Joining Technologies of Commercial Importance

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

Lecture - 03
Classification of Joining Processes

Hello, I welcome you all in this 3rd lecture on the program on joining technologies for the metals. In the last lecture, you have seen the need for classifying the joining processes. And now in this presentation, we will see, what are the different factors on the basis of which, joining processes can be classified. So, there are two categories.

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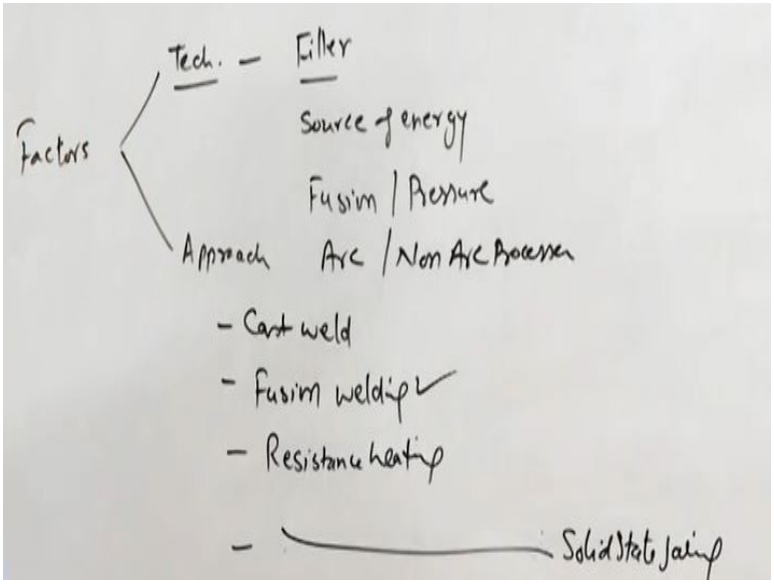

There are two broad categories based on which the processes can be classified. One is like say technological factors and another is approach, being used for joining purpose. So these technical factors are like whether the filler metal is used or not is one, then second is the source of energy, whether electrical energy is being used, mechanical energy is being used, radiation or any other form of energy is used.

And then third is, like in technical factors, the source of energy, then whether there is a fusion or the pressure is being used. So and then one more classification or the basis, which is Arc or non-arc processes.

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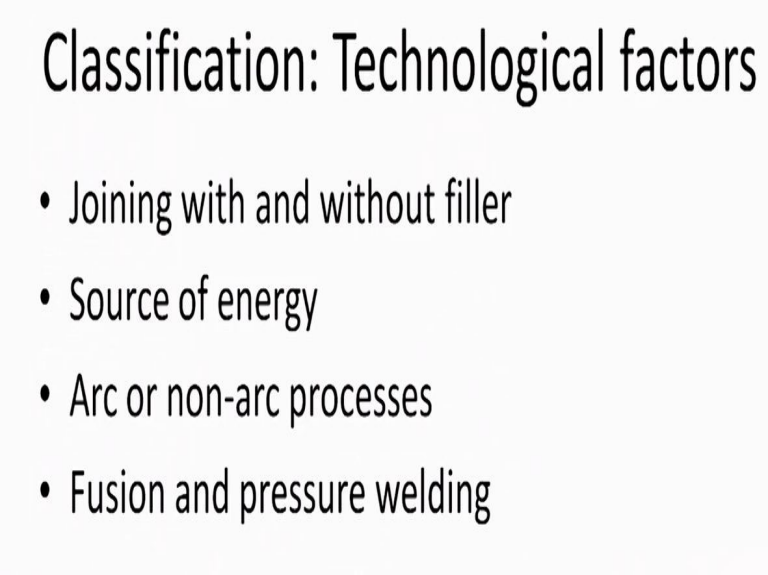

So, these are the 4 technical factors on the basis of which the different welding processes are grouped and classified. Another one the approach of developing the weld joints involving like say use of the cast weld processes, where it is expected that molted metal will be fed from the outside for developing the joint. Then there is a fusion welding processes, where the melting of the faying surfaces is achieved for developing the joint and achieving the metallic continuity.

And the third is like heat being generated through electrical resistance heating, so electrical resistance heating like resistance welding processes and then rather it is pressure or fusion welding, it is based on actually whether the processes is solid state joining process. So basically, the fourth classification or the fourth factor is here fusion and here the solid state joining process. So, cast weld process, fusion weld process, resistance heating based process and the solid state joining processes.

