Joining Technologies of Commercial Importance

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Lecture - 01
Introduction: Manufacturing and Joining

Hello. Dear, participants of the class. I welcome you all in this first lecture on the joining technologies for the metals and in this one I will try to talk about the manufacturing process and how the joining processes are related with the manufacturing. So, here we will start with the manufacturing.

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Manufacturing, you know that it is used for giving the desired size shape and properties to the material being processed. The purpose of this in manufacturing is that we try to achieve the desired size then the different shapes are given by using the variety of processes and then if required then desired combination of the mechanical properties, chemical properties is achieved through the treatments.

These treatments may be in the form of the chemical composition, modification like in carburizing, nitrating etcetera or it may be in the form of heat treatment just to change the structure of the material so that the change in properties can be achieved. We know that for the manufacturing we have to use a range of the shapes and the sizes. The shapes may vary from

very simple to very complex.

So, the simple shapes can be easily manufactured say by the processes like forging or the casting. But when the shapes become complex our reliance to achieve the final complex shape becomes difficult and we need additional process like machining. So, the range of the manufacturing process that are required for achieving the complex shapes is more you can say it is very large in number.

And it requires more number of the processes while the simple shapes can be achieved easily. Similarly, if we will see the kind of material that we have to process to manufacture the products of requirement. The range of products, range of materials which are to be processed in manufacturing can vary significantly which may vary in terms of the mechanical properties, physical properties, chemical properties and the dimensional properties.

These are the four important properties of the materials that significantly affect our selection for the manufacturing process. For example, the mechanical properties if the material is very hard and strong then the selection of the manufacturing process becomes different then the case when the material is soft and ductile.

Similarly, the physical properties in terms of the thermal expansion coefficient and the melting point especially they significantly affect the selection of the manufacturing process. Chemical properties involving like the kind of the wave they behave after reaching to the elevated temperature may be in terms of the producing the poisonous gages or the way by which they decompose after going at elevated temperature say in specially for the materials like plastics.

And the dimensional properties are very important because we have to see that what kind of straightness, flatness, and the surface roughness is to be achieved. So, in the final product if the requirement for the surface roughness is very stringent like very good finish is required then we have to go with one kind of the manufacturing process. Similarly, if a very good dimensional accuracy is needed then the selection of the manufacturing process for the product they become quite different.

So gradually we will talk about the things that matter actually in the manufacturing process and their selection.

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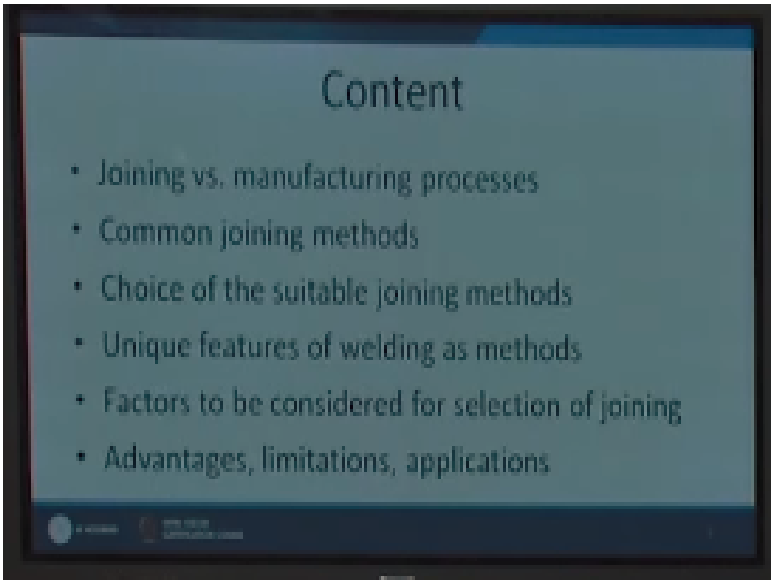

Now, we will see like these what I have already talked about.

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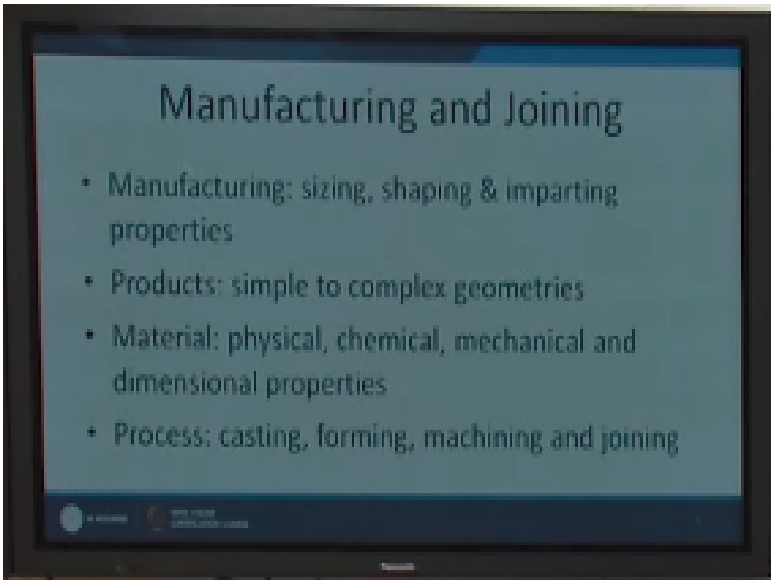

The common manufacturing process which are used for the metals include casting, like forming, machining and joining.

