Welding Engineering
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Module - 1
Introduction
Lecture - 3
Classification of Welding Processes - II

So, continuing with the classification of the welding processes, in today's presentation we will see in the classification of the welding processes on the basis of the way by which the weld joint is made like a the pressure welding or fusion welding. Another criterion based on which welding process can be classified as a welding processes and allied processes.

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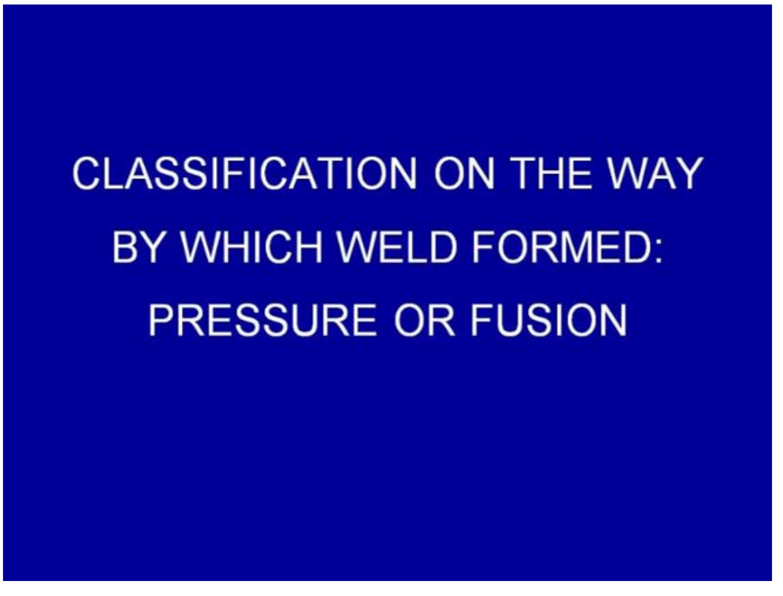

So, while in the last presentation, I gave the classification based on the various factors like the use of the filler metal whether presence of arc, whether arc is there or not with a particular welding processes or the source of energy being used in welding process for development of the weld joint. So, here we will be starting with the classification of the welding processes based on the way by which the weld joint is formed using pressure or using the fusion.

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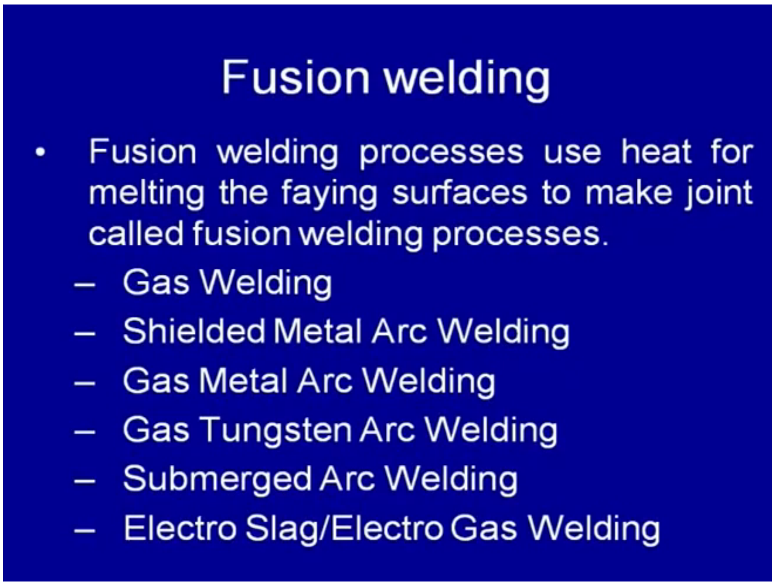

So, the fusion welding processes are all those welding processes where the faying surface, that is the edges of the plates to be joined together are brought to the molten state. Then the solidification of the weld metal, whether the filler metal is used or not results in the weld joint. So, in the fusion welding processes the faying the melting of the faying surfaces is a key aspect and the solidification of the weld pool, subsequently results in the development of weld joint.

The processes in which the fusion of the faying surfaces is carried out include the gas welding, shielded metal arc welding, gas metal arc welding process, the gas tungsten arc welding process, submerged arc welding process, electron slag and electro gas welding processes. In all these processes, one thing is common that whether we use the filler metal or not, one of the edges of the components to be welded are brought to the molten state. Subsequently, solidification of the weld pool results in the development of the joint.