So, one by one I will talk about the different factors and the processes falling in the different categories and their suitability to put in that particular category and what are the related controversies or we can see the problems related to the classification of putting a particular process in particular category.

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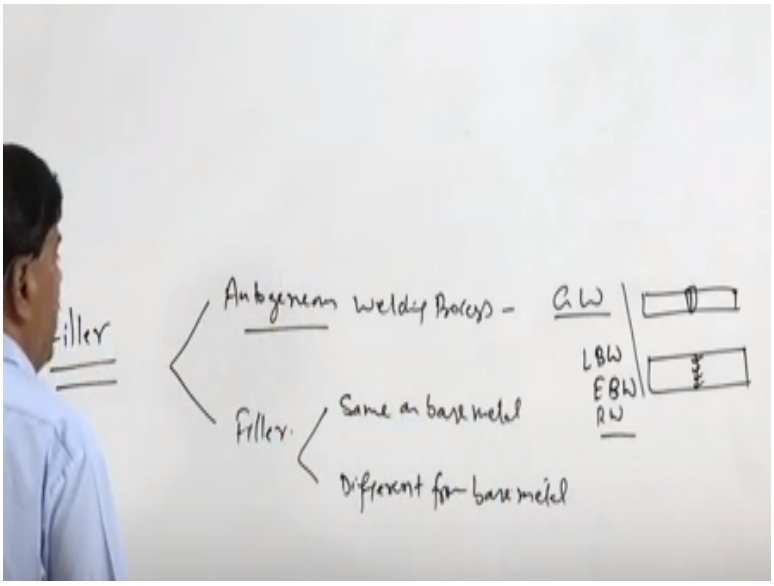

So, like the filler based process, the classification of the different process based on the filler. There are two categories, where no filler is used, those process are categorized as autogeneous welding processes and when the filler is used, then based on the filler, like the filler is used, the filler can be of the composition same as base metal or it can be different from the base metal.

So, all those processes like initially the gas welding was the process, which was the only process wherein joining of the thin sheets by melting the faying surfaces through the flame of the gas used to be achieved and this process was categorized as the autogeneous process but later on development of, like say, the laser beam welding, electron beam welding and where like say, the melting of the faying surface can be achieved and without development of, without applying any filler the joint can also be made.

So in this category, earlier there was just the gas welding but the development of the laser welding and the electronic beam welding processes, which also do the same thing like melting on the faying surfaces to develop the joint, also fall in the same category, so this classification was not found that fit like defining the processes autogeneous welding just for the gas welding, but there are so many processes where autogeneous weld is made without addition of the any filler metal. Like in this category, we also have the resistance welding processes.

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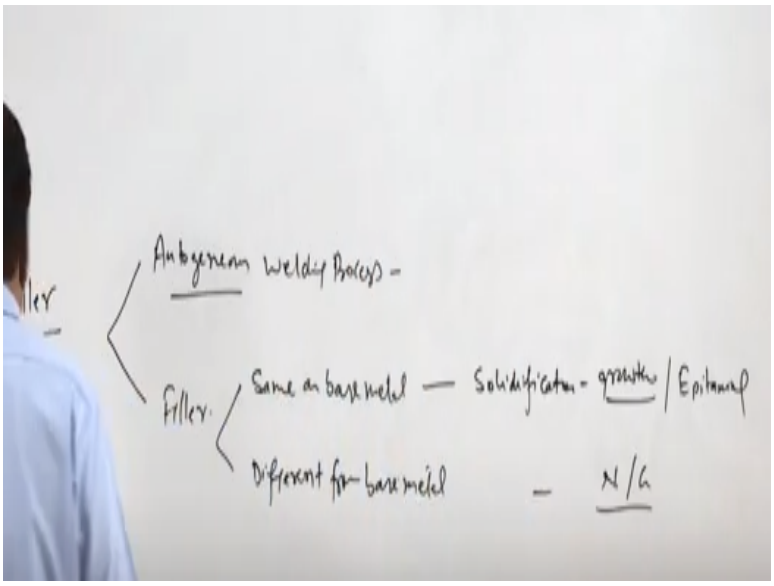

Then those processes which uses the filler metal, filler metal is optional, there are certain processes, where the filler metal is used or filler metal may be used or filler metal may not be used. We will talk first about the filler metal of the same base metal. When it happens the filler metal of the same base metal, in that case, the solidification of the weld metal is achieved only through the growth mechanism.

