Welding Metallurgy
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Lecture - 02
Overview of Welding Processes

Welcome to the lecture on overview of welding processes. So, in this lecture, we are going to have you know description about different types of welding processes. With regard to the content of the or the theme of the course that is welding metallurgy, we will be more interested in knowing those processes where there is basically there is metallurgy involved, you know the phase transformation involved.

So, mostly we will be discussing about the fusion welding processes and the aspects basically which are going to be of use you know that because some of the welding processes, in some of the welding processes you know you have the welding taking place in solid state, so we need not go into detail into those processes but we need to know about basically about the fusion welding processes.

Now, coming to the welding process which is basically a variety of joining process, you must have studied that joining process can be classified in terms of either you know either it is semi-permanent type of joint or it is a permanent type of joint or it is a temporary joint. So, you know normally you have a mechanical joint as well as you have the metallurgical joint or the atomic bonding.

So, joining can be based on those things, so if you talk about the normal classification of joining.

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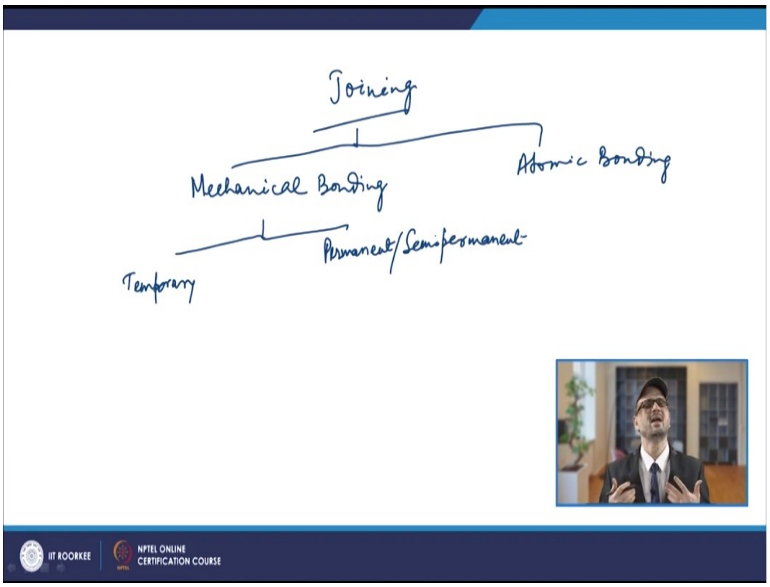

So, basically joining can be you know mechanical and there will be you know based on the atomic bonding. So, bonding maybe you know mechanical bonding or atomic bonding. Now, in mechanical means you are using mechanical means to join something and in that you have two types of again mechanical bonding; one will be your temporary and another will be your you know permanent or semi-permanent.

So, if you talk about the temporary joint, now what does it mean, it means that temporary means you can whenever you feel you can take the two pieces you have joined you know so you can take them, separate them and also the medium with which it is joint that is also intact. So, that is temporary joint and normally you have nut and bolt joint. So, these are you know the example of temporary joint.

Whereas in the case of semi-permanent joint, you have you know the examples such like rivets or so. So, in that case basically whenever you try to remove the two plates which are riveted together, the plates you know does not face any damage whereas the rivet which has been used that cannot be used again, so that is gone. So, that is the example of semi-permanent type of you know bonding or joining.

Now, coming to the atomic bonding; now in atomic bonding, the bonding basically takes place at the atomic level so that is why it is known as atomic bonding and in this lecture, we are going to have the overview of those type of bonding processes where the bonding is done at the atomic level. So, again in that you have solid state you know bonding, then you have liquid state bonding, then you have solid liquid state bonding.

So, solid state means you know in that case you have two solid pieces which are joined and in the solid state itself they joined because at the mating point because of some reasons because of friction or because of the diffusion they join together. So, similarly you have liquid state in that you know between the two pieces there is a liquid pool formed. So, that is fusion you know welding known as and that zone basically will be intact with the two plates which are to be joined on both the sides and that will solidify.

So, that is you know liquid state bonding and then you have solid liquid state, in that case you have two solid pieces and in between the bonding material will be in the liquid state like you have brazing and soldering or adhesive bonding, so they are the example of the solid liquid state bonding. Now, these here all these welding where you have the liquid state you know welding that is also known as fusion welding.