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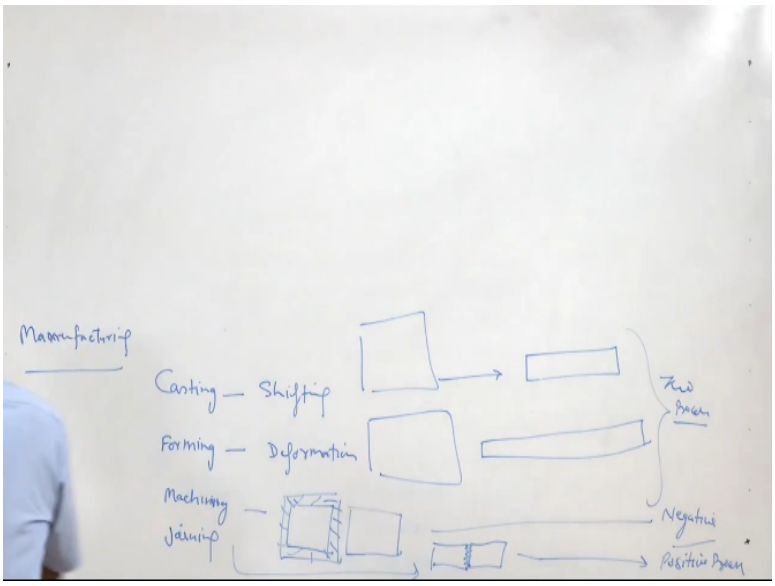

The casting is a simple process where just shifting of the material takes place from one shape to the another for example this is the block of the material. It is melted and after melting pouring into the mould. We can get the different sizes and shapes as per our requirements. So, here mainly the shifting of the material takes place from one region to another there is no major, the loss of the material just it is shifted from one region to another.

Similarly, in the forming material basically is subjected to the plastic deformation. So, in the plastic deformation using processes like forming, like rolling or forging. Again the material is shifted from one block shape to like say the shape of the strips. So, this is shifting basically just if these two process primarily involve shifting of the material from one region to another and that is why these two process are called Zero process where just shifting is involved, no addition and there is no deletion.

While in case of the machining processes the unwanted material is removed from the stock or from the raw material to get the desired size and shape. So, for that purpose material is removed in form of the chips which are not actually used for any other purpose it is just wastage of the metal worth. So, machining is therefor since we use stock initially the raw material and they are using a combination of process or single process unwanted material is taken off.

So that say this is the material which is taken off to get the final size and the shape. So, by

removing the unwanted material we try to achieve the desired size and shape and whatever dimensional properties which are required. Since, the removal of the material from the stock is involved here. That is why, this kind in of process is called all the machining process fall in the category of the negative process where removal of the material is involved to achieve the desired size and shape.

While the joining is a process where the simpler shapes are brought together to achieve the desired size and shape in the manufacturing. So, basically it involves bring the two simpler components together to achieve the desired size and to make the desired assembly. It involves basically bring the things together to achieve the desired size and shape.

So, this basically involves the addition of the material or this is addition process where the two things or two or more components are brought together to achieve the desired size and shape that is why these are called positive processes. So, here based on the way by which the raw material is treated we can categorize and the range of the manufacturing process in the categories Zero processes where basically shifting of the material takes place.

And in the machining process, where unwanted material is removed to get the desired size and shape that is their negative process and the joining process where the simpler parts or the material are brought together to achieve the desired size and shape. So, they are put in the positive process categories. So, the joining is basically a positive process where simpler shape components and simpler components are brought together to achieve the desired size and shapes.

So, we will talk about the joining process which are commonly used here.

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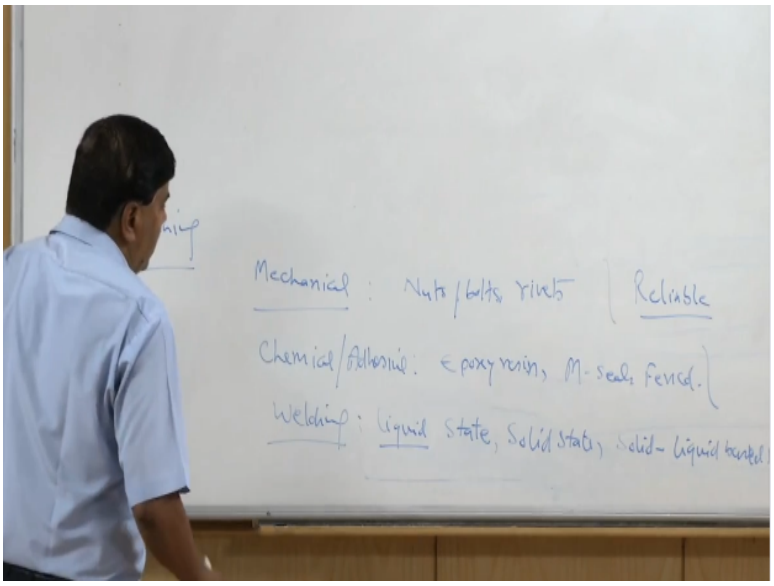

You know most of the joining as I have said it is a positive process involves bring the things together.