Because of the partial presence of the partial melted grains directly, the liquid metal is consumed through the growth mechanism and this kind of the solidification is called Epitaxial solidification. But when the composition is different the solidification is completed through nucleation and the growth mechanisms. This is one case, where in most of the cases when the matching filler is used the solidification is achieved through this way.

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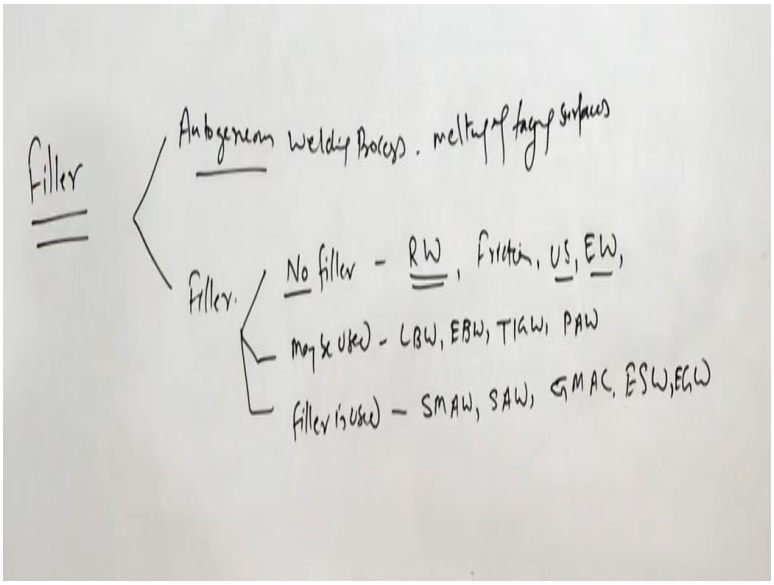

Then we will see, there are certain processes, which do not use any filler and certain processes, where filler may be used or may not be used and filler is used compulsorily like the processes, which use no filler or the filler may be used and the filler is used in any case. So, there are 3 categories of the processes. So like, if we talk about the resistance welding processes, the no filler is used and similarly friction welding processes, ultrasonic welding processes, explosion welding, in these processes the filler metal is not used.

So, here some of these processes either they are carried out in a solid state or where in their processes like resistance welding, where the heating either through the partial melting takes place or just softening of the metal is involved. So, there are certain processes where the filler may be used or may not be used. They are like laser beam welding processes, electron beam welding processes, even the thin sheets welded using the gas or the Tungsten arc welding or the TIG welding processes or the plasma welding processes.

The filler metal may be used or may not be used. There are certain processes, where filler metal is used in any cases, whenever they are applied. In this case the arc is established between the consumable welding processes, the arc is established between consumable electrode and the base metal. So, these processes like shielded metal arc welding or is also known as manual metal arc welding process and the submerged arc welding process.

And the gas metal arc welding process, these also known as MIG and the submerged arc welding process, shielded metal welding process, electro slag welding process, electro gas welding process. All these processes the filler metal is, in any case, is applied during the welding. So, this is the kind of the grouping of the different processes based on the filler, whether the filler is used or no filler is used, this is the case where just melting of the, melting of faying surfaces is involved. In other process, filler metal may be used or may not be used.

So, this is the classification of the different welding processes or the joining processes based on the use of filler. So, if you see, this a classification is especially problematic in respect of autogenous weld, where in the gas welding used to be known as autogenous welding process. But subsequently development of the laser beam welding and electron beam welding also was capable to do the same things, so this led to the confusion over rate.

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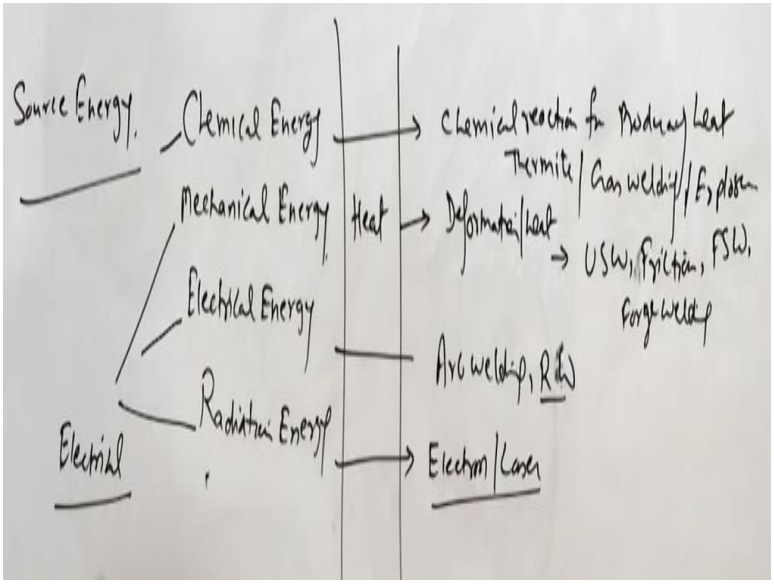

