Theory of Production Processes
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Lecture - 41
Classification of Joining Processes

Welcome to the lecture on Classification of Joining Processes. So, so far in the course we have discussed about two of the manufacturing process that is casting and forming. Now, we will discuss about another important manufacturing process that is known as welding or joining process, joining is a broad term and welding is one of the joining technique. So, broadly we will discuss about the classification of joining processes in that welding will come and typically we will discuss about different types of welding processes.

So, coming to the need for the welding process or joining process it is necessiated in many situations when you cannot cast or form a component of certain shape. So, suppose it has a very small component joint and which cannot be otherwise designed to be formed by casting or forming or sometimes something breaks and you need to further use it. So, in that case how can you further use it either you replace it or the only remedy is that if it can be used by joining the two pieces which has been broken off either during handling or during the operation. So, this way you need to join it. So, unlike the manufacturing processes employed to produce a single component the joining processes are used to assemble different members to yield the desired complex configuration, so that is what is the need for the welding process or joining process.

Now, when we talk about the joining of components. Now, that joining of components may be either temporary or permanent in nature. So, temporary means you know that they can be taken apart further they can be separated without losing you know the identity of the two parts which is added and then the other is permanent. So, in the permanent case when you are trying to separate them out then certainly there will be damage to the parts. So, that way side entity is in question. There will be certain modification in the characteristics of the two parts which you are joining. So, that is what the difference between the temporary and permanent type of joining.

Another category is there and that is the semi permanent type of joining. So, in the semi permanent type of joining basically you do not have that choice to restore the mechanism

by which you join although the parent material which you are joining they will be intact they will be, but then other things you are not that way you know further restoring completely that way. So, that is, there is damage to that part. So, suppose like you take the example of nut bolt if you join the two parts with a nut and bolt that is something like very temporary because whenever you want you take the nut and bolt out and two seats which are joined they can be again apart. So, they can further be joined whenever you need. Similarly if you do by you know arc welding. So, that is, so that joining whatnot volt is a type of temporary type of joint. Then if you join it using the welding process fusion welding process typically where you are making the plates meet each other and then you are heating at the junction point and then you are converting it into liquid state so that they are solidifying and being one unit. So, that type of you know joint is permanent joint and whenever you have to take the separate the plate out you will have to break it.

So, while breaking you know they are very damaged to the seats because it is like a metallurgical bonding. So, it will be a single piece. So, you have to cut it or whatever. But if you do some bondings like braze welding or soldering in that case you can just hit little bit and take that you know sits out certainly the bridge or solder will be you know removed. So, you have to further use that for further joining. So, that is of semi permanent type where the plate is alright, but the solder which was there any way that is again if you have to add it you have to further use that solder material or you have to use the process again. So, this way you have this either temporary type of joining or semi permanent type of joining or permanent type of joining that is in nature.

Again mechanism of bonding may be either mechanical bonding or atomic bonding. So, as we discussed we can use it the mechanical means and then see that they are bond to each other or they are maybe bonding at the atomic level so there is a diffusion of atom or atoms are there they solidify there is a bonding between atoms and that way the strength develops. So, they it may be either mechanical bonding or atomic bonding.

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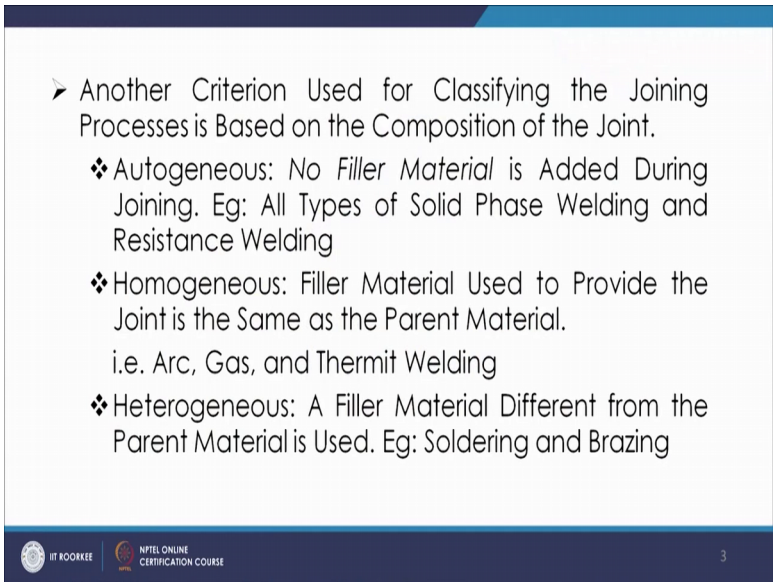