Because you are you know you have a liquid completely liquid zone in between which also because some part of the parent metal also is a part of that liquid pool and then that gets solidified. So, you have a metallurgical joint between the metal which is there already liquefied which is liquefied because of the use of certain heat energy source and then also the parent metal.

So, you have that as the zone that is your fusion welding processes. Now, that also you have now so what we talked about is the heat, I mean source, energy source and that energy source can be different, it may be based on electric energy or it may be based on the you know chemical energy, so based on that you can classify them. So, based on electrical energy you can have arc welding, you can have induction welding or you can have a resistance welding.

All these are examples where the fusion zone you know is created because of the melting of the filler metal by the heat energy either in the form of arc which is done by the electrical you know energy source or by the induction you know source or by the resistance of the element and it may be also by burning the fuel, so chemical fuel like you have acetylene.

So that kind of you know gas or maybe sometimes in the form of certain reaction products like Al_2O_3 and iron they mix and they give you a tremendous amount of heat to melt the material. So, based on that you have different types of the welding processes.

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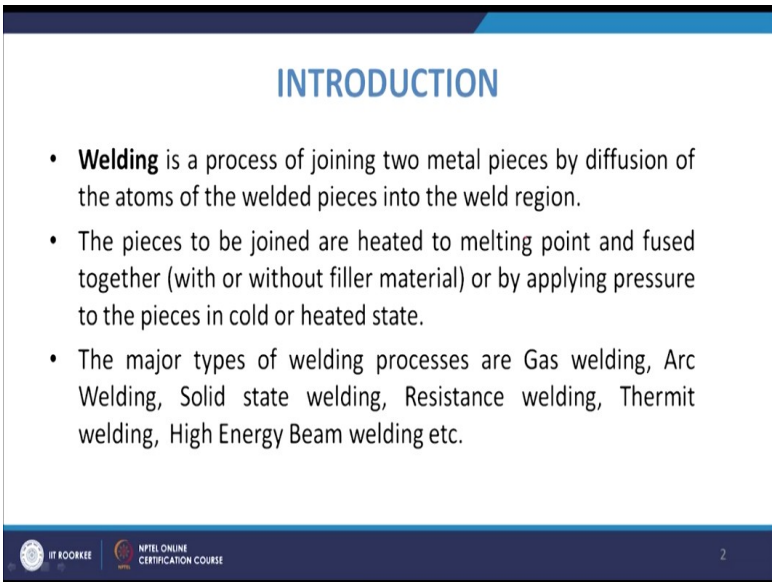

So, coming to introduction so as we know that welding is a process of joining two metal pieces by diffusion of the atoms of welded pieces into the weld region. So, that is what we have understood that in this case you are joining the two metal pieces and you will have the diffusion of atoms. So, by that basically the joint is formed. The pieces to be joined are heated to melting point and fused together.

So, what we do is, in that case you are you know heating in a certain locality to the point that it becomes molten. You can use the filler metal or you cannot use, you may not use the filler material and you may apply the pressure either in the cold or in the heated state. So, the different types of welding processes are gas welding, arc welding, solid state welding, resistance welding, thermit welding, high energy beam welding all these.

And we need to know something about you know some of the process parameters of these welding processes so that when we talk about the metallurgical issues and welding metallurgy related topics when we discuss, then we can correlate these points while discussing you know those topics. So, coming to the gas welding first, so as you know that this depending upon the type of energy source you use to fuse the material you have different names.

Gas welding means a gaseous mixture is there which is used to make a flame and this flame has certain temperature and this temperature, this flame will be you know it will be subjected to a certain reason where the locality is to be melted.