Then, the source of energy is another criteria based on which the welding processes can be classified. The source of energy is in the form of, like say, mechanical energy, chemical energy and electrical energy and radiation energy. So, these are the different forms of the energies which are used for the welding purpose, for joining purpose. These are used primarily for developing the heat.

So heat, which will be used either for the purpose of fusion or to facilitate the diffusion or for lowering the yield strength, like in the solid state deformation processes. Or there is one more electrical resistance heating, so this also actually using the electrical energy only. So these are the 4 different forms of the energies which are used. So if you see the chemical energy, energy uses the chemical reactions for producing heat.

So that the melting of the faying surfaces can be realized. Mechanical energy is used not just for developing the heat but also for the deformation purpose, plastic deformation purpose either at the surface layers or of the bulk material. So, basically this uses the deformation and the inter-frictional heat. So, these chemical reactions are producing the heat.

This approach is used in the processes like thermite welding and the gas welding, where the chemical reactions between the fuel gas and the oxygen are used for producing the heat so that the melting of the faying surfaces can be achieved and the thermite welding, where the metal oxides are interacted with certain metal, so that chemical reactions takes placed for producing the heat.

And in the mechanical energy, where the friction and the deformation both are used for producing the heat and the deformation at the interface and this approach is used in that processes like ultrasonic welding, explosion welding, actually, this is used in explosion welding also in the chemical energy process, ultrasonic welding, here, the friction welding and commonly known as friction stir welding, forge welding.

These are the joining processes which use mainly the mechanical energy. Then the electrical energy is used in all Arc welding processes and the resistance, electrical resistance, heating means the resistance, basically the resistance welding processes like spot welding, seam welding, projection welding, instant welding, etcetera and the Arc welding processes like the shielded metal arc, gas metal arc welding, submerged arc welding etc. and flux welding etc.

So many processes, which fall in this category and then the radiation based processes, where the either electron beam or the laser beam is used for generating the heat for the purpose of melting

the faying surfaces. So, if we see, except the chemical energy all other forms of energies like radiation energy, electrical energy all these are come from basically the electrical energy. The electrical energy is converted into mechanical energy or the radiation energy is in control way for producing the heat and using the in different forms.

So, here the problem is the origin in mechanical and radiation energies in electrical energy while we are saying that the categorization as a mechanical use of mechanical energy and the radiation energy. The form in which the electrical energy is used for the welding purpose in the two cases is different but the main energy, which is used for generating the mechanical energy and the radiation energy is coming from the electrical energy only.

So, this is the problem related with this, actually it is electrical energy only which is used in form of mechanical energy or in the radiation energy. So, this is you can say, non-clarity side, where in although the form of energy, which is actually used is the mechanical and radiation, but these are also coming from the electrical energy. So although process can be grouped like this but there is a non-clarity in the sense that the radiation and the mechanical energies are being or coming from the electrical energy.

So it is not bad right to say that they are of the mechanic using the mechanical energy or electrical energy or sorry the radiation energies.

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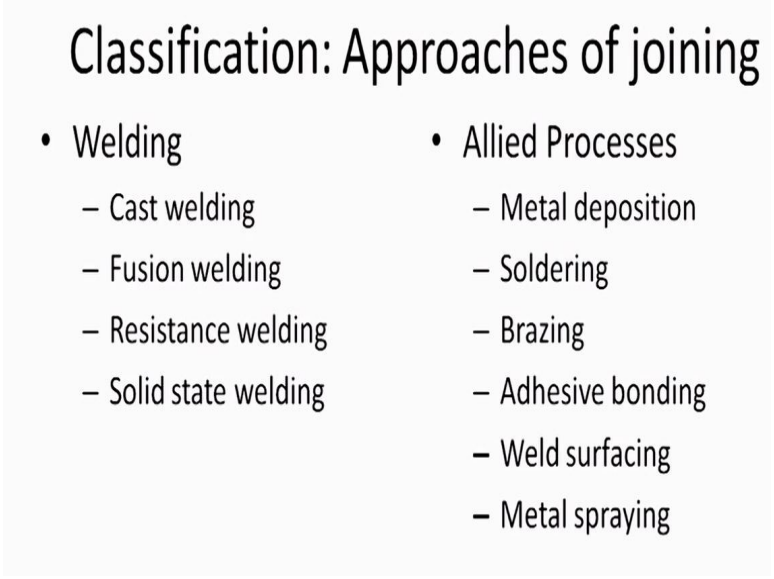

