Welding Engineering

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Module - 1
Introduction
Lecture - 2
Classification of Welding Processes - I

In the last lecture, you have seen the importance of the welding as compared to the other manufacturing processes to get the desired size and shape, the component which can be used by us in our daily life or for fabrication of the various machines or their components. Today, will see that the welding processes are which are available; are many. Each welding process has a unique advantage. During the welding, some of the things which happen are very common. In general, the welding welded joint.

First, the metallic continuity between the members is to be joined. For this purpose, to obtain the metallic continuity, various approaches are used. Each welding process is based on the use of specific approach. For example, for obtaining the metallic continuity between the members to be joined, the edges of the faying surfaces are brought to the molten state. Thereafter, solidification of the weld metal results in the continuity of the material and a produces are weld joint.

So here, the application of heat for melting the faying surfaces is important. This there can be different sources, which can be used to apply heat. In the different processes like an electron beam, high velocity beam of electrons is used. Like a laser beam, a beam of a laser is used. In arc welding processes, arc heat is used for melting the faying surface and to get the metallic continuity in form of the weld joint. Similarly, in some other processes only the faying surfaces are brought to the molten state and get a metallic continuity in form of the weld joint. But, the filler material is not added from outside.

So, those processes in which the filler material is added from the outside, they behave in different way. Their approach is different as compared to those in which filler material is not used. Similarly, there are certain processes, in which in addition to the heat, pressure is also applied to consolidate the members and get the weld joint which can serve the purposes. There are many welding processes. Each process offers us specific set of the conditions under which weld joint is made.

Therefore, it is worth to look into the fundamental way by which these processes can be grouped in different ways. That is why, we will see that what are the different possible ways through which the welding process can be grouped and classified, but before going into that, it is important to see that what is the need of classifying the welding processes. So, here this slide shows the various components, which will be covered in this presentation.

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The first starts with the need of the classification and then the basis on which the welding process can be classified, as a welding with or without filler material, welding using the variety of sources of to apply energy during the welding and as welding based on the arc or welding without use of arc. Welding where fusion takes place or welding where processes were only pressure or milli pressure is applied to get the weld joint. So, these are the various parameters or the factors on the basis of which will try to classify the welding processes. We will also try to comment critically on the way by which each criteria have to classify the welding processes and the deficiency is related to with that particular criteria.

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So, as far as need is concern for classifying the welding processes, they have us to group the various processes based on the fundamental similarity in the nature. Like those processes, in which the weld joint is obtained by applying the heat to melt the faying surfaces only or by using the high temperature just to soften. Then, apply pressure to get the metallic joint or just applying the high temperature and getting the metallic continuity through the diffusion.

So, they are certain basic features basic mechanisms through which the weld joint is developed. So, if we try to group various processes the way by which the weld joint is made; can help us in understanding the welding processes in better way. So further, when the welding processes are classified based on the fundamentals similarity; is a separated based on their dissimilarities in nature, it help us to have the better understanding of the each process.

It also helps to make the communication regarding the welding processes, its feature easier by having just one name for each of the process like arc welding process. Under the arc welding process category, we have many names related with the arc welding process. Like submerged arc welding, where arc is submerged under the flux. Metal inert gas arc welding, where consumable filler is use to develop the arc. The arc is covered by the inert gas or shield in metal arc welding process. The consumable arc is developed between the consumable electrodes and the base metal.

So, when the processes are classified under one particular heading, it helps to make the communication regarding the welding process easier. Further, it helps to organize the information about the welding processes in better way. Like what are the arc welding processes, what were the processes and in which only the fusion. They after solidification help to get the metallic continuity in form of the weld joint. What are the processes, in which pressure helps to the get the metallic continuity and obtain a weld joint?

So, when the welding processes are grouped and classified on the basis of; there are different parameters. This helps to organize the information about the welding processes in better way. Further, the grouping based on the fundamentals natures related with the welding processes also helps in naming the new processes, which are being developed. The hybrid processes, which are being developed by the researchers and technologist top deal with the difficulties associated with the existing in the conventional welding processes.

So, when the welding processes are classified based on the various factors related with the processes, it helps us in understanding the processes better. It helps us in a communicating and organizing the welding processes in better way. So, this is how we can say that classification of the welding processes is important in understanding the welding processes in better way. So, the first parameters are the criteria based on which welding process we can classify. Those welding processes where to get the metallic continuity whether be use a filler material or not so. Whenever we use filler material, it is also brought to the molten state and use to fill the gap between the components to be joined.

So, based on these criteria, the welding processes can use the filler material. They may not use any filler material. So, when the welding processes do not use any filler material is the welding processes without a filler material. Those weld joints are called autogenous weld joints. These processes mainly cause the melting of the base material only. Thereafter, solidification of the molten base material results in the metallic continuity.

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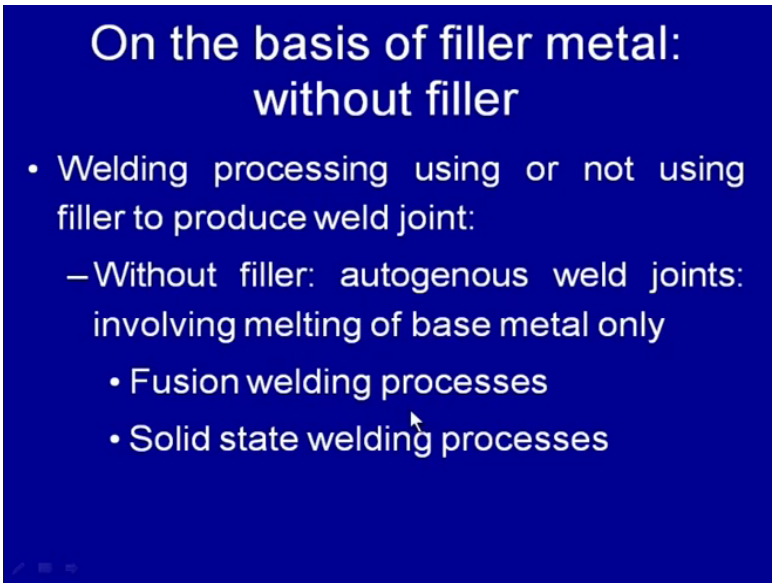

Under this category, we have the fusion welding processes where the edges of the plates to be welded or brought to the molten state. Subsequently, their solidification results in the metallic continuity to produce weld joint. Similarly, these processes where no filler material is used, solid state welding processes like the friction welding is spot pack welding. A ultrasonic welding in exposal explosive welding where the metallic continuity is obtained without addition of the filler material.

So, those processes where no filler material is used and the two components to be joined or welded together, either may be application of heat or with the application of heat pressure both or only application of the pressure. This results in the autogenous welds. So, those welding processes, we can say are auto result in the autogenous weld where filler material is not used.

Those welding processes will where filler material is used for is specially in case of a when the thick sheets are or thick plates are joined. These welding processes involve the melting of the base material and the filler material both. When it is done means when the filler material is used to get the metallic continuity between the members to be joined, there can be two situations. When the filler material is having the composition similar to that after the base material or it can have the different composition.