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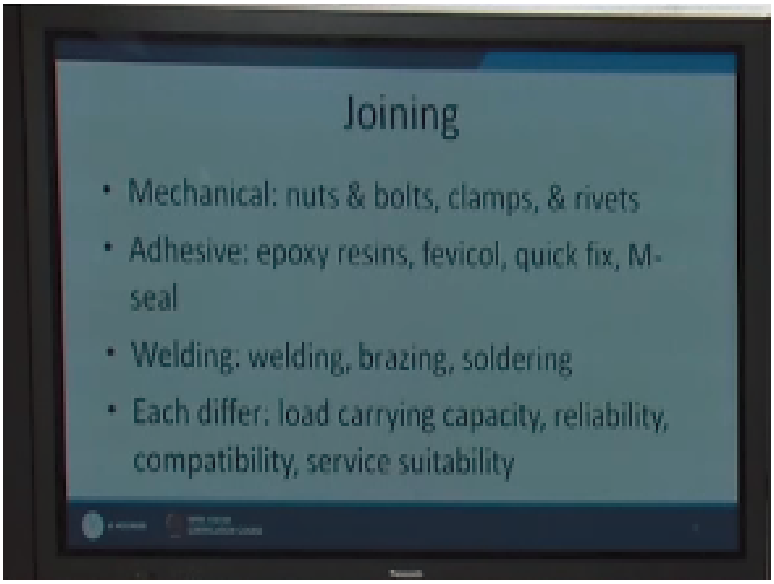

So, for this purpose basically we use the three approaches involving like the mechanical joining, chemical joining or the adhesive joining and welding. So, mechanical joining basically involves the use of nuts and bolts, rivets and a similar kind of components where two things are brought together by holding them together mechanically. Well, the chemical or adhesive joining involves the use of like say Epoxy resin and the commercially known the joining substances like M-seal or Fevicol etcetera.

So, here these adhesives are placed between the components to be joined and then after the scouring the suitable joint is formed. Welding involves very wide range of the process involving like the liquid based process where the components to be joined are brought the things of the components to be joined or brought to the molten state or they are just deformed in the solid state.

So, the solid state joining like the friction welding or friction stir welding and they are certain joining process which involve like the base metal remain in the sold state and the filler metal is brought to the molten state in the process like the brazing and soldering. So, basically they fall in category of the solid, liquid based processes. So, these are the three process, three broad categories of the process.

Since, each of the approach being used in each of the process is different and that is why they differ in terms of the performance significantly. For example, the mechanical joints are considered to be very reliable they have very good load carrying capacity and adhesive joints they are good just to make the connections they do not have very high load carrying capacity and they are very sensitive to the environmental conditions because they degrade like say at high temperature or as soon as they interact or they come across with the chemicals.

Welding processes involve the use of like you can say the joints made by the process which fall in this category they can have the joint strength very low to the very high where the joint strength can be even higher than the base metal strength. So, joint efficiencies ranging from 10% to 15% to more than 100% can also be there where the joint can be much stronger then the base metal.

But reliability of these joints becomes mostly questionable because lot of efforts are needed to ensure that the joints are made free from the discontinuities and free from the stress rages. So, that they really perform for long as expected. So, these are the three the broad joining category of the processes. We will try to focus in the subject on the welding related processes which involves a solid state joining, solid liquid based processes and the liquid based process where faying surfaces of the metals are brought to the molten state.

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So, like we can see the different joining processes which have been show in the slide. The joining positive process used for assembling the different members to get the desired configuration. Like, this is where fusion is being achieved in using the gas welding here. The chemicals are being applied to develop the joint between the plastic components in adhesive joining, spot welding is being done to join the strips.

And here fusion welding like may be using the arch the joint is made and the soldering to join the like wires mostly used in electronic components nuts and bolts for joining, for making the mechanical joints and the brazing where the system to be joined in metallurgical in computable metals are to be jointed like say for the brazing or where the load carrying capacity requirement is not much so the brazed joints are used.

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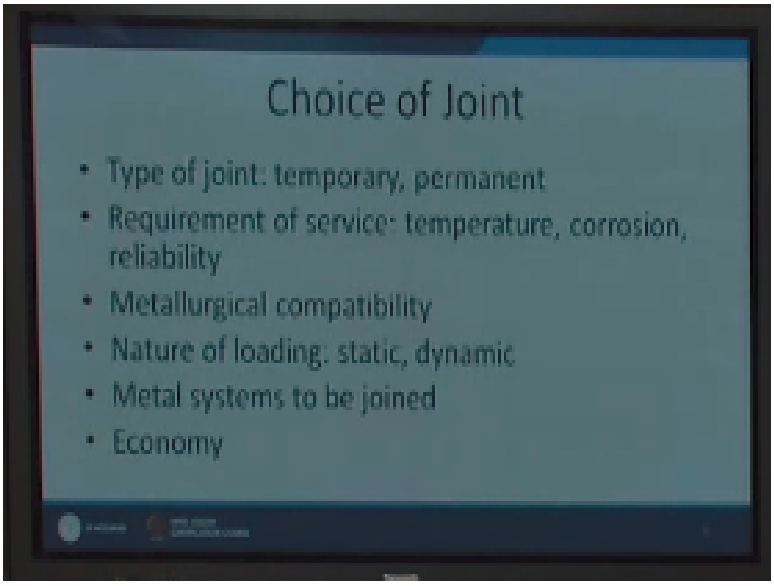