Now, we will see another classification based on the technical factor which is the pressure or the fusion welding Arc and Non-Arc based processes.

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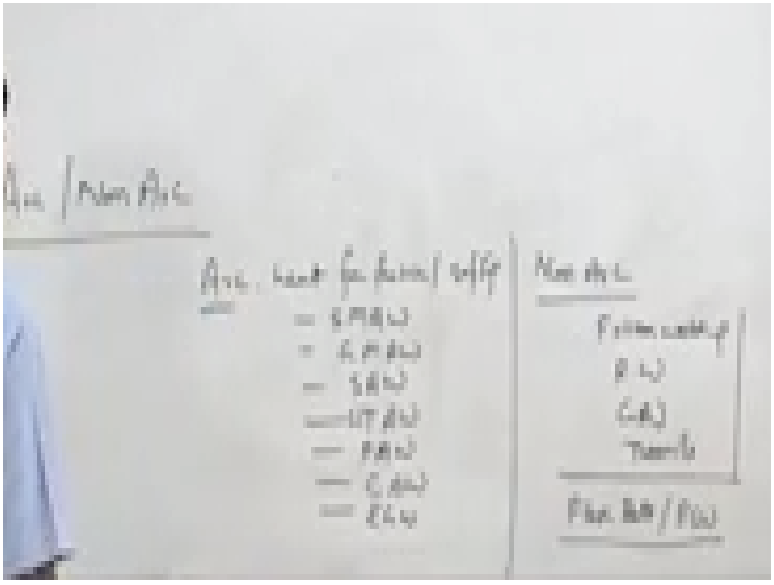

So the first one is classification based on the Arc or Non arc based processes. All those processes, where heat for the purpose of melting or softening is used from the arc, like say, the arc generates the Heat for basically fusion and very really it is used for the softening purpose mostly it is for the fusion purpose. So that, so all those processes, where arc is established for generating heat for the fusion purpose.

They can be put in this category, like shielding metal arc welding, gas metal arc welding, submerged arc welding, tungsten arc welding, plasma arc welding, like say similarly there is carbon arc welding and then electro gas welding processes. So, all these are the processes where arc is used for generating the heat and all other processes where no arc is used non arc based processes like the friction welding, resistance welding, gas welding and thermite welding.

So, all those processes actually arc is not used for, can be placed in this category, but is still there the controls exist in case of the two processes. One is the flash butt welding and another is the electro slag welding. These are all the two processes were found to be difficult to be placed in either of the categories like the flash butt welding or the electro slag welding. Why it is so?

Elaborate that because clarity does not exist in terms of the way by which heat is generated in these two cases or the purpose for which the heat is used in these two cases. So for that, we need to see first the way by which these processes work in.

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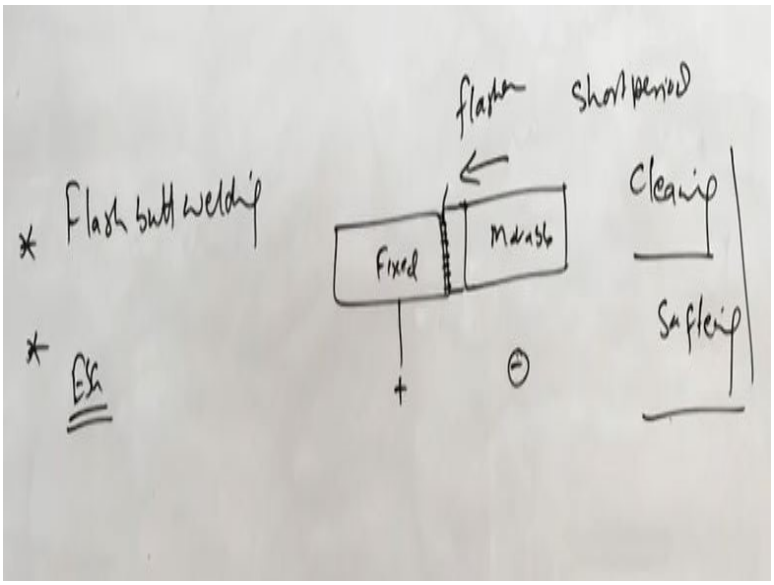