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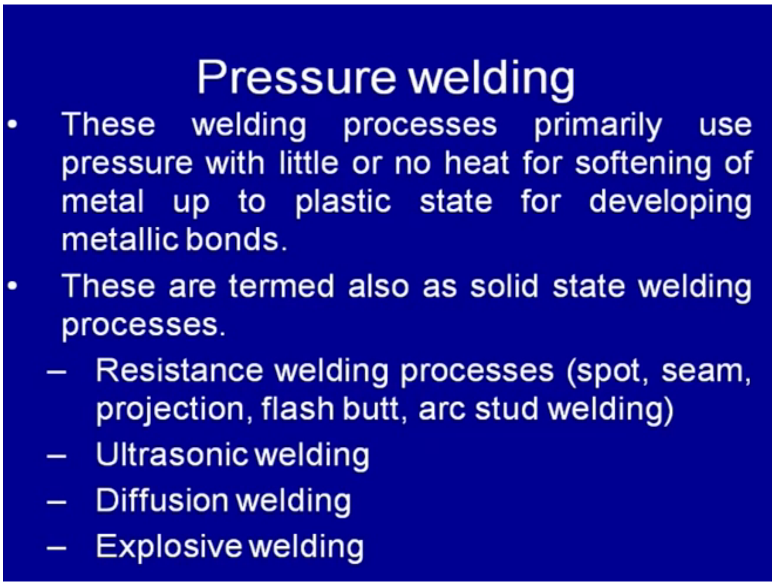

While in case of pressure welding processes, these welding processes primarily use pressure with or without application of the heat to get a plastic state and then get the metallic continuity to produce the weld joint. So, primarily the pressure is used to get the metallic continuity with or without application of the heat. If the heat if at all is used then that is mainly used to plasticize the metal edges being joined or the components to be joined. These are also termed as solid state welding processes and the melting is not there in these welding processes.

Mainly the heating is done through the various ways in very small amount to soften the faying surfaces of the components to be joined. These processes include resistance welding processes which are like resistance spot welding resistance, seam welding resistance, projection welding, flash butt welding, arc stud welding. In all the resistance welding processes, first heat is applied to soften the component, components surfaces and the contact interface by developing the heat through the electrical resistance heating. Thereafter, pressure is applied to develop the weld joint in all these processes, same sequence is used whether it is a spot welding, seam welding, projection welding, flash butt, welding or arc stud welding.

In case of the ultrasonic process, ultrasonic vibrations are applied in the components to be joined and these results in the interfacial, the frictional effects and a mechanical interlocking to produce the weld joint. In case of the diffusion bonding, pressure is applied between the components to be joined; the components are finished very properly, to have the perfect metallic contact between the surfaces to be joined. The high temperature components to be joined are placed together under pressure, so that the diffusion can take place across the contact interface and the bond can develop.

Similarly, in explosive welding some impact pressure force generates plastic deformation at the surface and results in the development of the weld joint. In these processes, the application of the heat is not to melt the faying surfaces, but mainly whatever heat is applied is to soften the metal system. With the application of the pressure or force, the metallic consolidation can be done to develop the metallic continuity and so as to develop the weld joint.

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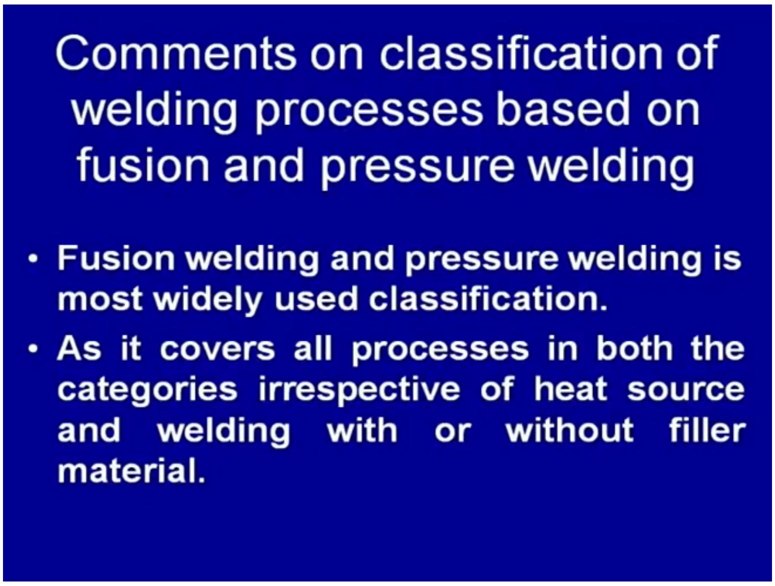

As far as comments on this classification, that is the fusion and pressure welding fusion and pressure welding process, classification is most widely used and accepted one because it covers all the processes in both the category respective of the heat source. Welding with or without filler material is used and because of these which are this is one of the most accepted the basis of classifying the welding processes.

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Further in the fusion welding processes, all those processes are included in which weld metal is allowed to solidify freely while in case of the pressure welding processes.

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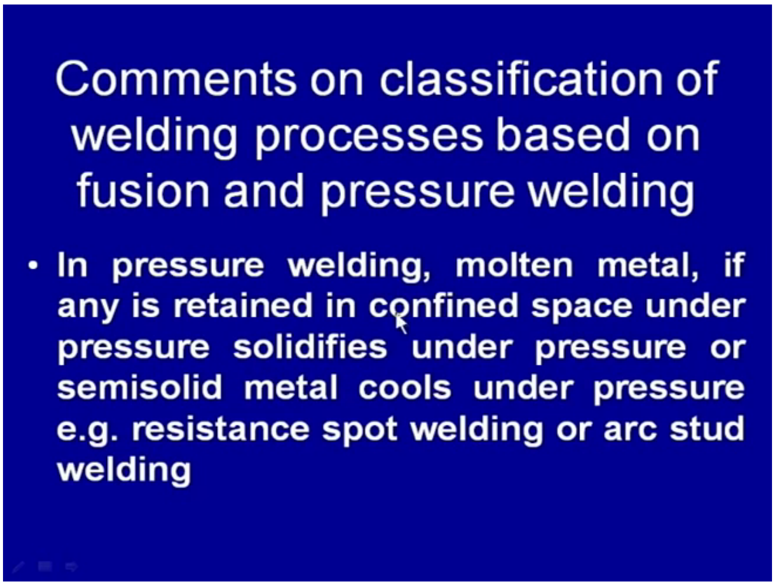