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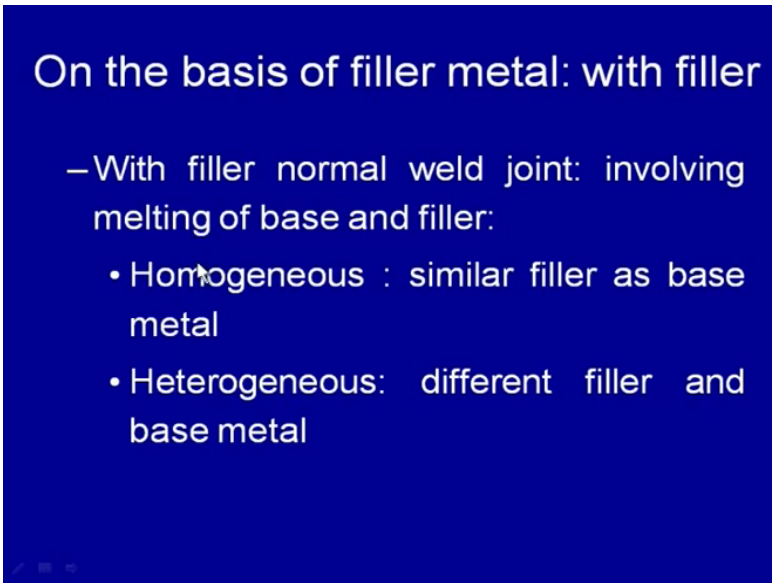

So, when the composition of the filler material is similar to that of the base material, we call it homogenous weld. The composition of the filler is similar to that of the base material. We get the heterogeneous weld when the filler material composition is different from the base metal. But, in both these groupings whether it is homogeneous weld or heterogeneous weld, the filler material is used. The filler material is brought to the molten state along with the base materials faying surfaces to get the metallic continuity and get the weld joint.

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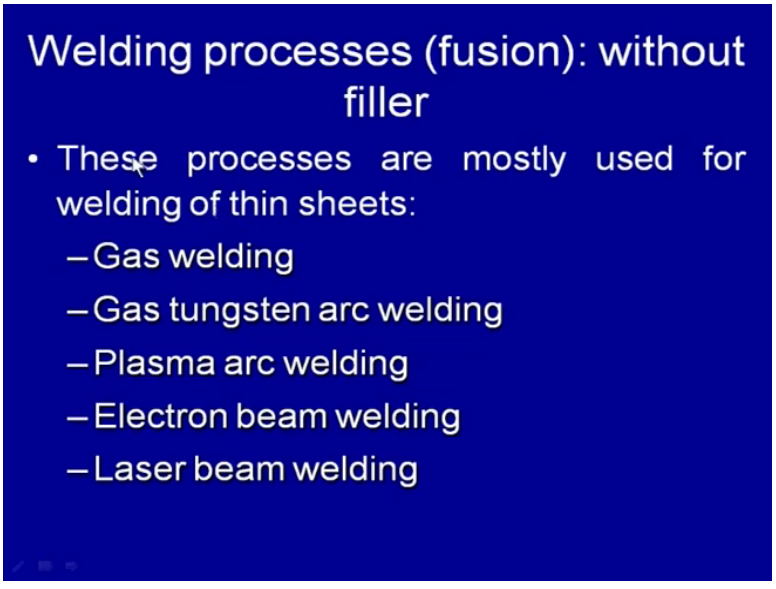

So, those welding processes in which the fusion takes place, but the filler material is not used. So, this is a first category where filler material is not used. But, the faying surfaces are brought to the molten state to get the metallic continuity under to produce the weld joint. These processes are mainly the gas welding, the gas tungsten arc welding, the plasma arc welding, electron beam welding and the laser beam welding. These processes are basically different in the way by which heat is generated.

Because the gas welding, the source of the heat in this welding processes is different. But, in all these cases, there is with the thin sheets. When welding thin sheets, the filler material is normally not used. The gas welding process uses the chemical reactions for generating the heat through exothermic reactions. In tungsten gas, tungsten arc welding, the heat required for melting the faying surfaces of the component to be joined is obtained, so the arc between the tungsten electrode and the base material, where arc is well covered by the inert shielding gas.

The gas can be effectively protected weld pool from the atmospheric contamination. Well, in case of the plasma arc welding, the plasma is generated either between the electrode tungsten electrode and the nozzle or the plasma generated between the tungsten electrode and the base material. This plasma provides the heat required for melting the faying surfaces and get the metallic continuity without adding any filler material. Similarly, electron beam welding process heat required for melting the faying surfaces is obtained by applying a high velocity electron beam in vacuum. The component is brought to the molten state through the beam of the electrons hitting to the faying surfaces and generating the heat.

Similarly, in the laser beam welding process, heat required for melting the faying surfaces of the thin sheets without use a filler material is obtained by applying the beam of laser. This can be performed even under the atmospheric conditions. But, the plasma, sorry, electron beam welding requires the vacuum because beam of electron when moving through the atmospheric air in the ambient condition. The velocity is reduced very significantly.

The beam is not able to generate heat enough to produce to bring the faying surfaces to the molten state and to produce the weld joint. So, in all these welding processes, there is a difference in the way by which heat is generated. But, since the filler material is not

used while using these welding processes specially, when welding the thin sheet; that is why these are categorized under the fusion welding processes without filler material.

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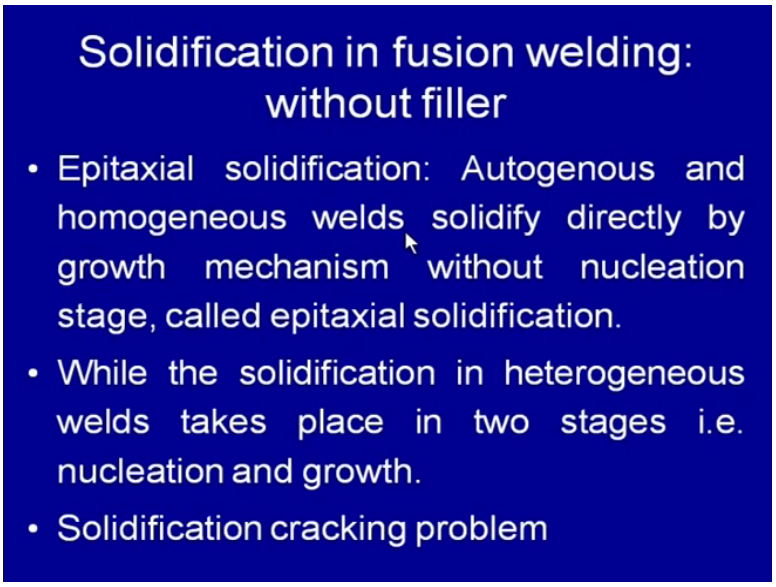

So, in these welding processes where just the melting of the faying surfaces carried out without addition of the filler material solidification normally starts from the faying surfaces or the from the fusion boundary without any nucleation stage. The partially melted grains of the base material start to grow directly and produces weld joint. So here, primarily it involves the growth mechanism without nucleation stage. It is called epitaxial solidification. So, those situations where either the only the base material is brought to the molten state for developing a weld joint like in your autogenous weld, those situations will have where filler material composition is similar to that of the base material.

The solidification normally takes place directly by the growth mechanism where partially melted grains start to grow directly without the nucleation stage. This type of the solidification is called the epitaxial solidification. Those situations where the filler material composition is different from the base material, the solidification requires the two stages, first the nucleation of the grain. Thereafter, there is growth to complete the solidification sequence and produce weld in solid state.

So, the solidification in the heterogeneous weld where composition of the filler material is different from the base material takes place in the two stages. If we see in those

situations where the filler material is not used but the base material itself is having very wide solidification temperature range. Those weld joints, that autogenous weld or homogeneous weld are found to be sensitive for the solidification cracking because lot of recellular stresses are set in along the weld center line. That encourages the cracking tendency along the weld center line. It results in the solidification cracking.

Solidification cracking is called so because it occurs just the terminal stage of the solidification or just after the completion of the solidification. As soon as high recellular stresses set in along the weld center line, it leads to the cracking. So, to overcome this problem of the solidification cracking, various methodologies are used to change the grain morphologies, even in the autogenous weld. The homogeneous welds if thus change in composition of the base material is not possible. Apart from the use of the fusion welding processes, some solid state welding processes like friction welding or friction stir welding process can also be used. The solidification cracking is a major problem in case the fusion welds if filler material is not to be used.