Another criteria which is used for classifying the joining process is based on the composition of joint. So, on that basis you are classifying that process on the basis of that composition of joint that is autogenous, homogeneous and heterogeneous. So, what is the autogenous type of welding? So, in autogeneous type of welding you do not use any filler material. So, during that joining, you know no need of any filler material. So, all type of solid phase welding and resistance welding they are under that. So, basically you have two pieces and somehow you do not use any external filler material to add.

So, you must be you know knowing you must have the idea about the filler materials parent material in welding. So, in the case of autogenous you do not use these you know filler material during that joining. Then you have you know homogeneous. Now, in the homogeneous the filler material which is used for joining you know two parent material parent material having two sections. So, they are having a same composition as the parent material. So, when you are joining two plates in that case, whenever we do the welding. So, what we do is you have to you know plates and then we try to weld it like this. So, this is, these are the you know these are the parent materials and this is the you know weld pool normally that you must have studied so far.

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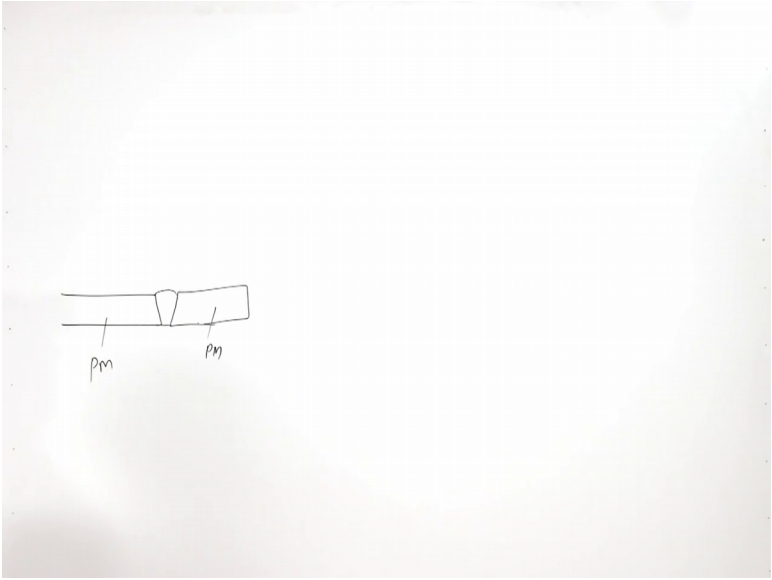

So, this is the pool where the fusion takes place or the binding takes place in the case of fusion welding. Now, the thing is that this material it may be having the composition same as parent material or it may have the different kind of composition as compared to the parent material. So, suppose if this is steel and this is also having that similar composition that of steel in that case it is known as homogenous type of welding. So, the example of this is normally arc gas or thermit welding. Now, in the case of arc welding you produce arc and they try to melt here. So, parent material as well as a filler material will be melted and then they will form this weld pool. So, if an in typical case in normal case in the case of arc welding or gas welding or even thermit welding or so, you try to see that the composition of the liquid metal which you get by melting the you know filler material it is similar to that of the parent material in that case it is the example of homogeneous material homogeneous welding.

Then you have another classification another varieties the heterogeneous type of welding. Now, in the case of heterogeneous welding you have the filler material which is different from patent parent material. So, what we have. Now, in the case of heterogeneous the composition of this and this is different than this. So, the filler material which is used for joining the two parts that is different, then the parent material which is added, is which is joined. Now, in that case you know it have will have different composition, it has the different properties. So, the example is soldering and brazing. So, in the case of, in the case of soldering and brazing this is either solder material or this is

either the braze alloy switch we use you have not sold as you have tin lead alloys in the braze you have silver based alloys are used. So, and you have copper and all that is used in the case of prism. So, in that you have this as the different property then this.