Since, there are three broad categories of the mechanical joints and each type of the joint offers the different kind of properties. So the factors that should be looked into for selection of the joints

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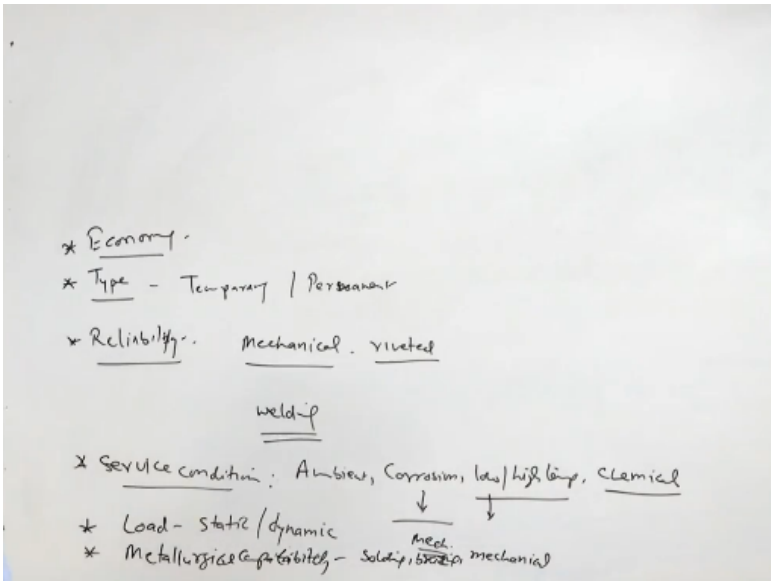

Basically it involves the type of the joint that we are looking for it may be like say temporary or it may be permanent. So, if it is permanent so if it required that the frequent assembling and dissembling is needed of the members to be joined then it is better to go for the mechanical joining. And if the joint is permanent then of course we will be looking for like say the adhesive joints or like the welded joints.

Similarly, the kind of the reliability which is need, reliability is very important because the joints to be used for the critical applications where lot of the life and the property is at stake so there mostly either mechanical joints are used like say riveted joints are mostly used for making the bridges and also in the aircraft. But if the criticality of the joint is not high then probably the other joints like that welded joints are also used.

The load requirement is another crucial or you can say the service conditions. So, keeping in mind that service is to be performed in ambient condition or in some special environment like corrosion, or like low or high temperature or like say the involvement of some chemical. So depending upon the kind of the service conditions or the service environments the suitable joints is selected.

Like we would in chemical environment we would like to avoid the adhesive joints and the low and high temperature conditions we need to see that the joints for high temperature application can resist the creep and the elevated temperature deformation and for the low temperature conditions it has required ductile to brittle transition temperature. So, depending upon the kind of the service conditions we have to select suitable joining method.

In corrosion, we need to see really like welded joints mostly heat effected zone and sometimes weld joints itself offers poor corrosion resistance. So, the filler metal for the weld joint is designed in such a way that it offers the desired corrosion resistance otherwise it is better to select the mechanical joints if corrosion is really very crucial and if it is performed in ambient condition then a normal moderate, the loading moderate temperature may be soldering, brazing adhesive joints can also work good under those conditions.

Then here we have the kind of loading the kind of load or the service load conditions. So, the load may be static and may be dynamic like where the fatigue or impact load condition exists or in the static condition. So, for the static condition any kind of the joint will be good and for the dynamic conditions we really need to see that it performs. It is able to sustain the dynamic loading conditions.

Metal systems to be joined and the metallurgical incompatibility are the other two factors. Another important thing like if the incompatible things are be brought together then we have to use like the process like soldering and the brazing are like the mechanical joints. But if metallurgical incompatibility is not an issue then even fusion welding process can also be used.

So, incompatible systems require the process where there is no direct metal to metal connection in the liquid state where they can interact with each other so soldering, brazing or adhesive joining kind of process can be used or the mechanical joints can be used and lastly the important thing is the economy. We need to see really whatever type of the joint we are selecting that we are able to produce at low cost and it can perform the function which is intended.

So, these are some of the characteristics which need to be seen so that the joint performs as expected at minimum cost. As far as the welding is concerned now we will see welding and the joining is concerned.