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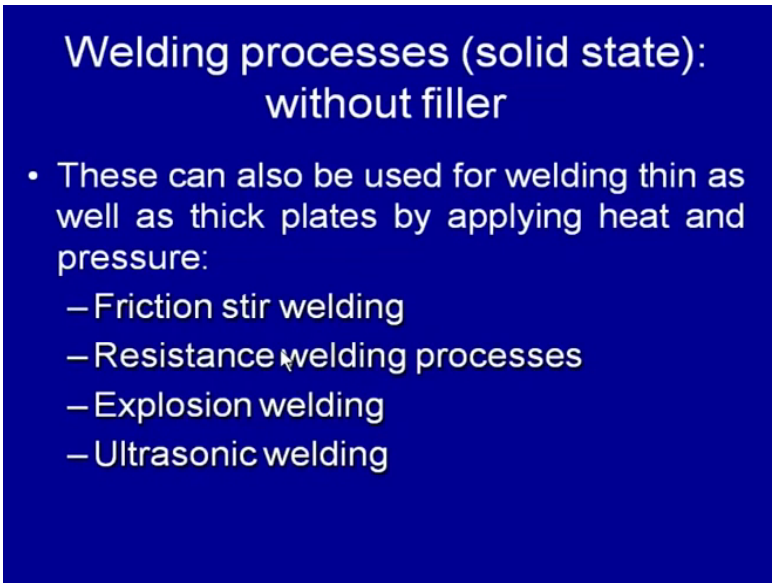

Now, we will see the welding process. Well, filler material is not used but they are carried out in the solid state without fusion of the faying surfaces. In the previous sets, we have seen that the fusion of the faying surfaces is done. But, no filler material is used. In these welding processes, the certain welding processes where filler material is not used but the weld joint is performed in the solid state itself. These can be used for thin as

well as thick plates by applying the heat and the pressure.

This various approaches are used for developing the weld joint in the solid state or in the semisolid state. For example, in the friction history of welding material is heated by the frictional heating to about 300 to 400 degree centigrade. Thermal softening of the material like in alumni in case of aluminum sheets softens the base material. The mechanical churning along the edges results in the consolidation of the metal. It forms a weld joint even in the solid state. In this case, no melting takes place. Maximum temperature goes in case of aluminum to around 300 to 400 degree centigrade.

Similarly, in resistance welding process, material is softened first by the electrical resistance heating. Then, pressure is applied to consolidate the weld joint to at the interface and a produce the metallic continuity for producing weld joint. In explosion welding, the high velocity of one of the members to be joined is obtained by putting in the explosive material over it. Then, high velocity plate allowed moving in a specific way and hitting another member under certain controlled conditions to get the metallic continuity. In this process, the joint is mainly formed by the mechanical interlocking at the inter face. Well, in ultrasonic welding process, the joint is obtained under very low temperature conditions without addition of the filler material.

The required frictional heat is obtained by supply the ultrasonic vibrations at the interface through the suitable ultrasonic welding device. That helps to generate the minor frictional heat. At the same time, leads to the mechanical interlocking in the diffusion the interface to produce the weld joint. In all these welding processes, if we see material is not brought to the molten state. However, in resistance welding, there may be semisolid state condition.

But, the pressure is used to consolidate the things. But, no material is added from outside. That is why, all these welding processes are generally carried out and of the solid state or semi solid condition. The filler material addition is not done. These welding processes include the friction stir welding, resistance welding processes, explosion welding processes and ultrasonic welding processes. We will see now some other welding processes where fusion is carried out and the filler material is used in these processes.

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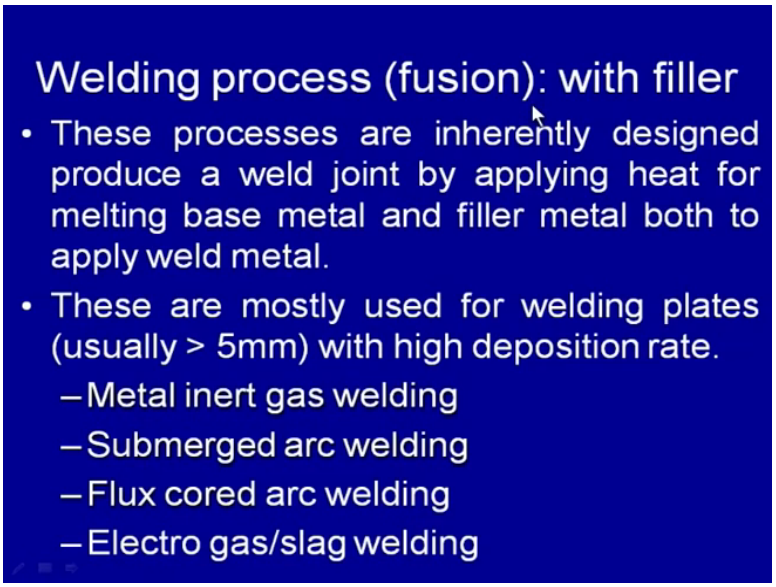

The filler, these processes are inherently designed to produce a weld joint by applying heat for melting the base material and the filler material both. So, that weld metal can be applied in the places where it is required. The continuity, metallic continuity can be obtained to produce the weld joint. So, these processes like sealed in metal arc welding processes or metal inert gas welding process or submerged arc welding process. The nature of the process itself is such that the electrode arc is developed between the electrode and the base material.

The arc helps to melt the base material and the filler material both simultaneously. It helps to deposit the material from the base filler material into the group between the base materials to get the metallic continuity and to produce the weld joint. These fusion welding process with filler are normally used in case of the thick plates usually greater than the 5 mm. These processes also offer the high deposition rate then as compare to those processes where filler material is not used. For example, tin. We can use with both filler material or without filler material.

But, because of the low heat input just possible with the tic processes itself, this cannot the tin does not offer the higher deposition rate. So, those processes are designed to melt with the heat of the arc or with the heat source. They are being used along with the base material usually offers the higher deposition rate. Then, another processes; these processes are normally used for joining the plates of thickness greater than 5 mm. These

processes are metal inert gas welding process, submerged arc welding process, flux cored arc welding process, electro slag and electro gas welding process.

In all these welding processes; in first three, if we see some arc is generated between the consumable electrodes and the base material. It is covered by the inert gases. In case of metal inert gas discovered by the sub, the flux all around the arc to for protecting the weld pool, in case of flux cored arc welding, arc is a covered by the inactive gasses that are generated by the decomposition of the flux within the electrode during the welding. In case of electro gas and electro slag welding process, the heat required for melting in case of electro slag is obtained by the electrical resistance heating.

In case of electro gas welding process, the arc is established between the weld pool and the electrode. It is well covered by the shielding gases. In all these processes, deposition rate is then will high. Deposition rate is used. For example, submerged arc welding process can be used to for welding up to 1 inch or 12, 25 thick sheets in single pass. Further, thicker sheets can be effectively welded using the electro slag. Electro gas welding process, even up to 300 to 400 mm thick sheets; thick plates can be welded using a electro gas welding process.