The molten metal if any is generated or the semi solid state is achieved, then the solidification occurs under pressure conditions in very confined space. The solidification or the consolidation takes place under the pressure conditions, so this happens say in resistance spot welding, arc stud welding process. So, mostly in pressure welding either the melting does not take place even if some semisolid metal is formed, it is consolidated under the pressure conditions to develop welding joint.

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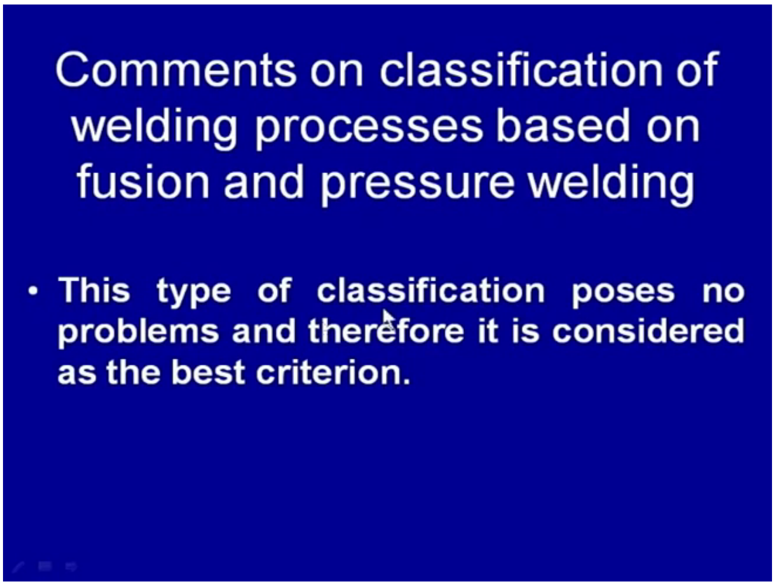

Further in this type of classification, this classification does not pose any problem therefore; it is considered as best criteria for classifying the welding processes.

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Classification of the welding processes further on the basis of the way by which joint is formed or material is applied. Much positive joining process involving addition or deposition of the metal will first be classified under the welding processes. They are mainly used for developing the joint and the allied process, which was used to apply the molten metal onto the components, this has resulted in another way of classification. We will see in the next slide, how the welding processes were grouped under this way of classification?

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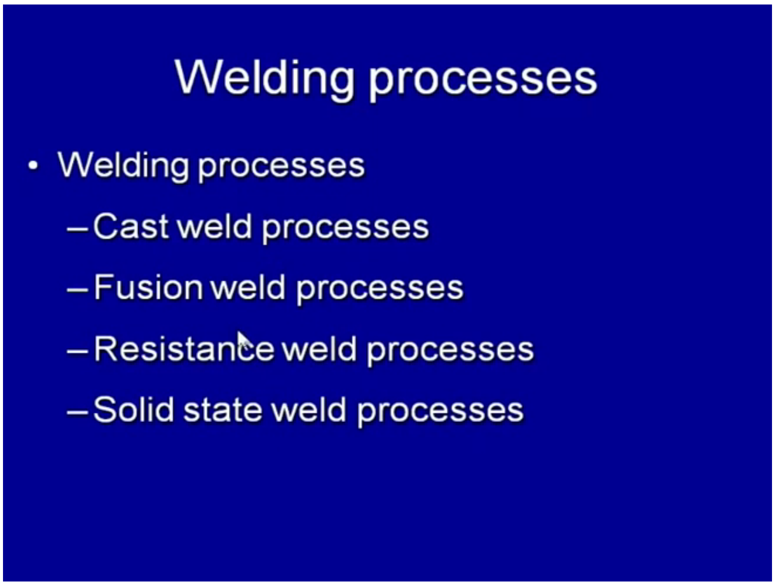

The welding processes were classified as cast weld processes fusion weld processes resistance weld processes and solid state weld processes.