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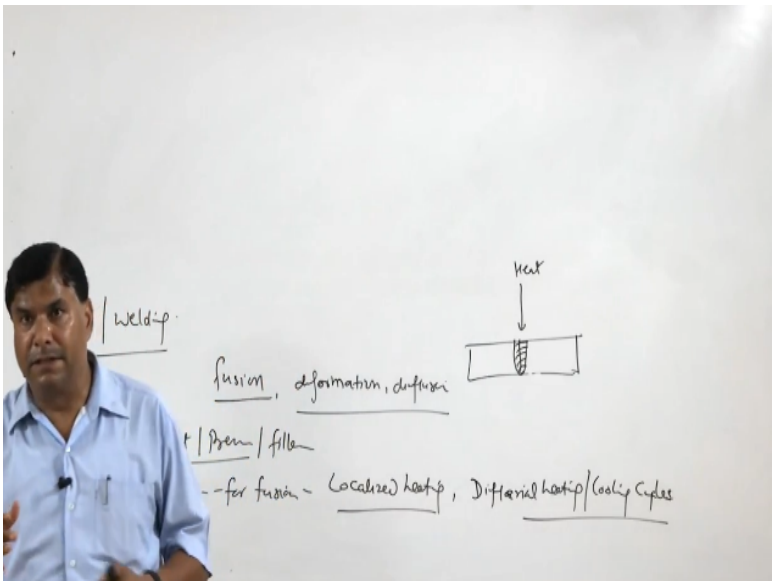

The joining specially involving the use of welding, welding you know that involves the two or three main things one either it will be involving that fusion. Fusion of the components to be joined or it will be involving the deformation or diffusion. These are the three broad categories, broad mechanisms which are involved in the development of the joint. So, whenever like say the fusion or the localized deformation or the diffusion kind of thing is applied you will see these

will be using the application of heat or pressure with or without use of the filler metal.

So, especially in case of the welding when we use heat for the fusion purpose like welding processes involving the use of heat for fusion. So, this brings in the unique situation where very localized heating is involved. Localized heating means if this is the component, these are the two components to be welded. So, involving the application of the heat for fusion of the faying surfaces so that they are brought to the molten state and after the solidification of joint is formed.

But this involves the use of very localized heating and another unique thing here is that happens that the different regions close to the weld experience the differential heating and cooling cycles means the kind of the rate at which the things are heated, the maximum temperature which is attained and the kind of cooling rate which is experienced by the different regions close to the weld region they are different.

So, the different points close to the weld experience the different the heating and cooling cycles. So, these are the two very unique things and because of these two things only various unique responses are offered by the welded joints. So, the welding differs significantly as compared to the other manufacturing process because of these two unique characteristics involving the very localized heating and the differential heating and the cooling cycles experienced by the different zones.

So, now we will see because of these two factors as has been explained or pointed out here the welding versus other manufacturing process involving the localized heating and the differential heating and the cooling conditions experienced by the different zones close to the welding.

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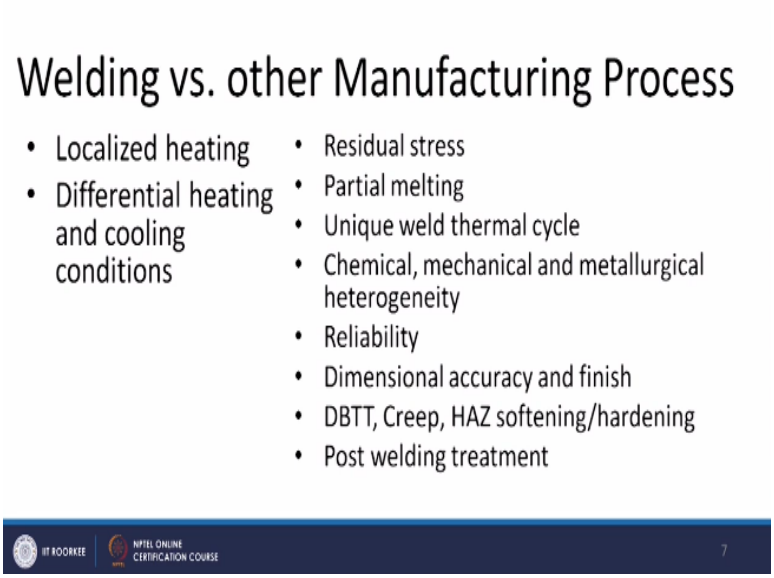

So, because of these two unique features related with the fusion welding, the welding offers the different unique behaviors or the responses and which will be appearing in form of the development of the residual recesses in the welded joints. The partial melting, unique weld thermal cycle experienced by the unique weld thermal cycle, chemical and mechanical and metallurgical heterogeneity, reliability, dimensional accuracy and finish and the unique properties like this.

So, I will elaborate each and every point one by one. So, the residual stress.

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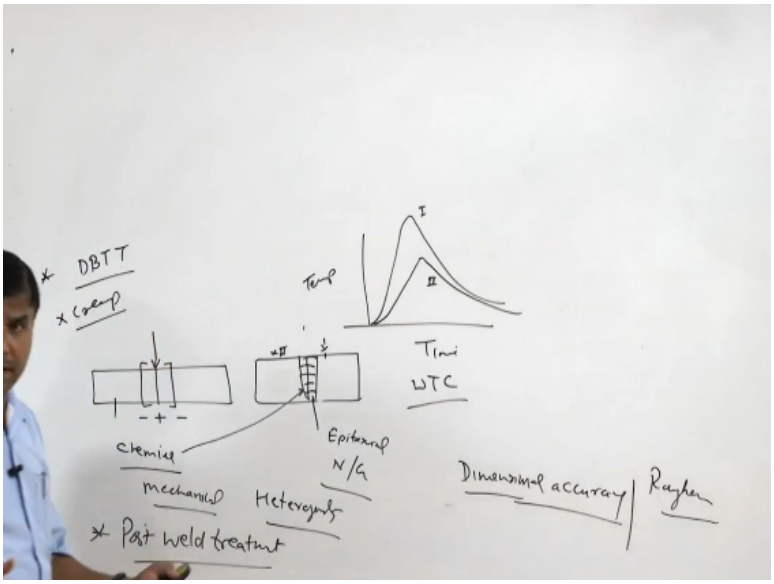