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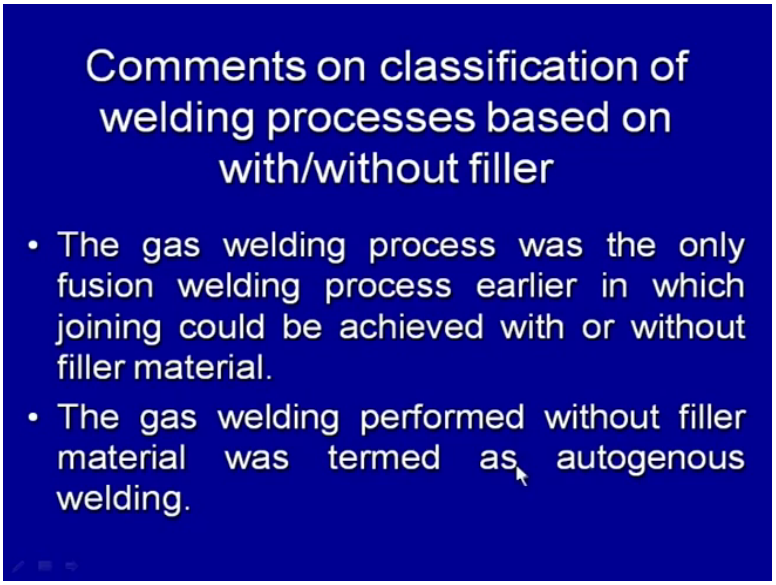

So, if we see the variety of welding process, which are available for developing the weld joints and try to see how effectively we can classify these welding processes. Based on the factor, based on the way whether we are using the filler material or not. If we see

here, the gas welding processes was the only fusion welding process earlier. In that, joining could be achieved with or without filler material. The gas welding process performed without filler material was termed as autogenous welding. So, initially when the gas welding process was used without addition of the filler material; those weld joints where termed as autogenous weld joints. But, these process can also be used; for can be used with the filler material also if we see here.

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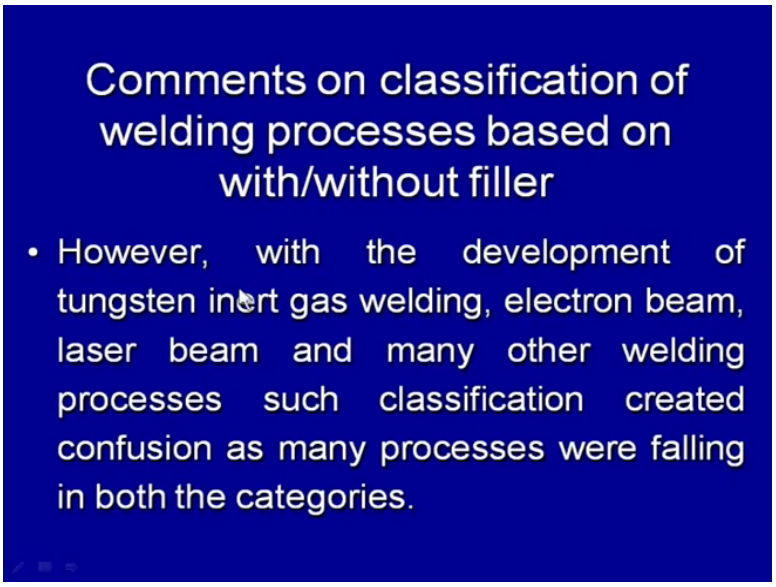

With the development of the tungsten inert gas welding process, electron beam welding process, laser beam and many other welding processes, such classification created confusion. All these processes can work with both filler material or without filler material. So, this classification in that way does not help much to group the processes effectively. Some of these processes can be used with both with the filler material and without filler material for developing the weld joints. This has a lead to the classification of weld joints based on a some other factors. So, the next parameter based on which welding process classification, we can see is the source of energy being used for developing the weld joint. So, this source of the energy mainly is used for how the heat is generated or how the metallic continuity is obtained.

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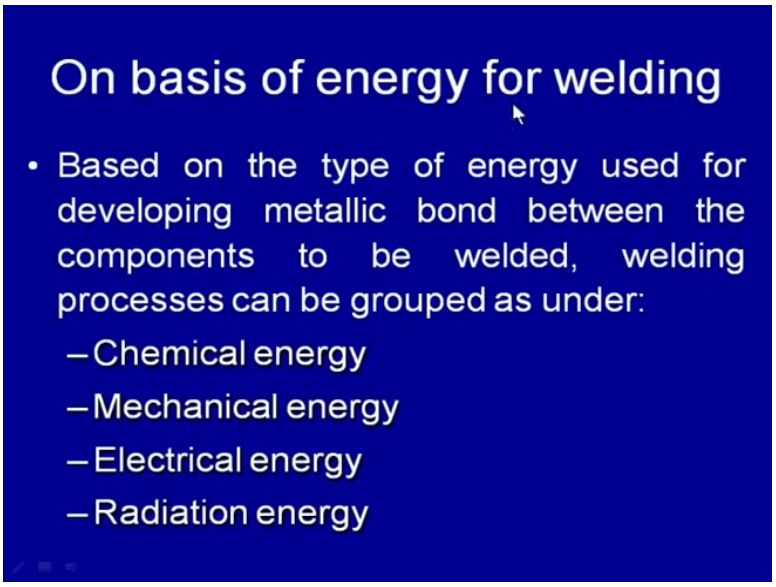

So, on the basis of the energy being used for developing the weld joint; based on this factor, we can classify the weld joints in the different way. For example, how the energy is being generated for developing the metallic continuity or the bond between the components to be welded. So, based on the type of energy being used for developing the metallic bond between the components to be welded, the welding processes can be grouped under the four headings.

For example, those processes, which use the chemical energy to generate the heat and get the metallic continuity to produce the weld joint, those processes, which use mechanical

energy to get the metallic continuity between the members to be joined. Similarly, those which use electrical energy to get a metallic continuity between the members to be join or the radiation energy. So, there are different processes, which use the different types of the energies. So, these now, efforts will you made to see that how these processes can be grouped under the chemical energy, those processes which are using chemical energy, mechanical energy electrical energy or the radiation energy.

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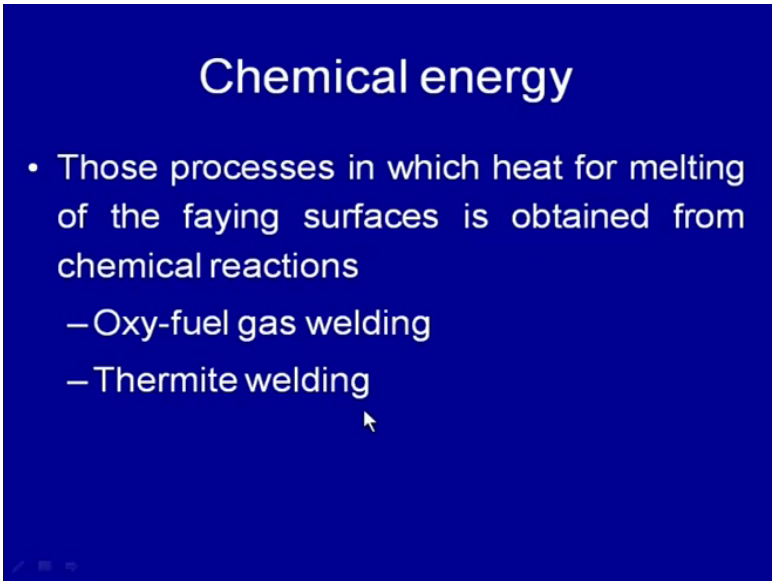

So, the first criteria say, chemical energy, based those processes, which use chemical energy for developing the heat required for melting the faying surfaces is obtained from the chemical reactions. For example, these welding processes, which use the chemical energy for developing heat for melting the faying surfaces, are the oxy fuel welding processes or thermite welding processes. In the oxy fuel welding process, hydrocarbon gasses are burn with the oxygen.

The heat generated so is used for melting the faying surfaces and get the metallic continuity after the solidification. Well, in case of the thermite welding, the chemical reactions are used to get the filler material in molten state. Then, it is supplied between the members to be joined. So, in both these process, chemical reactions, the exothermic chemical reaction are used for generating the heat required for melting the faying surfaces or to get the filler material in the molten stated supplied to the between the components to be joined for getting the metallic continuity.