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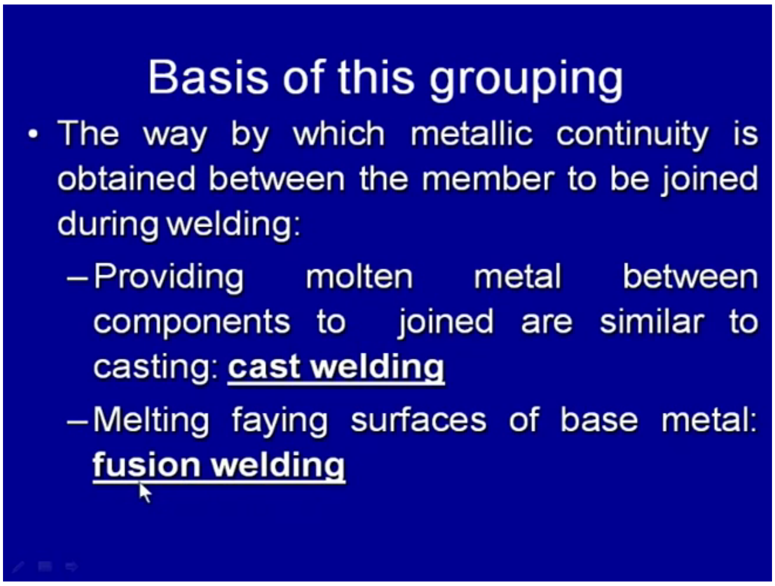

While the basis of this grouping was the way by which a metallic continuity is obtained between the members to be joined during the welding. It means that how the metallic continuity is obtained between the members being joined by welding. For example, in the cast welding process the molten metal is supplied between the components to be joined in the similar way as the casting, that is why it is termed as a cast welding processes. So, those processes where molten metal is supplied from the external source or the conditions during the solidification of the weld metal are similar to those of the castings.

Then these are termed the cast welding processes. Under the situations, where melting of the faying surface is of the base metal was used to develop the metallic continuity and get the weld joint, those were termed as the fusion welding processes. So, melting if the melting of the faying surface is involved, then these were termed as the fusion welding processes. If the molten metal to fill the gap between the components to be joined were supplied from the outside are generated in that way between the components to be joined then these were termed as cast welding processes.

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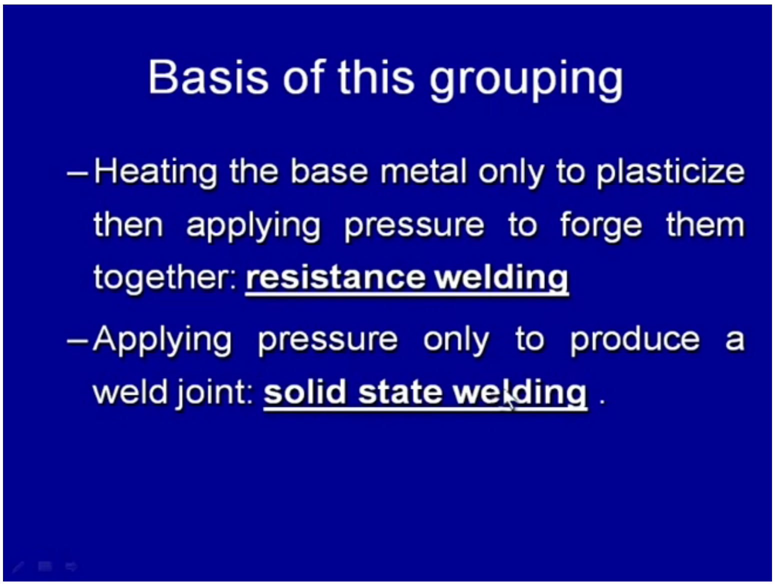

There are two more processes in this category; one is resistance welding and another is solid state welding processes. In resistance welding processes, heating the base metal is done mainly to plasticize the components being joined and then applying pressure to pose them together, so as to get the weld joint. In case of the solid state welding processes, mainly pressure is used between the components to be joined so as to get the metallic continuity. When pressure is applied and relative motion is used it develops some amount of heat that helps in thermal softening of the material. We will look into the detail of each of these four types of the welding approaches.

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But, before going into that we will see that what the allied welding processes are. According to this classification, allied welding processes are many where metal is deposited in one or other way in onto the base metal like the soldering is used for making the joint. Without fusing the base metal surfaces, so that metallic continuity can be obtained between the members even those who are having or which are having the metallurgical incompatibility. Similarly, the breezing is also used where heating of the base metal is done only to have the good bonding with molten breezing material.

So, the filler material is brought to the molten state by applying the heat and the melting of the faying surfaces. Avoided heating is done to have the good the metallic bond between the components being joined to have good fluidity of the filler material being applied over the service over the surface between the components. So, while the adhesive bonding in this case, the adhesive is the applied between the faying surfaces to be let the joint between the components being joined while in weld surfacing.

Weld are developed over the surface either to get the desired dimensions or to get the better corrosion and be a resistance surfaces while the metal spraying is another metal deposition process. The material metals are alloys and they are composites are spread over the base metal surfaces to either to enhance the weir resistance and corrosive resistance or to get the desired dimensions after machining or of the thermally spread components.

So, in all these processes except in weld surfacing the melting of the base metal is generally achieved and the surface is some sort of the deposition of the metal is achieved onto the surface of the component either to enhance the surface characteristics or to get a the disjoint between the components in consideration. So, we will see that in greater detail about the four welding the broad classification of the welding processes. They are four categories like the cast welding processes, resistance welding processes, solid state welding processes and the fusion welding process.