First of all, we know that with the application of the heat there will be expansion and the

contraction of the components and so when the heat is applied very locally so the nearby regions will be expanding and on cooling they will be contracting. So, this expansion and contraction is in a localized way develops the tensile residual stresses along the weld line and the negative or the compressive residual stresses next to the region which was subjected to the heating.

So, this is because of basically the very localized heating approach. In partial melting we know that the welding is unique in the sense that heat is applied at the faying surfaces. So just the partial melting takes place at the faying surfaces while rest of the base metal remains in the solid state. And because of this depending upon the kind of the weld metal whether it is autogenous or the fillers is used of the different composition.

We can have the epitaxial solidification or we can have the solidification through the nucleation and the growth mechanism. So, not the complete melting but the partial melting is involved weld thermal cycle is what where it shows in that how temperature at any point near the either in the weld pool or next to the fusion boundary does the temperature vary as a function of the time if we see.

You take any point, point one or the point 2 which is far away from the fusion boundary. So, the temperature variation as a function of time will show us the variation like it goes in this minus. Say this is for the point one which is very close to the fusion boundary and if we talk of the point two away from the fusion boundary here. Rate of the heating is slow peak temperature is low and then rate of the cooling is also low.

So, we will see that these are the two the variation in temperature as a function of time or the two points which are at different distances from the fusion boundaries or from the weld center. So, since each point offers a unique variation in temperature as a function of time that is what we say that weld thermal cycle experienced by in the joint is very unique. It varies with the location of the point.

Then the chemical, mechanical and metrological heterogeneity is the another thing like each weld joint differs in respect of these 3 parameters like the chemical heterogeneity. The zone

which fuses of first even of the same base metal it offers the different chemical composition because some of the things, some of the elements either they will get evaporate or they will go with the slack after interaction with the gases in the arc environment.

So, chemical composition of the weld is different and the structurally they are different it has typical cast structure like the (()) (29:42) structure and so the mechanical properties are different and metallurgical the weld joint is different. So, heterogeneity exists in the weld joint in terms of the chemical properties, mechanical properties and metallurgical properties and then we will see the reliability of these joints is poor.

Because of this heterogeneity aspect and the kind of stress concentration which exists in the weld joint. So, the reliability of these joints is poor. The dimensional accuracy and the surface finish is the another important aspect related with this dimensional accuracy. Dimensional accuracy of the welded joint is in general poor because of the involvement of the shrinkage and the expansion and contraction associated with the heating and cooling results in the lot of variations in the dimension and poor control over the dimensions.

Similarly, the surface roughness of the welded joint is also generally poor as compared to those which are produced by like say the forming or machining or casting. So, additionally they are two more points like whenever the material systems are welded they offer the unique differential behavior in terms of the DBTT. The welded joints of certain metal shows the drop in their toughness at low temperature.

That is what is called the ductile to brittle transition temperature. So, this kind of behavior is offered especially in the welded joints of the certain metals systems specially the mild steel and structurally steel. Similarly, the creep behavior of the welded joint is also poor as compared to their respective base metals because very fine grain structure is formed in the heat affected zone and which lowers the creep resistance of the material.

And sometimes, corrosion resistance is also very much compromised and the post weld heat treatment requirement like the weld joints require post weld treatment specially for the critical

applications. Like welded joints frequently develops the residual stress. So overcome to neutralize the residual stress developed during the welding sometimes post weld heat treatment is performed or the short blasting is carried out which will improve the fatigue resistance as well as induce the compressive residual stress.

So, for the critical applications sometimes post weld heat treatment or the short pinning or the special treatments are carried out so that the negative affect of the welding can be eliminated. So, in this presentation you have seen that the joining process which is a positive process as compared to the other manufacturing process and the localized heating and differential heating and cooling cycles experienced by the welding.

Specially, in the regions closed to the fusion boundary results in a very unique results in the very unique responses and properties to the welded joints. That is why the reliability of these joints of the welded joints is somewhat poor. In the next lecture you will see that what are the important advantages, disadvantages and applications of the welded joints. So, now you have seen that there are three broad approaches for joining one is mechanical joining, adhesive joining and the welding based joining process.

So, here since there are number of process in each of the categories so we have to see that which type of the joint is to be selected. For the selections of joints, we need to consider certain technical points like the metal to be join out. The section of the component to be joined. So, under this category basically it is the section thickness which is to be joined and the material properties especially the melting point thermal expansion coefficient.