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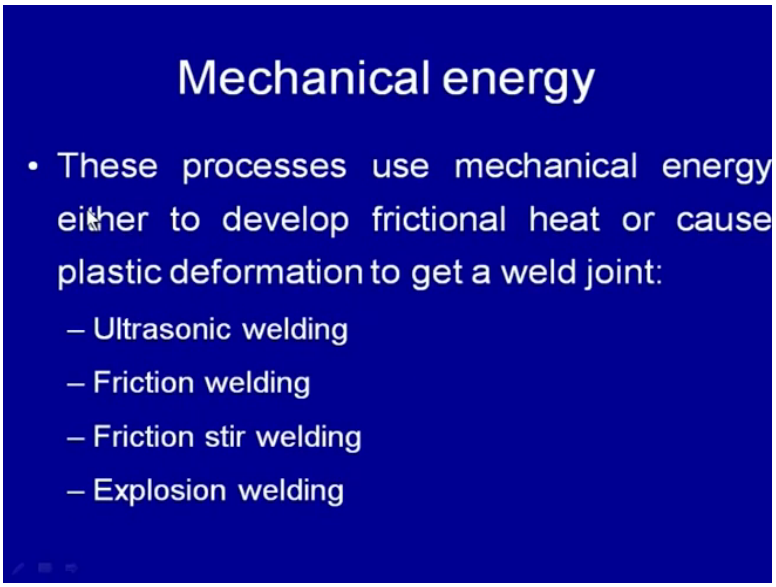

So, these now, another parameter, another type of energy based on which we can classify the welding processes, the mechanical energy. Those processes use mechanical energy either to develop the frictional heat or to cause plastic deformation, so us to get the metallic continuity to produce a weld joint. So, in these processes, somehow mechanical energy is applied between the members to develop the frictional heat or to cause a plastic deformation so as to get the metallic continuity.

In this category, we have the ultrasonic welding where ultrasonic vibrations are applied the interface through the components to be joined. It helps to develop the marginal frictional heat as well as leads to the mechanical interlocking to develop the weld joint. Well, in frictional welding, the friction, the components to be joined is subjected to have the relative movement between them under the normal pressure. So, the frictional heat generated is used to soften the faying surfaces.

Then finally, pressure is applied to get the weld joint. Well, in friction stir welding, the tool pin and shoulder; a tool having the pin and shoulder is rotated at high speed and force to pass through the plates to be joined. This results in the frictional heating of the edges to be joined there softening. Finally, the churning of the edges to be joined, then, a consolidation or mechanical forging helps to get the metallic continuity between the members to be joined.

Well, in case of explosion welding, high kinetic energy is important to one of the members to be joined using the explosive. The movable plate is guided and allowed to move through in very controlled way so that it hits to the another member in very controlled positions at particular angle. So, the metallic continuity between the members to be joined is obtained primarily through the mechanical interlocking. So, we see these welding processes where the mechanical energy is being used. Mechanical energy is primarily used to develop the heat through the friction. Subsequently, the plastic deformation at micro level at the interface results in the mechanical, sorry, metallurgical bond between the members to be joined and produce a weld joint. The electrical energy is another energy.

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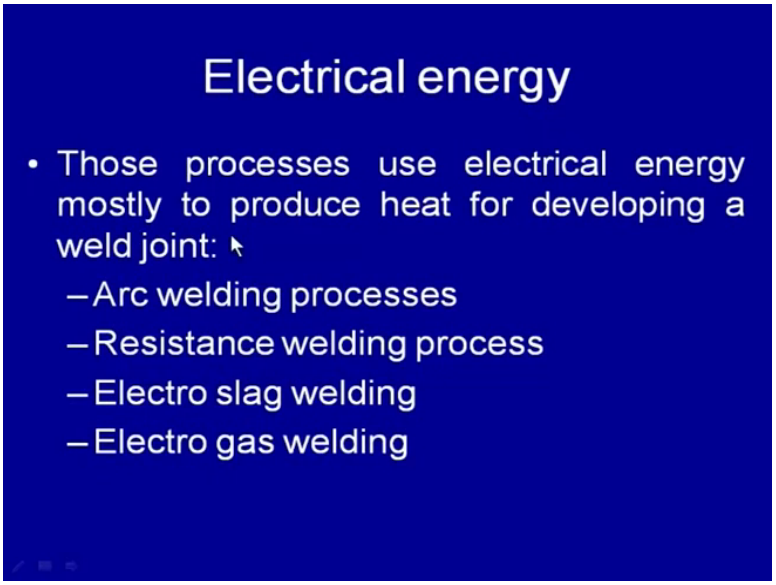

It is very commonly used in the welding processes, those welding processes using electrical energy to produce the heat for developing a weld joint like the welding processes, which use electrical energy to produce the weld joint. It includes the arc welding processes, resistance welding process, electro slag welding processes and electro gas welding processes, although they are many other processes, which use the electrical energy to generate energy in other forms like electron beam or the laser beam process.

They also use the electrical energy to generate the laser and electron beam. These are use subsequently for melting the faying surfaces of the base material and get the weld joint. So, in this processes, electrical energy in arc welding processes mainly used to establish

the arc between the either non consumable electrodes. Like in tungsten inert gas welding process or between the consumable electrode and the work piece, so the heat generated by the arc is used for melting the faying surfaces and get the metallic continuity when you using the electrical energy to generate the arc.

Well, in case of resistance welding process, electrical energy is mainly used to generate heat. So, the electrical resistance heating principal where i square or t i square r t formula is used to find out that how much heat is being generated at the interface. r stands for the contact resistance at the interface. i is the welding current that is being used. t is the time in seconds for which heat is current is applied to generate the heat. So mainly, heat in resistance welding process is generated through by supplying the electrical current through the components to be joined.

The high electrical contact resistance at the interface develops lot of heat which helps to soften the interface between the members to be joined. Subsequently, the application of the pressure results in the development of the weld joint. In case of the electro slag welding, heat required for melting the faying surfaces in obtains through the electrical resistance heating. Current is passed through the slag, the molten weld pool between the consumable electrode and the base material.

So basically, electrical resistance heating helps to melt the base material continuously and to produce the weld joint after the solidification. In this process, the electrical resistance heating basically takes place by the flow of current through the molten slag and the molten weld metal. The current is supplied through the consumable electrode. This work piece is made part of the electrical circuit. So, here, electrical current, electrical energy is used to generate the heat through the electrical resistance heating and to get the base material faying surfaces molten state. It also uses same energy for melting the filler material that is a consumable electrode.

Similarly, in case of the electro gas welding process, heat required for melting the faying surfaces and filler material is obtained by establishing the arc between the consumable electrode and the weld pool. So here, the arc is well covered by the inert or inactive gasses to protect the weld pool from the atmospheric contamination. So, in all these welding processes, we see that the electric energy is used for melting the faying surfaces by generating the heat through different mechanisms.

It is a development of the arc or through the electrical resistance heating or the electrical resistance heating. In case of electro slag welding also, by using the arc between the consumable electrode and the weld pool, in case of electro slag welding. So, we can see that certain processes which use the electrical energy primarily to produce heat so that weld joint can be obtained.

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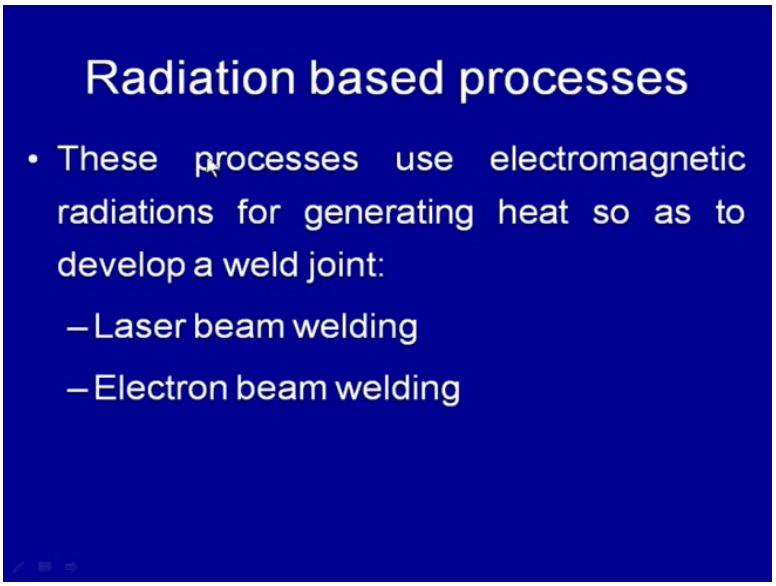

The certain processes, which use the radiations to get the faying surfaces in the molten state and guide the weld joint. These processes use the electromagnetic radiations for generating the heat so as to develop a weld joint. The one is laser beam welding and another is electron beam welding processes. In the laser beam welding, mainly laser is directed towards the work piece of is to be work piece members or the members to be joined. Here, it is important that beam diameter plays a significant role in bringing the edges of the components to be joined to the molten state.

