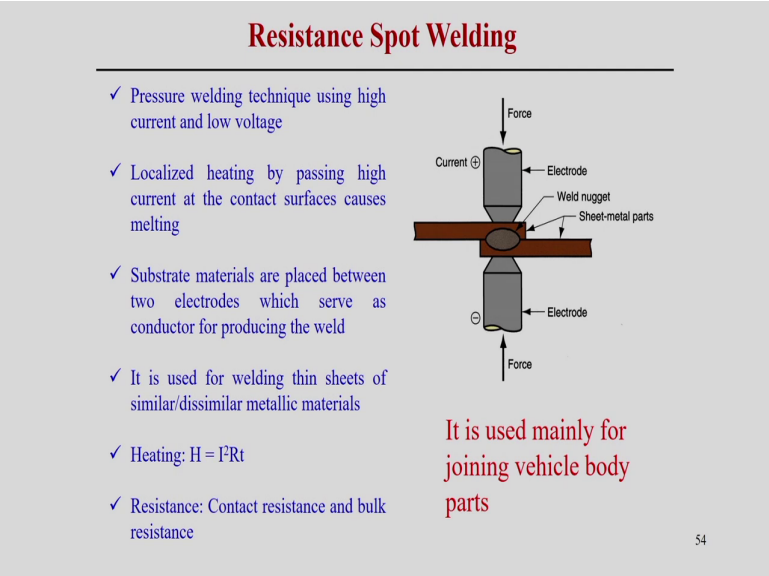

Now, we can also look the resistance spot welding process that is another welding processes where pressure of the electrode is required using the high current and low voltage. So, this is the principal of the resistance spot welding process.

You can see the figure, the two electrode is there and if it there are two sheet and then between the two electrode we apply the high pressure and then passage of the current at the particular very small time, then melt at the interface because of the contact resistance between these two sheet and that is responsible to generate the heat at the interface and the two materials can be joined.

So, localized heating by passing the high current at the contact surfaces causes the melting in this particular process. And, substrate materials are placed between the two electrodes which serve as the conductor for producing the weld.

It means that these two electrode high normally we use the high conductive; high conductive electrode because high conductive electrode and there are so many contact surfaces also in this particular zone and it is very important in the resistance spot welding process, what are different contact surface because each and every contact surface they generate the heat generation is there at the contact surfaces. So, that because of the contact resistance.

But, resistance can be used in the two different part – one is the bulk resistance which the resistance passage of the current to the bulk of the material that means, over the volume; another is the contact resistance at the contact surfaces. So, we can estimate the heat generation in this particular spot welding process is the H equal to I square at I is the current R is the resistance and t is the time, but resistance there are so many components of the resistance associated with the resistance spot welding process.

We will see a letter on then we will try to explain this particular process modeling, we will try to look into what are the different resistance we can account for the generation of the heat in the resistance spot welding process. But, main application of the resistance spot welding process is the mainly for the joining of the vehicle body. So, automobile industry we can get the main application of this resistance spot welding process ok.

So, thank you very much for your kind attention. I think that is all for today this particular sort of this lecture.

So, thank you.