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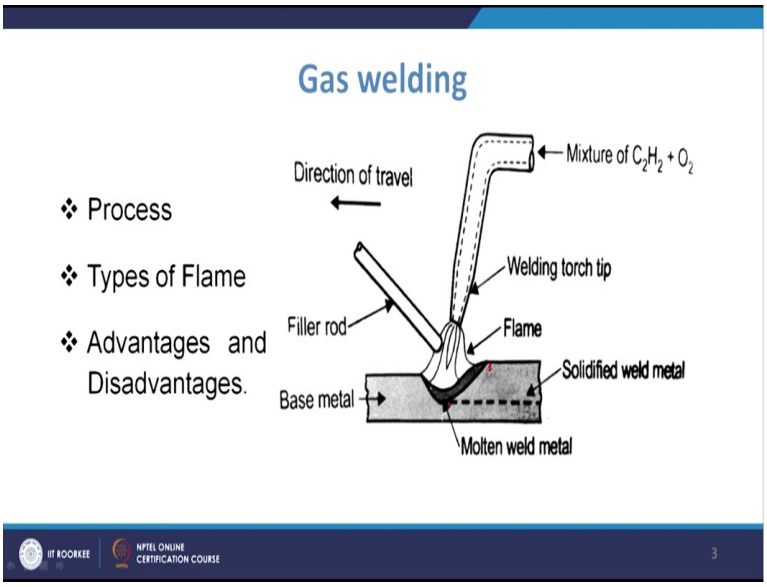

And then once it is kept at that point for some time, then there will be melting and further that will solidify and a joint will be formed. So, normally hydrocarbon gases are used and normally you use the mixture of C_2H_2 and O_2, so acetylene and oxygen gas is used. So, once you use the acetylene and oxygen gas, it is known as oxy-acetylene welding. So, you may have any you know name so oxy-fuel welding is the normal generic name.

Because you are using fuel and you are using oxygen to burn it, so depending upon that so this will come you know in a torch and in the torch it will be mixed and then here there will be ignition with the spark or with the torch you can you have lightning torch by which you can have the flame you know created and you can basically control the flow of C_2H_2 and O_2 separately.

So, depending upon the amount of C_2H_2 and O_2, you will have different types of flames. So, if you know enough oxygen is there, just enough oxygen is there to burn the C_2H_2 completely, there is no extra oxygen. In that case, the flame which you are getting, it will be oxidizing type of flame. That will be neutral flame basically sorry. So, that will be neutral flame because this flame is obtained by burning the C_2H_2 with oxygen which is just sufficient to burn it completely, so that will be oxidizing flame.

Similarly, if you give a large amount of C_2H_2 or less amount of O_2, in that case you will have a carburizing type of flame because it will have a carburizing type of effect. So, in that case you will get carburizing flame and again are the contrary, if you are having the mixture in

such a manner that C_2H_2 is less than O_2 or C_2H_2 you know or O_2 is more than C_2H_2. So, in that case, you will get an oxidizing flame.

So, normally you have 3 types of flames which you are getting and these flames have normally a temperature close to 3000 to 3500 degree centigrade depending upon this and so that there will be external envelope of the flame you have inner cone also which has the higher temperature you know in that case and when it heats the you know the metal at certain point, then that basically is able to you know basically melt it.

So, that way your melting is done. You have filler rod kept in this fashion so that when you know this filler rod will get melted and the groove which is here, this groove will be filled with this filler rod, melted filler rod as well as some part of the parent metal also will be melted because on this boundary it will be melted and then slowly and you can move further and this way your you know the deposition of weld metal will take place.

Now, in this case basically there are many issues, many you know other operational parameters like you may have the forehand welding or you may have the backhand welding. So, you know in one case it will be preheating, in another case it will be post heating. So, based on that you know it will be doing that you know all kind of you know processes that is followed.

And depending upon the type of metal you are joining, you may have the holding of also filler rod or torch also is kept at certain angle. So, all these are the process parameters which are being followed. You have two cylinders; one is of the acetylene; one is of the oxygen. You must have studied that acetylene is kept in acetone and then ultimately slowly acetylene is released.

You have source also to generate acetylene on site, so that is calcium carbide which is used with water, so calcium carbide and water reaction will give you the acetylene gas which is coming. So, this is about the gas welding. Now, what we see is that this is you know flame which is generated, this flame will be melting the metal at certain point but the size of these flames are normally wider and its effect will be on all the sides.

So, you will have the formation of heat affected zone you know in such cases and that needs to be you know that is one cause of concern. So, but that is unavoidable because you have to use the flame, flame will have certainly, there will be it cannot be at a point, so it has to engulf certain area and that reason will be certainly subjected to certain type of microstructural changes.