So, if the beam diameter is very small then, the gap between the plates to be joined is to be very fine. The edges of the plates must be straight otherwise beam will pass through the gap between the plates to be joining. So specially, when using the laser beam of a very small diameter say of a 100 micron or 200 micron, the edge preparation becomes very critical. If there is any lack of the straightness or the roughness presented the edges of the plates to be joined then, the beam will pass through the gap between the plates and the melting will not occur.

Similarly, in electron beam, the beam of the electron is directed towards the edges to be brought to the molten state, to be under the edges of components to be joined. They are brought to the molten state by the directing a beam of electron. They are moving at very high speed. The impact of these electron electrons moving at very high speed with the edges of the surfaces of the component to be joined generates lot of heat. That helps to bring the faying surfaces to the molten state.

But, these electron beam welding processes requires a vacuum. Electron beam and the electrons cannot move at high speed in the ambient conditions because of their collision with the atmospheric gases and molecules. That is why, it is mandatory to have the electron beam mandatory to have the vacuum in case of the electron beam welding processes. But, if we see errors for as this classification is concerned. The radiations in form of the laser beam and the electron beam welding processes or electron beam are used for melting the edges of the component to be joint together and get the metallic continuity to produce the weld joint. So, if we have to comment on this way of the classification of welding processes where some where the classification is based on the kind of energy which is used for developing metallic continuity.

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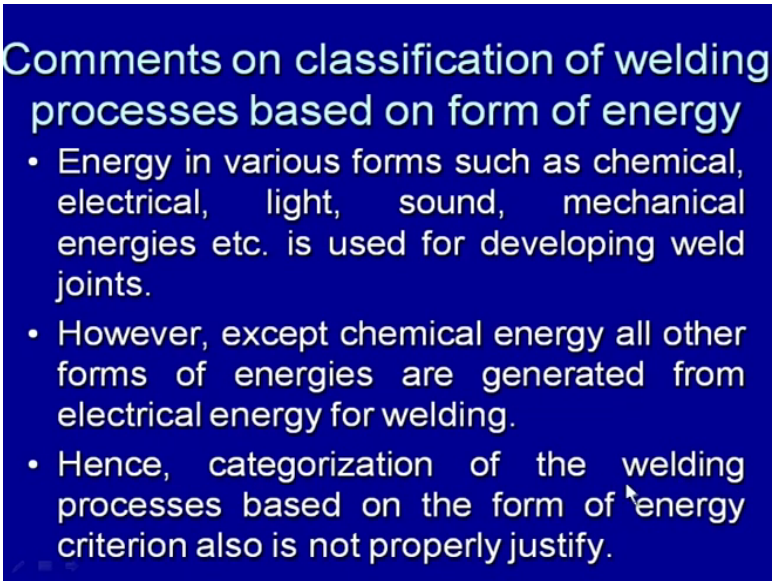

We see, we have seen that the energy in various forms can be used for developing the weld joint. Chemical energy, electrical energy, the laser in form of light, sound, ultra, mechanical energies can be used for developing the weld joints. However, except the

chemical energy, all other forms of the energies are generated from the electrical energy. So, whether it is the mechanical energy where vibrations or ultrasonic vibrations are applied or the electron beam or laser beam is used; in all these forms are generated.

These energies of all these form, whether it is mechanical light or electron beam, these energies are generated from the electrical energy for the welding purpose. So, except the chemical energy, all other forms of the energies are generated again from the electrical energy. So, in this way, this classification becomes slightly confusing. Hence, the categorization of the welding processes based on the form of the energy criteria is not very properly justified. So, except the chemical energy because in all other forms of the energies are using the electrical energy in; that is why this classification based on the form of energy is not very effective and the properly justified.

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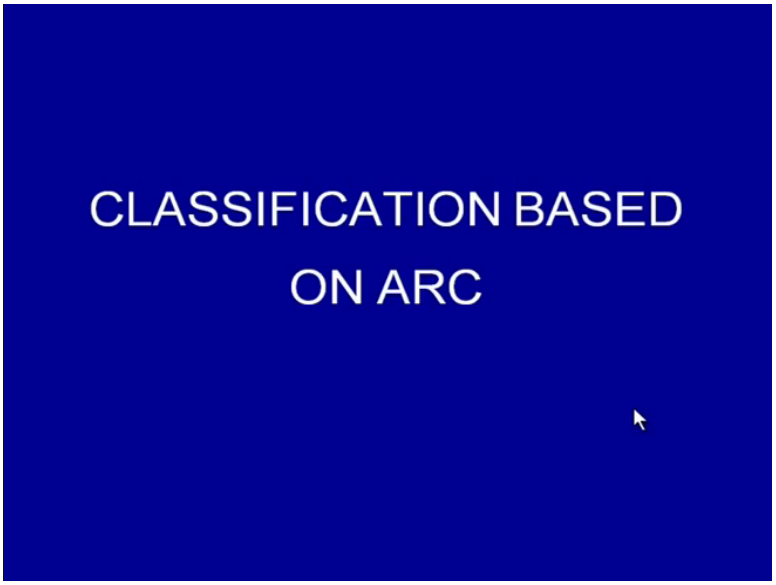

So, the welding processes, we can further classify based on the presence or absence of the arc, which is used for generating the heat required for developing weld joint.

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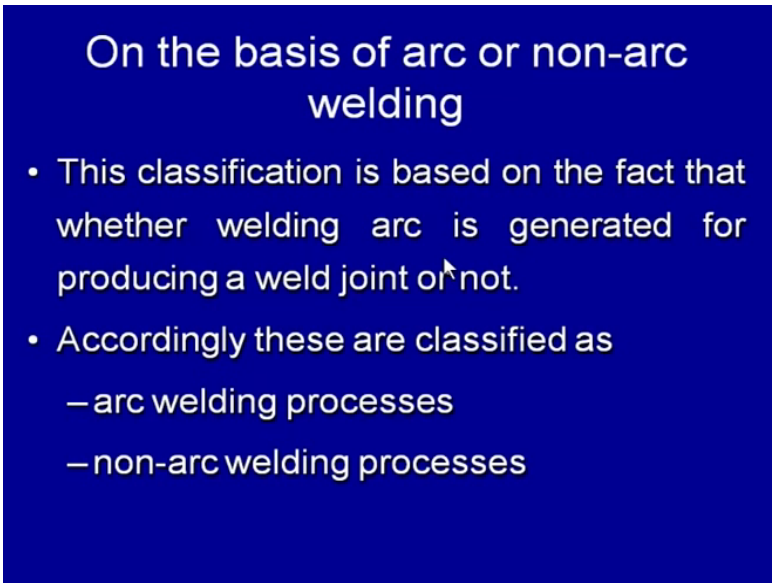

So, the criteria on the basis of which we can classify whether the arc is developed or not; this classification is based on the fact that whether welding arc is a generated for producing weld joint or not. So here, welding arc is mainly used for generating the heat required for melting the faying surfaces so that metallic continuity can be obtained, either with the use of a the filler material or without use of the a filler material. So, based on this, we can classify as arc welding processes or non arc welding processes. In the arc welding processes, arc is established either between the consumable electrode and the base material. Arc is established between non consumable electrode and the base material.