So flash butt welding, basically in this process, there is one component, there is another component and if the two are to be welded so one is kept fixed and another is movable, so both are fed with power supplies. This is one connected to one terminal and this is say another terminal and when the one is movingly brought in contact with the, brought close to this one and brought in contact with this.

So the flow of current starts circuiting and you see the flashes are generated. So these flashes are, they are for very short period. This helps to as I have said for cleaning purpose as well as softening purpose and once if it happened then it is taken apart and then it is forced using heavy pressure to hold them together so that the joint is formed. So, basically this flashes are being used not for the fusion purpose, just primarily for, these are the tiny sparks.

These are not arcs, the flashes or you can say sparks, which will be just cleaning the surfaces and maybe softening the butting and little bit and once if it happened then they are forced together. So, here these are basically sparks not arcs, so the flashes are difficult to put in either of the category not the resistance, normally it is kept under the resistance welding process, but it starts with the flashes and sparks.

But it is not the stable arc, which will lead to the melting of the faying surfaces. Similarly in case of the electro slag welding process, electro slag welding process also find it difficult to put in category of the arc welding, because the way by which heat is being generated in this category, it involves the use of both resistance as well as the arc.

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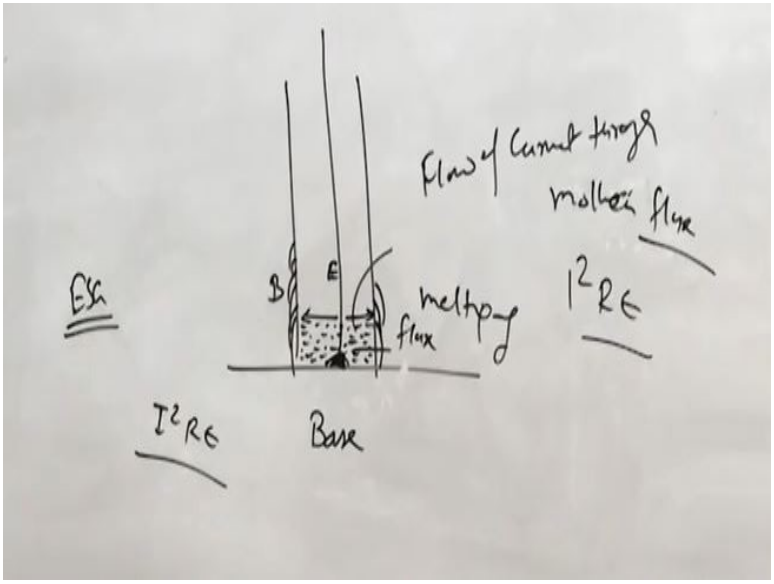

So for that we need to see the principle of this process. Here, these are the components to be joined in the front view, this is the base plate, here it is full of the flux, granular flux and our

electrode comes here, it touches to the back plate, sparks are there. So, this arc helps to initially melt the flux. So, melting of the flux is achieved through the heat of the arc. So, heat of the arc is primarily in the beginning is used for the melting of flux.

Once the flux is brought to the molten state and sufficient pool of the path is created, the arc gets extinguished and the flow of current from the electrode to the base starts to the molten flux and so the flow of current through the molten flux causes the electrical resistance heating I Square R t. So this heat is actually used for the melting of the faying surfaces of the best metal as well as of the electrode.

So, here once the sufficient pool of the molten slag is created the flow of current through the molten slag, molten flux by electrical resistance heating generates the heat and that heat is used for the melting of the faying surfaces of the base metal, so basically the melting or the fusion of the faying surface of the base metal is achieved through the I square R t heating due to the flow of current through the molten flux, not due to the arc.

But since this processes starts with the arc for the melting of the flux and thereafter it is which is used for the melting of faying surfaces. So, it is difficult to put in either of the categories neither resistance welding nor the arc welding processes.