So, advantage is that it is simple whereas disadvantage that it will be normally slow because the flame temperature is normally smaller and you know you cannot use for all the kind of materials. So, certainly there are also limitations with this process.

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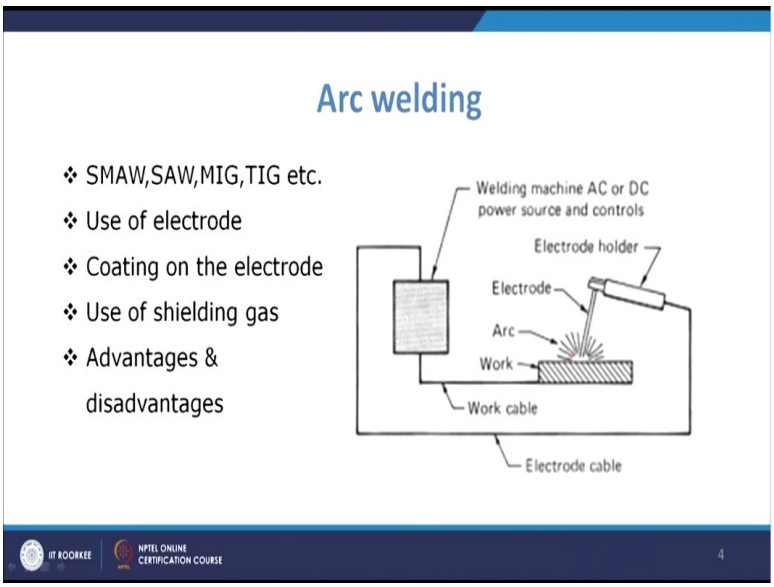

Now, coming to the another kind of welding process that is arc welding process and in the case of arc welding process, the arc is generated between the electrode and the workpiece or in between the electrodes and this arc has a higher temperature than the flame which is used in case of oxy-acetylene welding. Now, what we have studied in the case of gas welding that flame temperature is close to 3000 to 3500 degree centigrade.

So, you will have to you know strike the arc for some amount of time to ensure that there is proper fusion taking place, proper you know melting in that zone takes place. Now, in the case of and also you have to burn a lot of large amount of fuel. So, another you know method which is the most popular method which is the production of arc using the electrical energy and in that case what is done is that the arc is created that is nothing but the ionized plasma is there, so that is created in between so the electrode and the workpiece.

And this arc has sufficiently high temperature close to about 6000 degree centigrade and that strikes the material and it takes lesser time to completely fuse the material. So, if you look at the schematic of one arc welding process, what you see is that you have a welding machine that is it can be either AC or DC power source.

And then this is connected to the electrode holder and when it touches, so when it will be touching, the circuit will be created, I mean completed. However, when you if you touch and then further try to maintain a small distance between them, so you know electrons try to jump from one to other if there is a potential difference you know maintained. So, then that will be ionizing that gaseous column in between the two electrodes.

And then since there is because of the jumping of electrons at a very high speed, a large amount of heat is generated in the form of the arc and this arc basically will be having high temperature of close to the order of 6000 degree centigrade which will be basically melting instantly the material you know and then at the same time you can have the filler wire also. So, it will also be melted and then your fusion takes place.

Now, in this case you may have the DC source or the AC source. When you use the DC source, in that case the polarity matters, so you may have the straight polarity or reverse polarity depending upon how the object is connected to because either the workpiece or the electrode whichever is connected to the positive terminal, two-third of the heat is generated. So, depending upon the type of application you use you can change the polarity.

And you can use the welding process whereas in the case of AC as you know that the polarity is changing continuously, so there will be that way that that type of challenge is not there that of all how much amount of heat is generated is equal. So, then in the case of so you have different type of processes which are normally used that is shielded metal arc welding, submerged arc welding, metal inert gas welding, tungsten inert gas welding.

So, these are the typical welding processes. Shielded metal arc welding means that you will have you know a flux, the electrode which you are using basically it has, so in these cases since that temperature is higher, there will be higher chances of the contamination of the weld pool. So, what you do is you try to generate an environment, you know around the weld pool so that it does not interact with the external surroundings.