So, those if the arc is established between the consumable electrode and the base material; in general, we get the higher deposition rate and the higher productivity. In case of those processes where arc is established between the non consumable electrode and the base material like in gas tungsten arc welding or in plasma arc welding processes, the deposition rate is usually low. The filler material is added; either filler material is added from outside or the filler material is not added for getting the weld joint.

Well, in case of the non arc welding processes, it is required; either heat is generated through the chemical reactions or through the frictional friction. The joint is made using the mechanical interlocking or developing the pressure for causing the plastic deformation or through the diffusion or other mechanisms. So, those welding processes

where arc is not used for developing the weld joint and get the metallic continuity; they are called as non arc welding processes. Arc is used for generating the heat required for melting the faying surfaces to get a weld joint are called arc welding processes.

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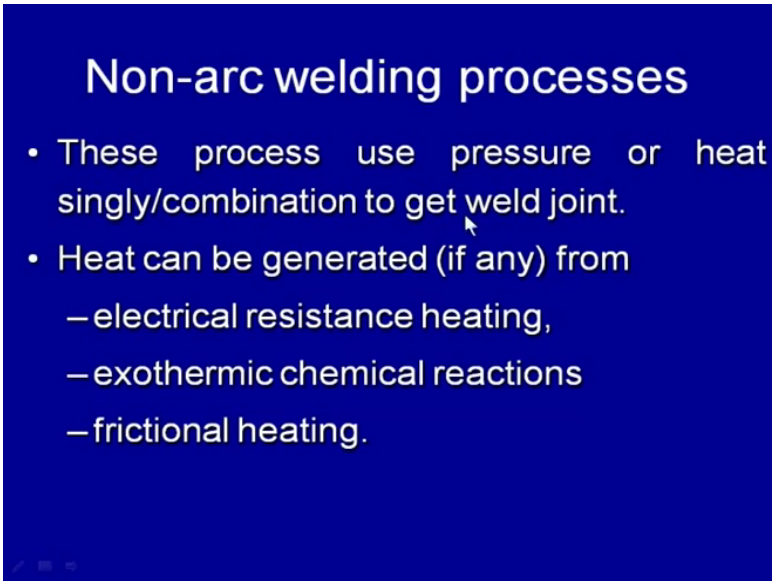

So here, we will see first non arc welding processes. These processes primarily use pressure with or without heat. So, these processes used pressure or heat either in singly means only heat or only pressure or combination of the both to get the weld joint. So, heat in these non arc based welding processes; if it is used can be generated using the electrical resistance heating principal or using the exothermic chemical reactions or frictional heat.

These are the three ways through which heat can be generated in the non arc welding base processes. There are other ways through which also heat can be generated for melting the faying surfaces and developing the weld joints like electron beam and the laser beam. So, in these processes, we can use pressure in combination with the heat or without application of heat to get the weld joint. Well, if the heat generation is involved then, electrical resistance heating exothermic chemical reactions and the frictional heating or some radiations can be used for generating the heat required and to get metallic continuity.

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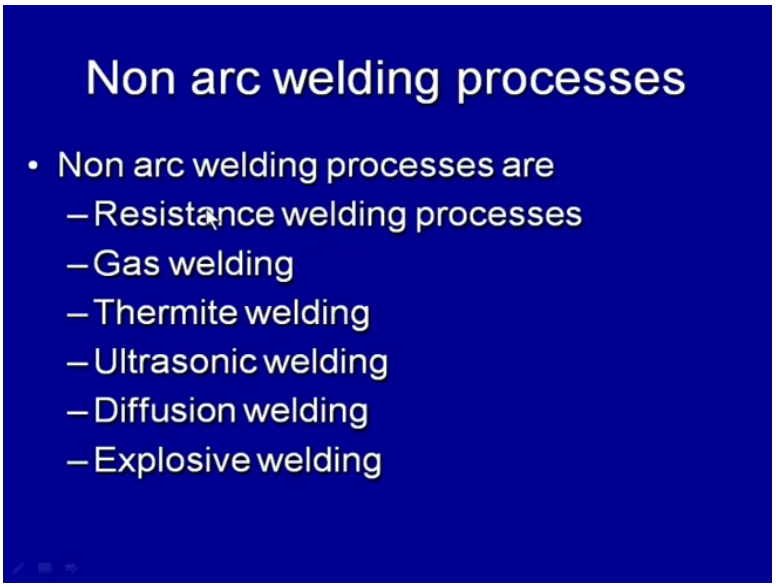

So, these welding processes where arc is not generated but the heat required for developing the weld joint is obtained through the resistance heating. Electrical resistance heating like in resistance welding processes arc is also not generated in gas welding. Here, heat is obtained through the chemical reactions between the oxygen and the hydrocarbon fuel gases. In thermite welding, the chemical reactions between the aluminum oxide, magnesium oxides and the iron mixture is used for performing for having the chemical reactions, which are exothermic in nature.

It can generate lot of heat for melting the filler material. Similarly, in ultrasonic welding, there is no arc. Under the required; frictional heat is obtained through the mechanical energy in form of the ultrasonic vibrations. In diffusion welding, absence of arc is also there. But here, the metallic continuities obtain by the diffusion through the interface between the members to be joined. For this, the components to be joined are kept under the firm metallic contact at high temperature for long under pressure. So, the diffusion cross the interface can take place from one side to another and the get metallic continuity.

Similarly, in explosive welding, there is no arc. The required joint is obtained through the mechanical interlocking by moving one plate or one component to be welded at high speed with respect to another. Under the impact results the mechanical interlocking at the interface and produces weld joint. So, in all these welding processes, we see the heat is generated through the various means like resistance heating chemical reactions. Again,

chemical reactions or the diffusion and ultrasonic vibrations or the kinetic energy between them; kinetic energy by impact of the high velocity moving in component against the another member with which it is to be joined under the explosive welding category.

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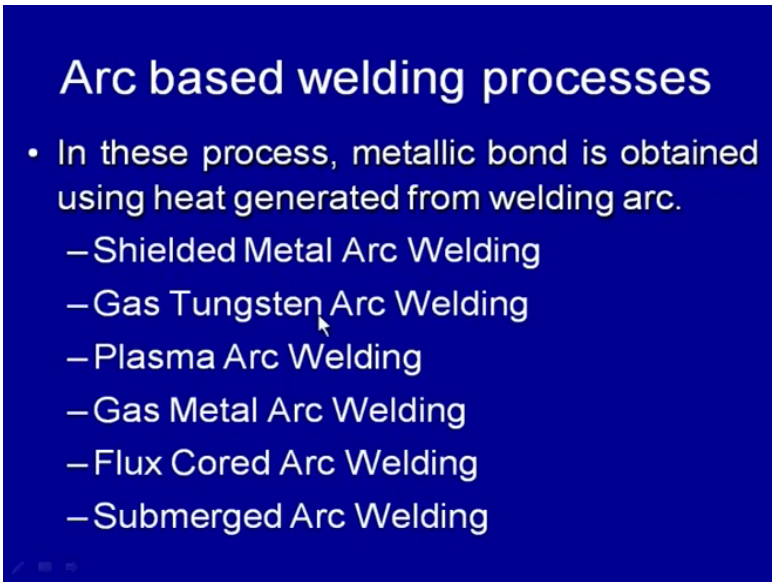

So here, well, are those processes in which heat required for melting the faying surfaces and get the metallic continuity is obtained from the welding arc. In these processes, arc is in variably part of the welding processes for generating the heat. Heat generated is used either for melting the faying surfaces or for melting the filler material and the faying surfaces both to get the metallic continuity, for example in shielded metal arc welding processes.