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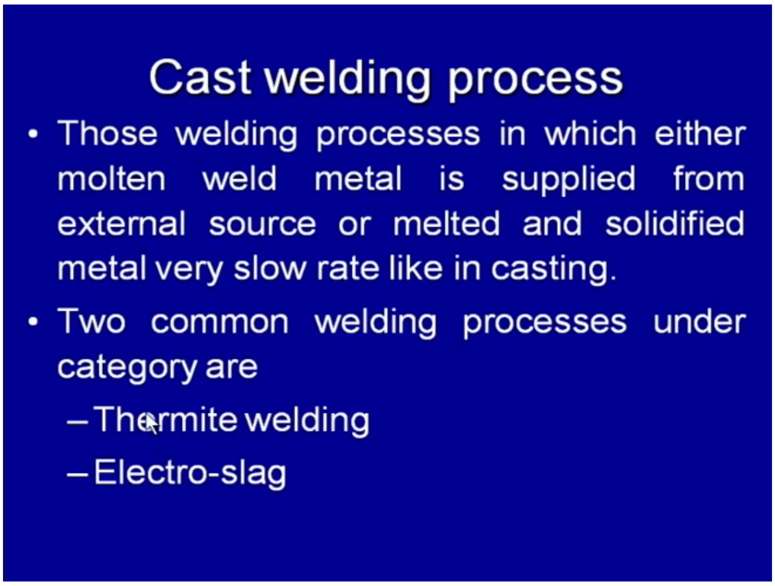

Cast welding processes are those processes in which either molten metal molten weld metal is supplied from their external source or it is melted in solidified between the components to be joined at very slow rate like in casting. Under this category we have the two welding processes namely thermite welding and electro slag welding. In thermite welding the molten metal is a weld metal is brought to the molten state through the chemical reaction outside the weld joints and then it is poured or supplied between the components to be joined.

In electro slag welding the weld pool the molten weld pool is developed between the components to be joined to the electrode resistance heating itself. But, the casing, the cooling conditions are very slow similar to that of the casting and that is why it has being put under the category of the cast welding processes.

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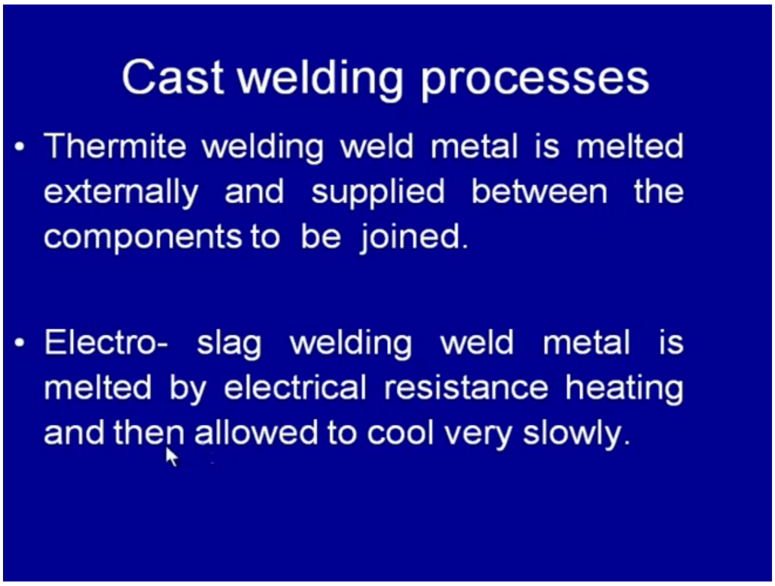

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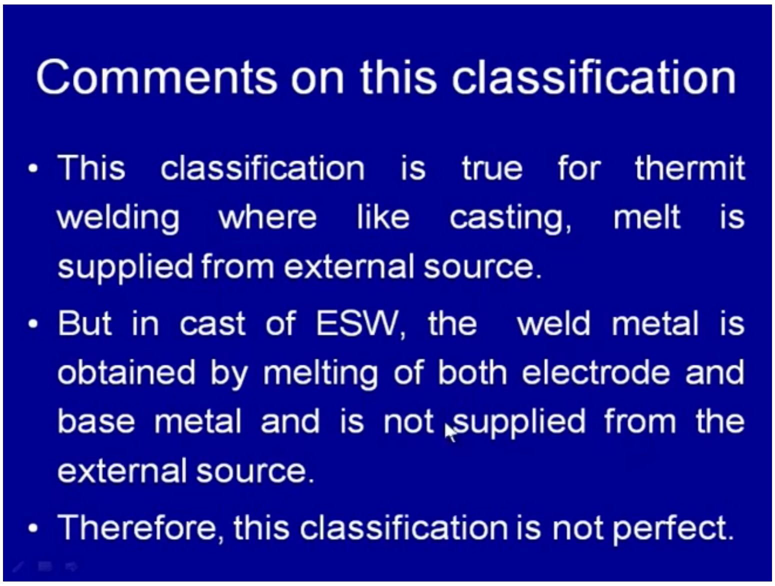

In the thermite welding the weld material is melted externally and supplied between the components to be joined, while in case of electro-slag welding weld metal is melted by electrical resistance heating. Then it is allowed to solidify under very slow cooling conditions these conditions are similar to that of castings.