And in the case of homogeneous is since in these having the same compositions their property will be similar, the property will be same. So, it is like a uniform property material whereas, in this case the property will not be uniform this and this will have the same property, but this property may be inferior. So, it is basically used for specific purposes where you are just working for the sake of holding its shape. So, in the soldering case the temperature is you know solarized melting temperature is even less. So, they are the even lists, but then they are normally that is a requirement suppose most mostly whenever you would go for the electronic criminals you know areas like printed circuit board or so, in that case of joining you go for soldiering because you cannot you have just to add them just to join them. So, strength is not the criteria.

In bridging certainly that is a little bit more. So, you have the bridge allows and here basically they are differentiated based on the temperature so that we will discuss when we discuss about the soldiering and brazing later on. So, that is your that this classification that is autogenius, homogeneous and heterogeneous.

Now, coming to the subcategories and you have examples.

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Bond Type	Sub Category	Sub-sub Categories, Examples, Remarks
Mechanical Bonding	Temporary	**Threaded Fasteners:** Screws, Nuts, Bolts ➢ Allow Easy Dissembling for Repair, Replace, and Adjustment ➢ Convenient for Human Assembly Workers but Difficult for Robots and Automated System
	Permanent or Semi-permanent	**Riveting and Crimping:**
		Press/Shrink Fit: Pulley or Gear on Shaft ➢ Interference Fit Between Mating Parts
		Snap Fit: C-Rings, Snap Rings, Retainers ➢ Temporary Interference of Mating Parts
		Sewing, Stitching, Stapling: To Assemble Soft Thin Materials ➢ For Fabrics, Cloth, Leather, Thin Flexible Plastics

So, now, we come to mechanical bonding and we talked about the mechanical bonding and we discussed that the mechanical bonding may be you know temporary permanent or semi permanent.

So, in the case of temporary as you know you have threaded fasteners like screw, nuts, bolts these are the examples of mechanical bonding that is temporary type. You will allow easy dissembling of you know repair replace an adjustment convenient for human assembly workers, but difficult for robots and automated systems. Then you have permanent or semi permanent type of you know mechanical bonding. So, in that you have semi permanent you have riveting and crimping. Now, in the case of riveting if you look at in the case of riveting also the composition of the rivet material that is very that trial basically you have to add the two seats using the rivets. So, the rivet can be you know you know damaged and the parent material can be taken off. So, you have that riveting is an example of that semi permanent type of melding welding then you have press or shrink fit then snap fit, fitting all that type of this. So, ensuing stitching or stapling all these things are the examples of semi permanent type of you know bonding.

Now, we come to the atomic bonding. So, that is your normally that is permanent type of bonding and in that we have the solid state welding.

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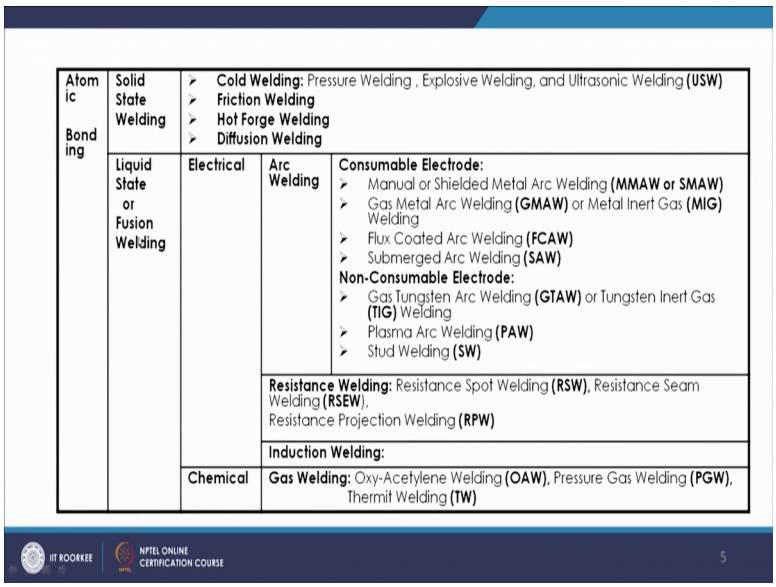