So, for that what you do is you have a coating on the electrode and this coating is a flux material, so that basically you know that will be under heating and that will be making an envelope. So, it will generate a gas, so normally you will have a blanket of you know inert gas type of atmosphere will be you know created above the weld pool. So, that is why it is shielded and this coating serves you know that purpose.

And then your welding process is carried out to ensure that your weld pool does not have you know any kind of you know contamination because of the reaction from the external environment. So, you have many job of these coatings, it will be you know saving that pool from the external you know any external gases or so contamination. Then, it is also used because it is an insulator, so it will also be saving in such cases when the electrode may touch to some other point and there may be chances of you know harm.

So, in that case that is also another job. So, that is one challenge. Now, the thing is that all these shielded materials, so you have submerged arc welding in the case of submerged arc welding, what happens that this envelope is submerged under the granular flux. So, you do not the flame. So, that is why it is known as submerged arc welding and normally for pipe type of welding or very quality type of welding is done.

And since it is not exposed to atmosphere, so that the efficiency is higher because there is no, there is less loss of the heat to the surroundings. So, the thermal efficiency becomes higher. The other varieties are the metal inert gas as well as the tungsten inert gas. Now, in these cases, you do not use inert gas, this inert gas or shielding gas environment is ensured by the combustion by the burning of the fluxes either it is by the coating of the electrode or be the granular flux.

Whereas in many case, we also use the separate inert gas supply. So, in those cases we use these we have one example is TIG. So, in the case of TIG, you have electrodes made of tungsten, so in those cases now in such cases you may have electrodes you know for MIG or TIG again we try to classify the electrodes in the sense that the electrode may be consumed or may not be consumed.

So, if it is consumed, it is known as consumable electrode and if it is not consumed it will be non-consumable electrode. So, in the case of TIG, it is non-consumable electrode type of you know process and here the electrode is the tungsten electrode which is burning which is basically creating the arc and simply you have to point it out which can use the filler or we can without using the filler you can do the welding.

And you use the inert gas, you may have helium, you may have carbon dioxide, you have mixture of the gases. So, these inert gases are also supplied at that point and that basically envelops and the welding takes place. So, normally used for aluminium because for most of the reactive metals, reactivity is quite prone to getting oxidized, so for them it is very much beneficial.

Similarly, you have metal inert gas where your electrodes are there and then there also you use you know inert gas. So, you have a consumable electrode and then you use the inert gases. So, as we studied I mean discussed that you will have the electrodes either as the consumable or the non-consumable type of electrodes, you may have you have the coating on the electrode and it has many purposes.

You use the shielding gas basically so that any contamination is basically avoided and if you look at the advantage and disadvantage, advantage is that you can have, this is very you know most of the processes, most of the welding processes they use this arc welding process but there are certainly some disadvantages and one of the disadvantage which we can cite is that since you are again the temperature is very high and it is certain you know localized region.

It is spread in certain region, so you have the chances of the zone which is thermally affected, so you have a heat affected zone which is formed also many a times you need to go for. So, since there is a chance of formation of heat affected zone, so there is need for the post-processing of the material like you may have the heat treatment, you may be stress relieving, all that is required to be done.

So, there are many other varieties of even the arc welding processes and in such cases as you see, you have zone where the high temperature is achieved. There will be metallurgical transact I mean transitions, there will be reactions taking place, there will be change to the

microstructure and that needs to be understood that because that necessitates what kind of treatment you should further give.

So, that the proper property is achieved. Apart from that, you have other miscellaneous welding processes.