So, if we see critically this classification, then this classification is true for thermite welding processes, where casting like conditions exist and in the molten metal is supplied from the external source. In case of electro slag welding, the weld metal is obtained by melting both such electrode and the base metal is not supplied from the outside. So, these conditions are not similar to that of the casting, only the cooling conditions are found similar to that of the casting that is very low cooling rate.

So, in case of electro slag welding since the weld metal is developed and obtained by melting both filler electrode and the base metal and is not supplied from the outside like in thermite welding, so this classification is not found perfect for classifying the welding processes. Now, we will see the fusion welding processes.

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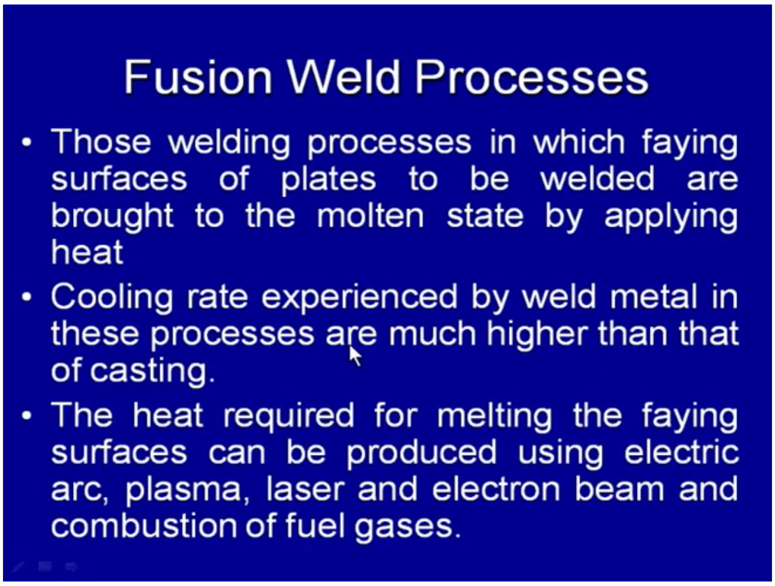

Fusion welding processes are those in which the faying surfaces are brought to the molten state and then subsequently solidification results in the development of the weld joint. The cooling conditions during the fusion welding processes are much higher than those experienced in the casting. This in turn results in much finer structure and much better mechanical properties of the weld metal than those produced by the casting process. So, the cooling conditions, cooling rate conditions experienced by the weld metal in these processes are much higher than the casting and this in turn results in the better mechanical performance of the weld joints.

Then the components made by in the casting process, the heat required for melting the faying surface can be produced in these welding processes either with the help of electric arc or the plasma laser or electron beam or by the chemical reactions between the fuel gases and the oxygen. So, there may be any type of the heat source which can be used for melting the faying surfaces and the subsequently on solidification obtaining a metallic continuity results in the fusion weld joint.

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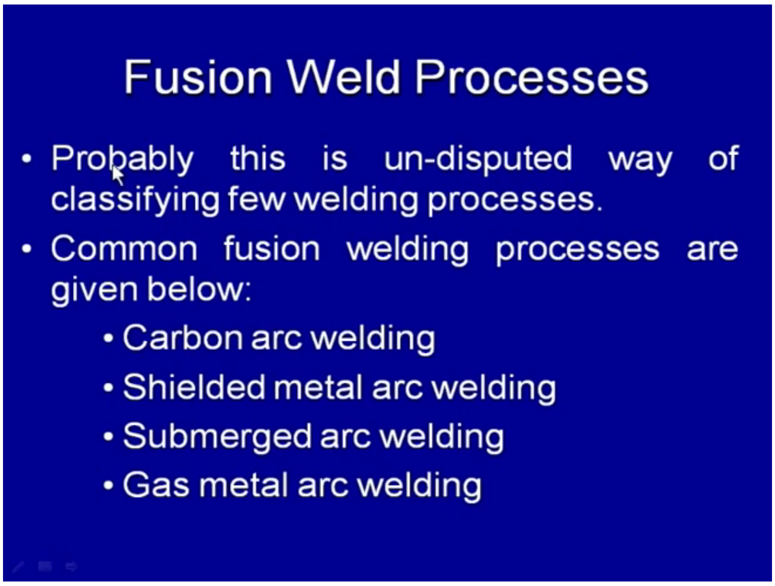

If we see further, this classification is undisputed way of classifying the welding processes, the common processes which are put under the fusion welding processes are like carbon arc welding, shielded metal arc welding, submerged arc welding, gas metal arc welding. We can put also the gas welding process, laser welding processes, and the tungsten inert gas welding process.

So, they are many welding processes which can be put easily without dispute under the fusion welding processes, where the melting of the faying surface is achieved by applying the heat from the external source. Subsequently, in the solidification of the weld metal results in the metallic continuity to produce the weld joint.