So, as we discussed that most of the solid state welding is normally autogeneous type where there is no filler required and here there is no liquid state formation because here

the while joining you do not require any filler as well as the material when it is joining externally it appears has to be in solid state and at the meeting point certainly something happens because of the rubbing action or because of diffusion or whatever it be and then the joining takes place. So, the example of solid state welding is the cold welding, friction welding, hot forge welding and diffusion welding. So, in the cold welding where that is you know pressure welding, explosive welding, ultrasonic welding. So, this is done at the normal temperature. So, you see that because of the pressure the joining takes place that is pressure welding. Explosive welding the exertion is carried out and because of that, the joining takes place ultrasonic welding because of the ultrasonic you know ultrasonic medium that welding takes place.

Similarly friction welding, you have the friction taking place and because of that the you know (Refer Time: 15:26) takes place or joining takes place. So, that is friction welding hot forge welding where you because of the high temperature and that and the pressure you know that welding takes place where the material is still in solid state. So, that is why you call it as the solid state welding and similarly diffusion welding where the diffusion occurs at a state of temperature and pressure the diffusion goes to a higher level and then because of diffusion the bonding takes place. So, these are the examples of solid state welding.

Coming to the liquid state or fusion welding. Now, in the case of liquid state or fusion welding the different kinds of you know the classification may be based on different kinds of fuels used. So, what is the mid source of energy which is used for doing this operation? So, for that there may be electrical means and when we go for electrical means there may be different processes and in the case of electricity when we use electricity as the source of energy then there may be welding using the formation of arc or using the resistance welding you know technique or using the induction welding technique.

So, on that basis you have different kinds of welding processes. So, again, this using the arc welding process, in this case the arc is produced. So, you will have the electrodes and there will be electrodes you have two electrode source will may have a single electrode and this sometimes either the work piece can work a second electrode or many a times the arc can be produced by you know using two electrodes only. So, that way the arc is produced.

Now, as we discussed that the arc can be produced by using the two electrodes either the two electrodes are used for making the arc or electrode used is one and the work piece works as the another electrode. So, on that basis you have consumable and non consumable electrode.

Now, consumable electrode means that the electrode is consumed as the welding process carries on. So, in that case as you move the after sometimes you have to use another electrode. So, in these cases you have one electrode which is used another electrode is yours the what piece of works has another electrode and then you still you go on producing the arc between the electrode and the work piece, and this electrode it well you know goes on. And you know consuming goes on getting consumed as the welding process is carried forward and so that is why you have to press like this and then after some time you have to further change the electrode. So, that is consumable electrode and in the case of consumable electrode as we discussed when we discuss about the homogeneous type of welding operation. So, in that case you will must ensure that the electrode composition is same as that of the parent material. So, that way you use this consumable electrode welding practice.

Now, in that you have manual or shielded metal arc welding process that is known as MMAW or SMAW, then you have gas metal arc welding that is GMAW. So, basically what we need to see is that there must be this pool needs to be shielded against the atmospheric attack because the weld pool if it is know, if it is exposed there may be gaseous pick up from the environment. So, we try to ensure that there is you know protection of the weld pool from the atmosphere, so for that you need to have a shielding atmosphere. So, that is done by some means.

Now, in the case you may have, you may have, you know mechanism by on the electrode itself. So, that you create one atmosphere. So, that it is saved the weld fully save you may use separate gas inert gases so that the pool the inert atmosphere is maintained and in that atmosphere the welding is carried out. So, there is based on that you have gas metal arc welding. Similarly you have flux coated arc welding and you have submerged arc welding. So, you know this way you have the different kinds of consumable electrode welding where the you know electrode is getting consumed slowly and then you have the welding taking place.

Similarly you have the non consumable electrodes. Now, non consumable electrode means the electrode does not get consumed it is only used for the production of arc the sustainable sustenance of arc. So, the two electrodes one is cathode and one is anode they are used for the production of arc this arc strikes at the appropriate position where the welding has to be carried out and then that has to you know move in the fashion it is desired. So, in that case basically you are only looking for the electrodes which should be efficient in producing the arc. So, on that in that category you have different types of processes where that is gas tungsten arc welding or tungsten inert gas welding that is tig. So, here basically tungsten is used as electrode and you have the inert gas which is used as a medium for you know protecting that weld pool by from contamination. Then you have a plasma arc welding, stud welding, these are the examples of this non consumable electrode type of welding process.