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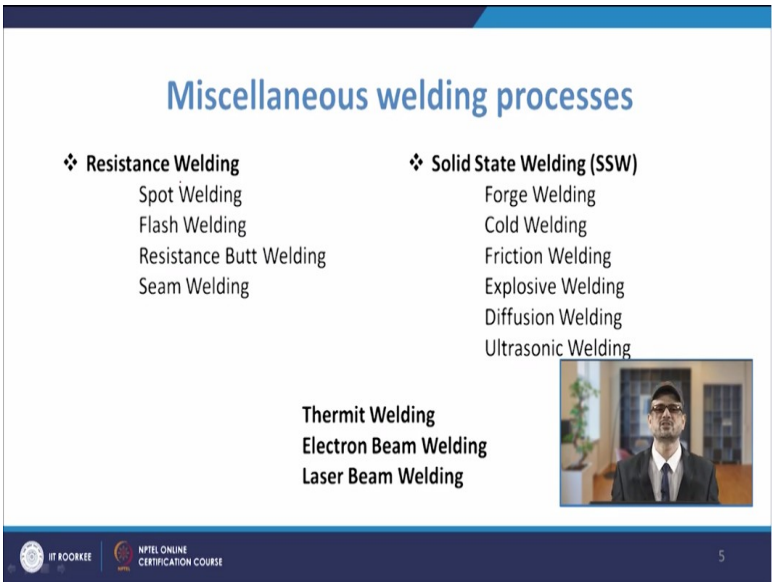

You have the resistance welding processes, where basically the resistance between the two parts, so you know so in between you have the medium which has the resistance, so because of that you will have heat you know form that is a based on I^2RT. So, based on I value and R value, so depending upon the time you will have the resistance that will be generating the heat and that heat will be enough to locally fuse the material, locally melt the material and do the joining.

So, you have spot building, flash welding, resistance butt welding and seam welding under this category. Similarly, you have solid state welding where like you have forge welding, cold welding, friction welding, explosive welding, diffusion welding and ultrasonic welding. So, these are the processes which talk about the welding in the solid state only like in forge welding when you forge the material.

So, if you are doing at high temperature so they may or even at in the normal temperature when you are forging because of that force they get you know attached. So, in the cold state also there may be joining taking place, you have friction welding where because of the

friction taking place and the heat generated at that point, you will have once you stop then there may be proper joining.

You have explosive joining, diffusion welding and ultrasonic welding are among these solid state welding processes. Apart from that, you have some special welding processes, you have like thermit welding where you have the reaction of Al_2O_3 and Fe is being carried out and that reaction mixture gives a large amount of heat which is instantly melting the material. So, that is your thermit welding.

Then, you have beam based you know welding processes like electron beam welding or laser beam welding. Here, you will have a very you know pointed heat source which will go and the temperature is achieved such high that the welding is done in no time and the advantage of these processes, electron beam welding or laser beam welding which are among the non-conventional welding processes is that the heat affected zones is very narrow.

Basically, the welding is carried out in a very narrow zone. So, the heat affected zones are really very small. So, metallurgically you do not see much of the changes; however, they are costly, the machines are costly. So, they are not very much used for the normal mass production runs but wherever required so we use the electron beam welding or laser beam welding you know depending upon its necessity.

So, apart from that you have other welding processes like you may have the electro-slag welding also. So, electro-slag welding and thermit welding, they are also known as a cast or welding process because it is like a casting process where the bulk of the material is there which is melted and then welding takes place. So, that is your electro-slag welding you know. So, the proper you know understanding about these processes I hope that you have.

You must have studied about these welding processes and if you talk about the solid liquid state welding process which we discussed, in that again you have the brazing and soldering is there, so as you know that in brazing basically, you have the braze alloy, so you have the you know copper-AG, copper you know aluminium all these materials can be used as the one which are used for joining two pieces where the strength requirement is little higher.

In soldering, you have solder alloy, normally it is a tin-lead alloy and its melting temperature is below 200. So, normally the temperature which is demarcating these two processes is 450 degree centigrade but for soldering normally that if you take the eutectic of Pb and Sn, it is close to 180 or so. So, normally for electronic components joining, you go for these soldering whereas for other you know applications where the strength requirement is little higher you go for the brazing process.

So, in these processes normally, the metal will go into the cavity by the mechanism of capillary action and then joining will take place. So, this way you have the solid liquid state welding taking place. So, this is mostly about the different types of welding processes and I hope that you will have an overview, you will have the understanding you just revise these you know process parameters of welding.

So, that when we talk about these processes in our subsequent lectures and whenever we have to discuss about the phenomenon's like you know like the formation of heat affected zone where and which kind of zone will be formed you know where how much temperature is you are expecting you know to be. So, in those cases, you know you can recall these facts about the different welding processes and use them to understand the phenomena even better. Thank you very much.