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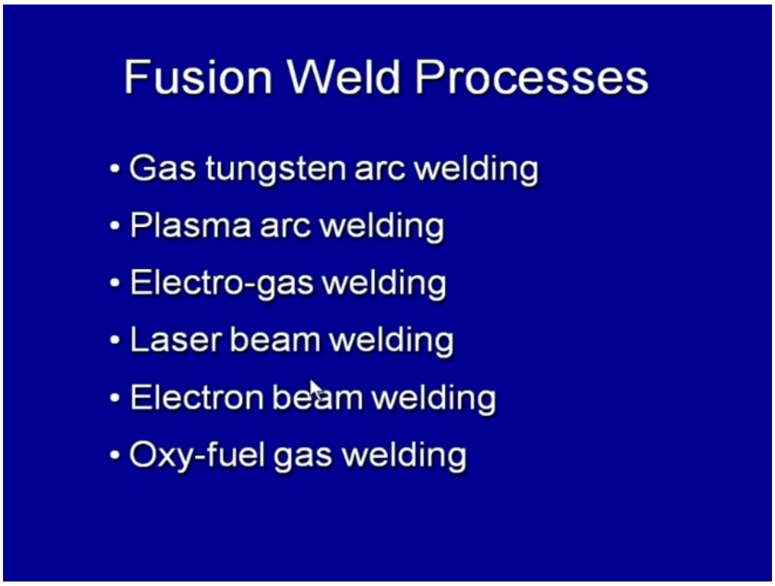

So, this is a list, further we can extend like gas tungsten, arc welding, plasma arc welding, electro-gas welding, laser beam welding, electron beam welding and the oxy-fuel gas welding process. The way by which heat is generated in these processes may be, the mechanism of the heat generation in these processes may be different. But, the common feature in all these processes is the same that is the faying surfaces of the base metal are brought to the molten state to get the metallic continuity between the components to be joined while in case of the resisting welding process.

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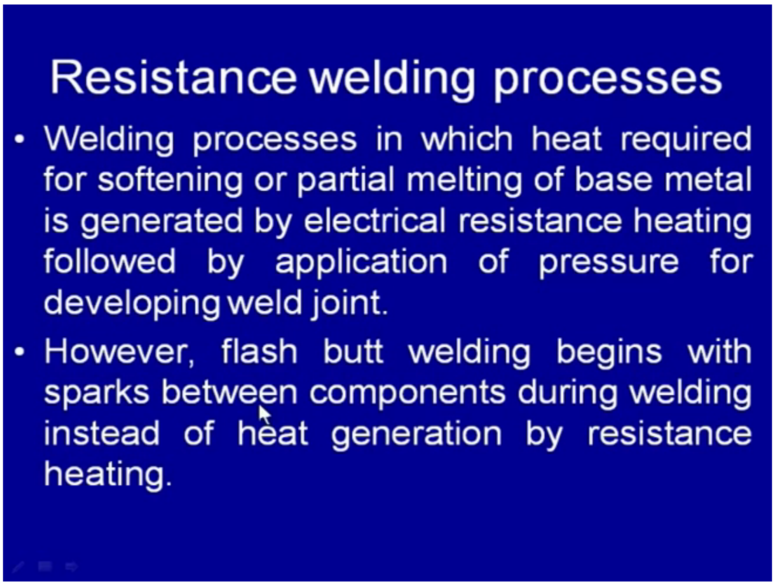

Heat required for in the in the resisting welding processes, the heat is used mainly for softening or for achieving the partial molten state of the base metal and this is done by the electrical resistance heating. Subsequently, the pressure is applied to pose a contact the components and get the metallic continuity by consolidating weld metal in form of negated the interface.

So, however in flash welding, butt welding which is a type of the resistance, but which is classified under the resistance, but welding this process begins with the sparks between the components during the welding instead of generation of heat by the resisting welding process. So, here mainly the heat is generated by this sparks and subsequently after cleaning and softening of the metal surfaces the pressure is applied to get the metallic joint by forging the components to be joined together.

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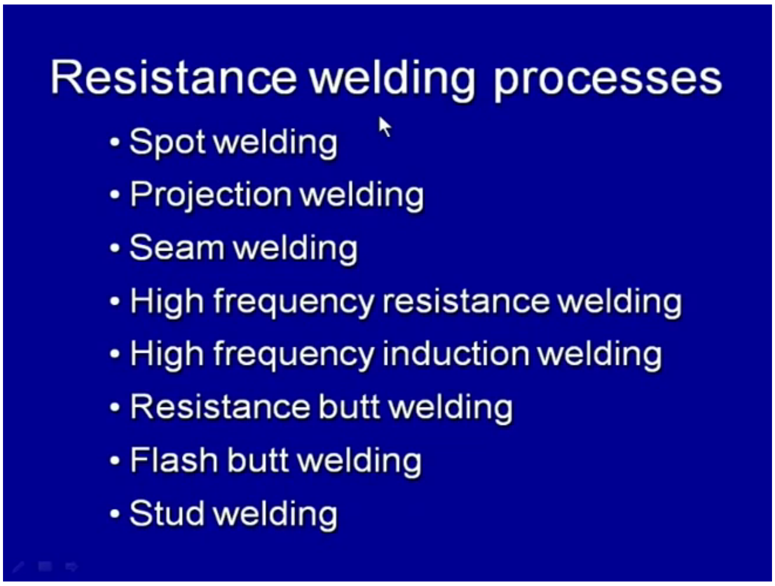

So, the processes which fall on this category where the electrical resistance heating is done to develop the desired heat for softening or getting the semisolid state at the contact interfaces and thereafter application of pressure results in the development of the weld joint. These processes the welding process which fall in resisting welding process category are the spot welding projection, welding seam, welding high frequency resisting welding high frequency induction welding resistance butt welding flash, butt welding and stud welding.