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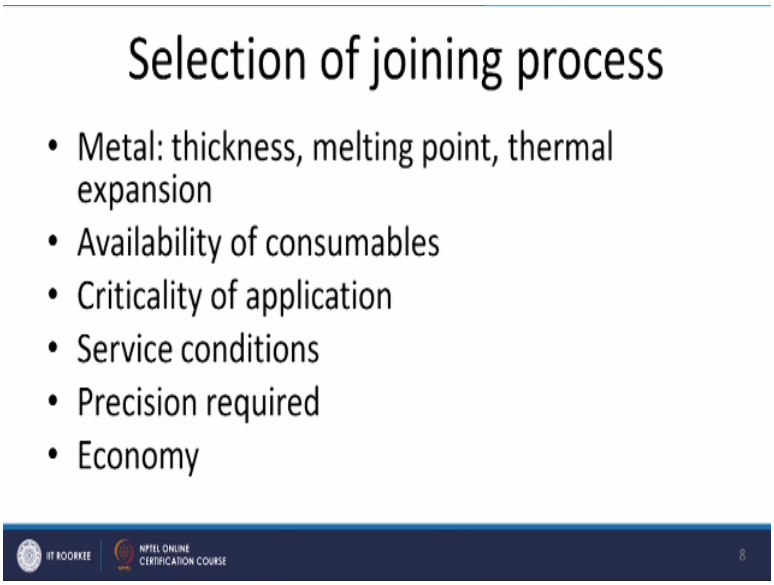

So, high melting point material required different approach for joining purpose as compared to low melting point material. Similarly, the high expansion coefficient metals offer more problem with the expansion and contraction specially in the welding in form of residual stresses and distortion so they are more problematic in that way. So, we need to consider the section thickness, the melting point of the material and thermal expansion coefficient.

Next is the availability of the consumers we need to see that that kind of process which is being selected for that process the suitable consumables which are required in form of shielding gas or the filler metal or the welding processes itself. The system also system expertise for handing the processes all that is available and then criticality of the application certainly plays a big role in selection of the suitable joining process.

Like the very critical joints where the life and the property is at the stake so mostly the mechanical joints are preferred or that welded joints. And similarly in the case of welding also like different range of the welding process existing. So, high quality weld joints are say produced like the gas tungsten arch welding or electron beam welding those. And for somewhat less critical applications.

So we may use the gas metal arc welding or even like say submerged arch welding process for pressure vessels. And for the most general purpose applications your silicon metal arc welding

processes used. Service conditions certainly play big role where in selection of the joint if the special environment is involved in form of the corrosion or involvement of the chemical or erosion etcetera.

Then we need to see that the joint is selected in such a way that it sustains the environment and it sustains that service condition in form of the loading and precision required. The welded joint offers somewhat lesser precision as compared to the adhesive joints and the mechanical joints and so accordingly the joints are selected. The economy certainly plays a big role in the selection of the joints we need to see that join not only performs the intended function for the designed life but also same can be produced economically also.

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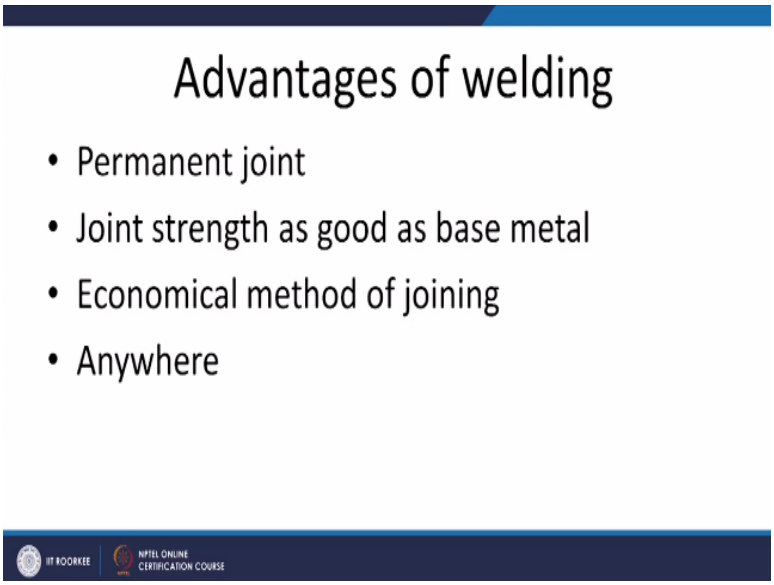

So, advantages as far the welding as a joining process involves the welding produces a permanent joint. This is very good side sometimes the strength of joint is also much better than the base metal itself which is also very good and the joints can be made very economically between the components whose assemblies is to be made or between the components to be joined and the other important thing it can be made anywhere.

The welded joints are not limited to the factory environment or the soft flow environment but this can be made offsite also using the suitable power source and power supply. So, these are the 3 or 4 major advantages permanent joint. The joint can be much stronger even then the base

metal. It can be produced anywhere and this can be made very economically. At the same time there are many disadvantages related with the welding.