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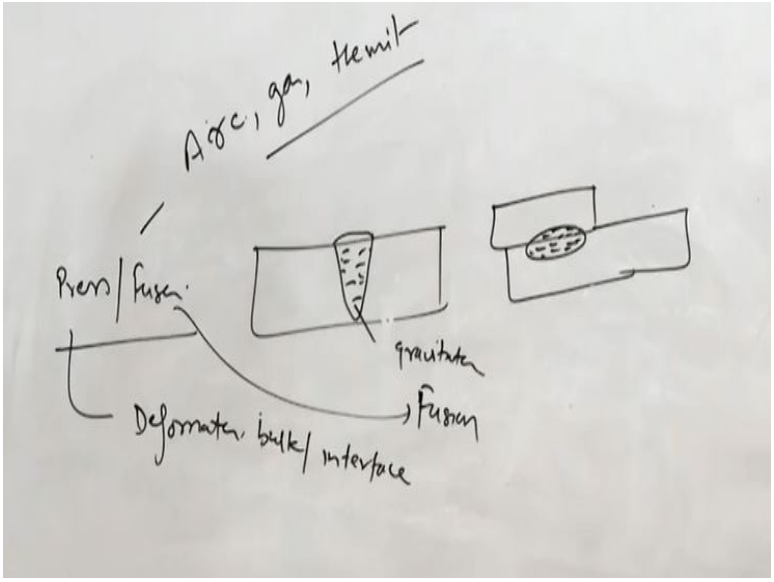

Now we have the other process like pressure and the fusion welding. In fusion welding wherever the melting of the faying surfaces is achieved and the solidification of the molten pool is allowed under the normal gravitational conditions without any external force. So if this is the case, then we will see that it is the normal fusion welding. Sometimes, if the melting of the pool, if the molten metal is generated.

And then it is allowed to solidify only under in confinement under pressure conditions then that is categorized under the pressure welding conditions. So, all those processes where molten metal is generated through the fusion of the faying surfaces or the wield pool is produced through the fusion of the faying surfaces and there after solidification takes place under the normal gravity conditions that is categorized as a fusion welding process.

And if either heating is done just for softening purpose or for the deformation of the, deformation at the interface or deformation in form of the bulk, deformation at the bulk level to have the metallic continuity using the pressure or even if the fusion is involved if the solidification takes place in very confined conditions under the pressure then it is characterized as a pressure welding.

So, pressure welding either involving use of the deformation, either bulk or the interfacial deformation for developing the joint, like ultrasonic welding processes, friction welding all those explosion welding all those will be coming in this category. Resistance welding processes because here confinement even if the molten metal is formed, it solidifies in very confined situation and the gravitational.

And if the solidification takes place under the gravitation conditions, then it is categorized as a fusion welding process. So our all arc, gas, arc welding, gas welding, thermite welding, in all those cases where fusion occurs in the normal gravity conditions, then they are put under the category of the fusion welding process and others, where the deformation is involved or the solidification is taking place in very confined conditions under pressure.

Then that will be categorized as, those process will be categorized as pressure welding process. This is the most acceptable non-controversial kind of the classification by putting the process in the fusion or in the pressure welding category.

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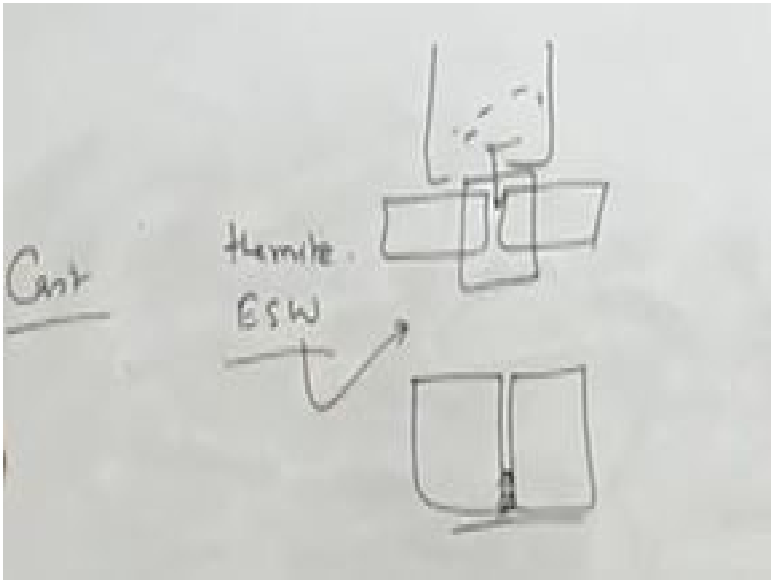

Apart from that there is another big group of the welding processes involving the approach of developing the weld joint. That is about, so that classification involves the uses of cast welding processes, so welding processes like the thermite welding and the electro slag welding, they fall in this category. In thermite welding basically between the components to be joined the molten metal is prepared outside and then it is fed between the faying surfaces.