Further you we also use that electrical means, electrical medium as a source of energy for the resistance welding operations where you have the use of resistance is you know applied for creating the bond between two seats or so, mostly in that case automotive applications. So, you have a resistance spot welding or resistance seam welding. So, in normally in the case of automobiles you have seats of automobiles and at the points if you have to do the spotting. So, you are pure tours coming from opposite end and you have the seat. So, they will be touching at the point a spot and because of the resistance the heat is generated and then there the joining takes place. So, this way using that resistance the welding takes place either on a spot or on a seam. So, that way this is known as distance pot welding or the resistance seam welding similarly your assistants projection welding. So, this is that kind of welding practices where this resistance is used resistance is basically used I mean between resistance between that medium.

Then there may be induction welding also. So, similarly resistance then you have the induction also induction in effect of the current. Then further you have the chemical, chemical energy is used for the welding. So, in that basically the fuels which have the chemical energy stored they are used for creating a flame and that flame has higher temperature and that flame basically melts the point or the spot and does the joining process. So, in that you have oxy acetylene welding pressure gas welding thermit welding. Here the concept is that you have a chemical you know energy. So, basically you are having the combination of you know as a gasses or any mix mixture and then

they are basically ignited and then by that you are getting the higher temperature and because of that higher temperature the localized fusion takes place wherever you are trying to direct it or wherever that mixture is placed in case of thermit welding and then the welding takes place. So, based on chemical means also welding has to take place.

Then now, we discuss about the solid or liquid state welding. So, in the case for the atomic bonding, now solid liquid state in that basically what happens earlier we have started we studied about solid state where everything is in solid state, and then you have liquid state where the parent metal as well as the filler metal in that will pull zone all is converted into liquid and then they are further solidifying to solid state.

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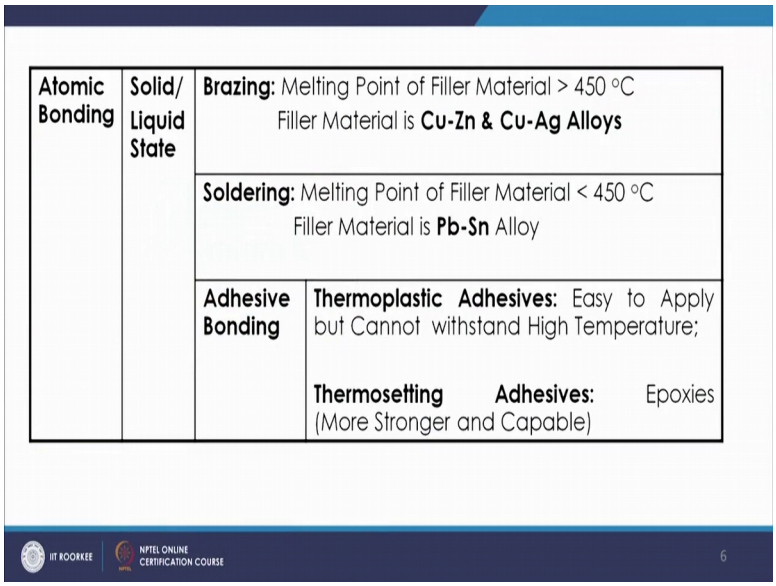

But then solid liquid state refers to that kind of welding process where the parent metal will be in solid state and the filler materials are used for joining them they are in liquid state. So, by that the joining takes place. Now, in that we use the you know typical type of alloys which are low melting point alloys normally, based on that temperature of melting, like if the melting point of filler material is more than 450 then we call it. So, we have in the case of brazing the melting point of filler material is more than 450 degree centigrade. So, filler material is normally copper zinc or copper silver type of alloys which is used for bridging. So, wherever somewhat more strength is required you go for brazing.