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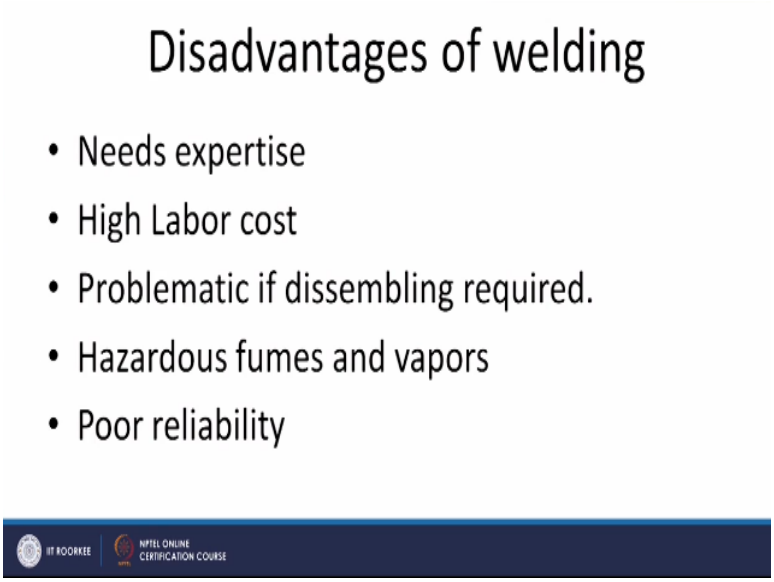

Like you need expertise to handle the welding process so that the sound and the reliable joint can be made and for that purpose. Lot of expertise is needed so the labor cost related to the welding is high and it is specially the welding is problematic because joint produced is permanent. So, if the disassembling is required either for the maintenance purpose or for the service or for any other purpose then the disassembling cannot be done so easily in case of the welded joints.

When the welding is performed normally hazardous fumes are generated which are harmful for the operators so special precautions are needed and to take out the hazardous fumes from the walking environment so that the people can work safely specially the welding processes applied for joining of or the welding of stainless steel offers lot of harmful gases for the operators so those need to be taken care of and the poorer liabilities since the jointed itself is considered to be discontinuity.

Because it has a lot of heterogeneity in respect of the chemical properties, metrological properties and the mechanic properties so it offers lot of variability in terms of these 3 parameters so the joint itself is considered as the discontinuity and the reliability also of these welded joint is poor. So these are generally not used for very critical applications and if these

need to produced.

Then very stringent conditions are applied for that purpose like joint used for the nuclear applications as for fabrication of aircraft components if they need to be welded then the welding is done very stringent conditions and it is ensured that joint is really reliable and capable to take the service load as per the requirement. Next is like the welding process and the different applications.

There are four common welding process which have been shown and their corresponding applications. For example, the first one.

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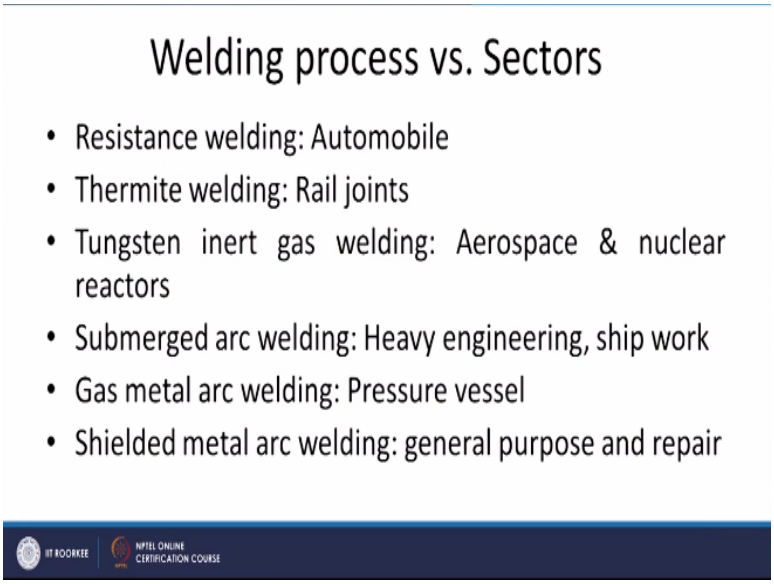

The resistance welding process is most commonly used in the automobile about four to five thousand of the spot welds joints are made using the spot welding and sometime even the seam welding is also used in case of the automobiles. Thermite welding is very common for developing the rail joints in the railways and the gas tungsten arc welding or GTAW process is used for making the high quality joints for nuclear applications as well as for fabrication of the components for the aircraft.

And then submerged arc welding process it is mainly used for welding of the heavy sections. So mainly used in the heavy engineering industry pressure vessels and the ship work and the gas

metal arch welding process is another process which offer very good quality weld joints but not as good as that of the GTAW process. And it is used for the high for the pressure vessels and wherever reasonably good quality weld joints are needed.

And the shielded metal arc welding process generally used for the general purpose welding and for the repair purposes. So, that is what you have seen that in this lecture we have talked about the comparison about the joining process and the other manufacturing process. Unique features associated with the joining process and the advantages and limitations of the joining process and some common welding processes and their respective applications in the different sectors.

So, thank you for your attention I will you in the next week. In the next lecture I will talk about what are the approaches which are used for the joining process and what are the common joining process. And how we can classify the different joining process whether they fall in the solid state or the solid liquid state or the liquid state joining process. Thank you for your attention.