This is typical, the processes, where just like in casting the molten metal is prepared outside and then it is put into the mold for developing the weld joint. But, it is not so in case of electro slag welding. In case of electro slag welding, the molten metal is generated between the faying surfaces itself and then after solidification the joint is formed. So this is the different in the thermite welding.

In true sense, the thermite welding is the cast weld process but in electro slag welding where the molten metal is generated between the faying surfaces only. It is a bit different from the cast weld process because in casting molten metal, it is not generated in the mold. So same is not true

for the electro slag welding process. The next based on the approach of the developing weld joints.

The fusion welding process wherever the fusion of the faying surfaces is achieved for developing the joint. Will those are categorized? So arc welding, gas welding, thermite welding, the gas welding, the laser welding, electron beam welding wherever the fusion of faying surfaces is achieved for developing the weld joint they are categorized under the fusion welding processes.

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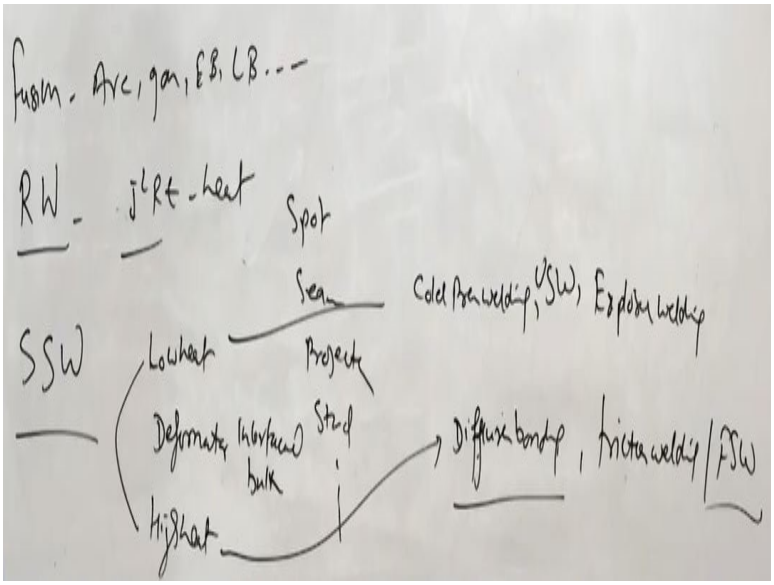

So, arc, gas, electron beam, laser beam etc. all those processes where fusion is involved can be taken as under the fusion welding processes and then resistance welding processes, where I Square R t heating principle is used generating the heat are kept under this category, so our resistance spot welding, seam welding, projection welding, stud welding and likewise there are number of resistance welding processes, which are put in this category.

The basic idea is that wherever resistance, electrical resistance heating is involved for developing the weld joint and then solid state welding process. Solid state welding process involve the two categories, where in the low heat generation or the high, use of high heat is involved. So basically the solid state joining processes they will be using deformation. Now this deformation maybe interfacial or it may be the bulk.

So in case of the interfacial formation the very limited heat is also generated. So like in this category, like cold pressure welding, ultrasonic welding, explosion welding mainly the interfacial deformation is involved very less heat is generated. While lot of heat is generated and all the very limited deformation is there like the processes use of the diffusion bonding. So diffusion bonding uses the high heat to facilitate the diffusion at the same time.

Your friction welding and friction stir welding based processes, all these use lots of heat and because of that it is categorized under the category of the solid state welding processes with the high heat. So, in this presentation you have seen the two basic effects based on which different joining processes can be classified, one is the technological factor and another is the approach of developing the joint.

And this kind of classification actually helps in to see how the different processes can be brought together or they can be separated based on the fundamental similarities or the dissimilarities. So, thank you for your attention for this presentation. In the next presentation, I will talk about the different ways by which heat is generated for joining purpose and the purposes for which heat is used as well as thereafter the requirement to protect the pools for developing the joints. Thank you for your attention.