Then soldiering in that case of soldiering the melting point of filler material is will be less than 450 degree centigrade. So, normally tin lead alloys are this kind of alloys which are used for soldering applications, so that is soldiering. Then you have adhesive bonding also. So, adhesive bonding you have to many a times you are required to join, so two components mostly in the case of automobile breaks or so.

Now, in the case you use the adhesives to join two components. Now, in that you have thermoplastic adhesives which are in liquid state at that time they are applied. And then joining takes place. So, certainly there will be some limitation to up to what temperature it can withstand and based on that you will have either thermo setting or thermo plastic. So, thermo setting certainly will be more stronger and capable and thermoplastics will be certainly naturally is softer, so it will be little bit less hard. So, that way you have the atomic bonding you know carried out.

Now, various advanced joining or fabrication processes. So, these are the conventional welding processes which occur and we have different bases of classification by which we can say that this is how the welding process is carried out. Now, there are advanced joining or fabrication process which are used for the advanced applications or here the conventional you know operations are not suitable to carry out the experiment. So, you know also when we go for the fusion welding then there are certainly some undesirable effects on the structure because of the you know large amount of heat which is accumulated at a point and then it moves and then the material you know you transfers this heat through it and certainly some part of material is affected because of that heat. So, there will be a heat affected zone where the structure is likely to change and it changes. So, many times we feel that that zones should be normally smaller or it should not be wider.

So, in those cases we feel that we must have or in many cases we need typical type of application of joining where the normal conventional operations cannot be done or we may have the joining of dissimilar materials or joining of larger thicker plates or many time, in many situations the conventional welding operations cannot be suitable. So, we have the advanced joining or fabrication processes. So, like you have electron beam welding or laser beam welding.

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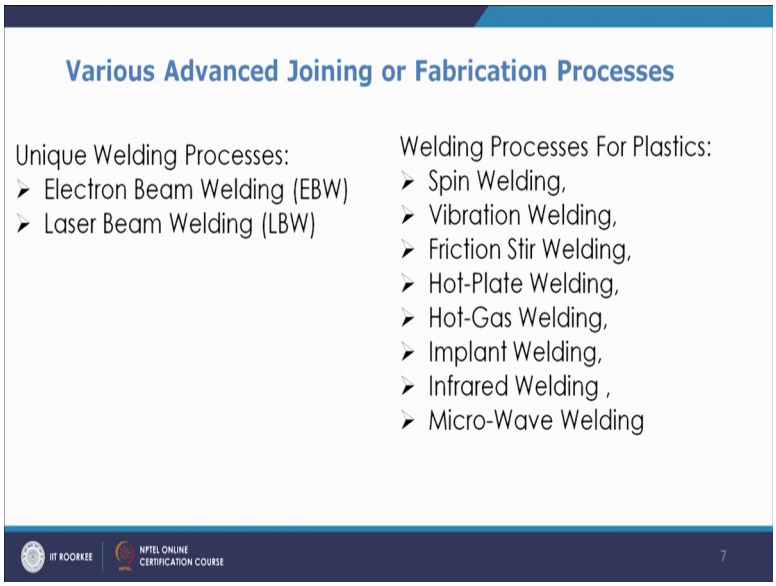

Now, these are basically we have to join to various thin point. Now, if that is not possible by normal welding process so that can be done by electron beam welding, laser beam welding or maybe sometimes for extremely hard materials or extremely high melting point materials. So, on those cases where about the conventional welding operation is not power you know suitable we go for such kind of unique welding processes.

Similarly you have the different welding processes for plastics. Like you have spin welding vibration welding friction stir welding when friction stir welding is also used for the materials metals also. Then you have the hot plate welding hot gas welding implant welding infrared welding or micro wave welding. These are now so, most of the welding processes which we discuss in the right hand side for plastics they are also used for materials metals also. So, there is lot of research going on. And people work towards the situations so that the weld ability you know is better for materials you can weld or join the material with list of the difficulties and with best of the properties you can achieve by these welding processes.

So, that is how you can define the different kinds of welding processes. And in the coming lectures we will discuss about the different effects of welding process, the thermal effects of welding processes, then we will discuss about different types of welding processes and its characteristics which are required to study these processes.

Thank you very much.