The arc is established between the consumable electrode of shielded electrode and the base material and the heat generated by the arc is used for melting both consumable stick electrode and the base material. Development of the weld pool molten weld pool and subsequently, solidification results in the weld joint. Well, in case of the gas tungsten arc, welding arc is established between the tungsten electrode and the base material. The heart available from the arc is used for melting the faying surfaces of the base material. If thicker plates are being joined, that filler material can be applied from the outside.

Here, the filler material is placed in the arc. Then, melting of the filler material and getting it mixed with the molten base material results in the metallic continuity. But, this filler material in the GTAW process is mainly used when the thick plates are to be joined. Similarly, the plasma arc welding process. The heat of the arc is used for melting the faying surfaces of the base material to be joined, are for melting the filler material. If it is being used because, in both these two welding processes the non consumable tungsten electrode is used. Therefore, to fill if the large amount of the weld metal is to be applied then, filler material is used from outside.

In case of gas metal arc welding process again, consumable electrode and the consumable electrode is used. The welding arc is established between the consumable electrode and the work piece under the heat generated by the arc. It is used for melting the consumable electrode as well as the base material and get the weld pool which after the solidification results in the weld joint. Well, in case of the flux cored arc welding, in flux cored arc welding processes is similar to the gas metal arc welding process.

But, with the difference in the sense that the electrode is a having flux field in the cored portion of the electrode. The flux decomposes by the heat of the arc, provides the cover or shielding to the arc and the weld pool by the inactive gases during this flux cored arc welding processes. So, heat of the arc generated between the consumable flux cored electrode and the base material is used for melting of both electrode as well as base material; so as to produce the weld pool and a weld joint.

Well, in case of submerged arc welding process, the arc is established between the consumable electrode and the base material. The arc is submerged under the flux pool. The flux forms complete cover around the weld pool and the arc to protect the pool from the atmospheric contamination. So, submerging feature of the arc in these processes is a different from other welding processes. It helps to shield the welding arc and pool effectively. At the same time, it also reduces the heat losses from the arc to the surrounding. That is why; this process offers very good penetration and the high deposition rate. Hence, used for joining of the thick sheets.

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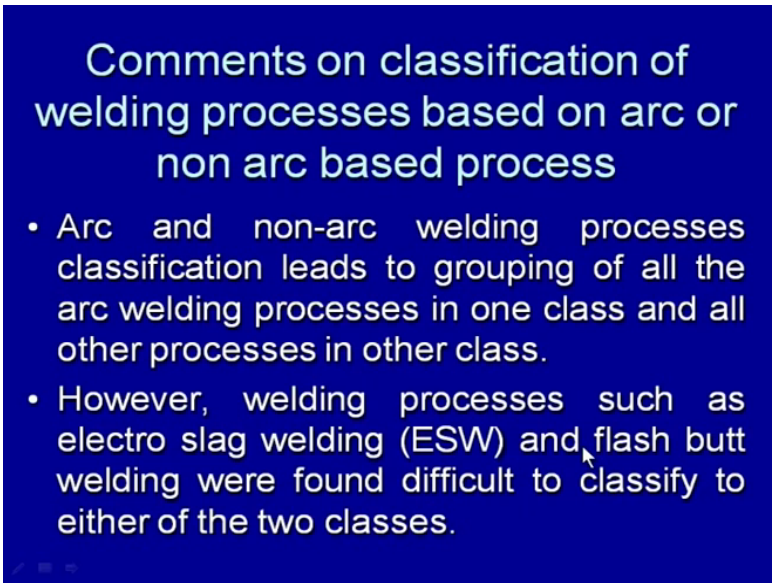

So, if we have to look into that how effectively this classification can be used to categorized various welding processes based on the fact whether there is arc or there in no arc. If we see here, the arc and non arc welding processes classification leads to grouping of all the welding processes. In one class and all other welding processes in other class, which those welding processes where arc is unrated or kept in one category, all those for welding processes where no arc is generated and arc is used; they are put in another category.

However, they are welding processes, where there is confusion. There is a presence of both the arcing for the short while followed by the electrical resistance heating. For example, in the welding processes such as electro slag welding and the flash butt welding processes, it is found difficult to classify under either of the two classes. It is difficult to put either under the arc welding processes or non arc welding processes, because arcing is there in for a short while. Thereafter, main heating takes place by the electrical resistance heating or by or the joint is made by the forging and the plastic deformation.

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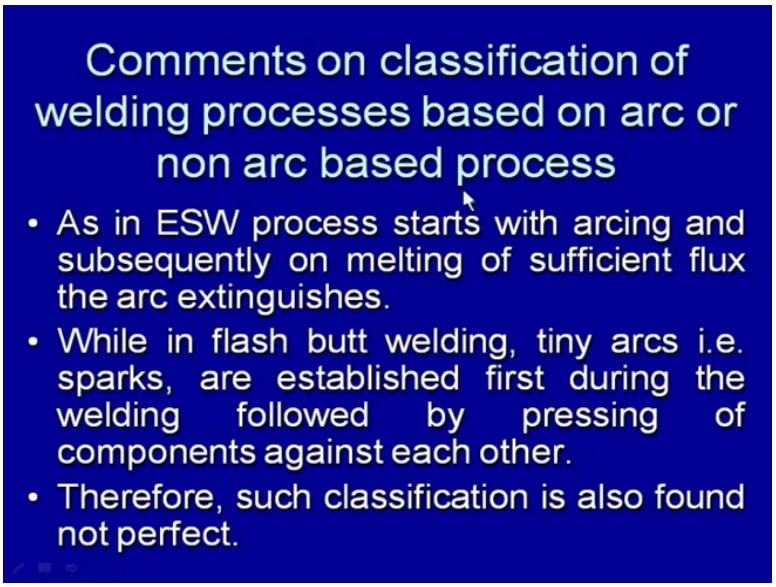

So, if you see here as in case of electro slag welding process, this process is start with the arcing. Subsequently, as soon as the sufficient a pool of the molten flux is formed the melting of the arc is extinguished. Melting of the base material takes place primarily by the heat generated due to the flow of current through the molten flux by the electrical resistance heating. So, in this case, arcing is mainly used to for the melting of the fluxes. Once the sufficient pool of the molten fluxes obtained, the arc is extinguished.

Then, by flow of current through the molten flux heat is generated by the electrical resistance heating. It is subsequently used for melting of the consumable electrode as well as melting of the faying surfaces of the base material. In case of the flash butt welding, tiny arcs or a sparks arcs first established between the components to be welded. Once these are established, lot of heat is generated. Even the cleaning of the edges to be joined takes place. All impurities are removed from the surfaces. Once this happens, the forging pressure is applied between the components to be joined to get the metallic continuity.

So, in these processes also, the arcing, the process begins first with the arc for a short while. Thereafter, forging pressure is applied to get the metallic continuity. Therefore, the classification of the welding processes is based on the presence of arc or there is no presence of arc. It becomes difficult, because the processes like electro slag welding processes, electro slag welding process and the flash welding process cannot be put

under any of the categories effectively.

For such classification is also not found perfect so, we will see that they are certain parameters based on which welding process can be flayer can be classified. But, each criterion is having some deficiency and not will to clearly put all the welding processes under the different headings. So now, we can conclude this presentation. In this presentation, we have seen the various factors or the parameters based on which we can classify the welding processes.

We have seen in detail that how we can classify the welding processes based on the use of the filler material or based on the use of the energy for developing the weld joint. Based on the whether the arc is being used or there is no arc in welding process for developing the weld joint. So further, we have seen that each of these criteria is having the deficiency of a one or other form and not able to cover or include all the welding processes effectively in as very justified when are under the each criteria. So, we will continue in the coming lecture. In the next lecture see that how we can classify the welding processes based on the other parameters also.

Thank you for your attention.