Here, it is important to see these resistance inductions welding basically induction effect helps to induce the current near the surface layers and when the these current is generated. Again heating is, heating is realised through the electrical resistance heating only and that is why this process high frequency induction welding processes is also has been categorised now the resistance welding processes.

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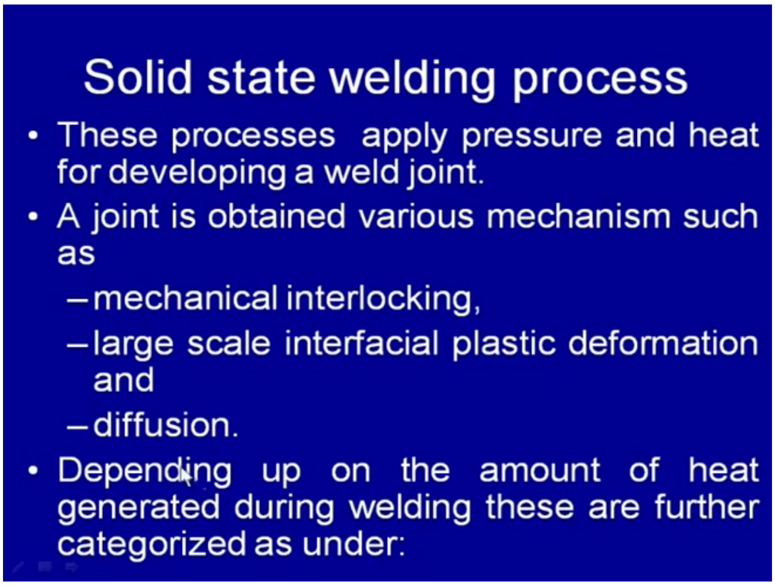

Now, we will see the solid state welding process these processes mainly the pressure is applied and marginal amount of the heat is applied for developing the weld joint. However, the melting of the base metal is not achieved; heat is applied mainly for softening of the components being joined, so as to get the plastic state of varying amount in the different processes. The joint in these processes us obtained through various mechanisms such as the mechanical interlocking which is main mechanism.

In case of the explosive welding, while large scale interfacial plastic deformation is involved in case of the friction welding. Diffusion is another mechanism through which metallic continuity is obtained in the solid state welding process, where the contact surfaces are finished and smoothen to such an extent that there is perfect metallic intimacy between the components being joined. Exposure at high temperature results in diffusion of elements from one side to another and then it turns results in the metallic continuity to produce the joint depending upon the amount of heat generated during these processes.

These can be further classified as a high heat input high, heat input solid state welding process, allow heat inputs solid state welding process. Low heat welding processes are like ultra sonic welding where through the ultrasonic vibrations little amount of the heat is generated at the interface.

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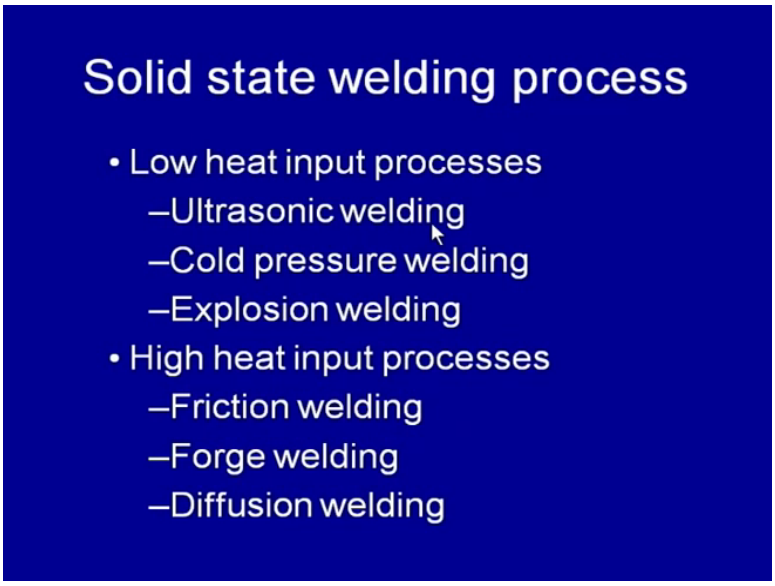

So, mechanical interlocking plus thermal softening associated with the marginal heat development, results in the joint at the interface by the ultrasonic welding process. Similarly, in cold pressure welding and explosion welding process, in these processes mainly mechanical interlocking is the mechanical interlocking, which takes place by the plastic deformation of the surfaces present at the component surfaces results in the development of the weld joint. The minor heat development at the contact interface helps to soften the surface layers and the present at the surface while in case of high input solid heat welding process lot of heat is generated by the friction or by the external source.

This heat is used in different ways for example, friction welding application of heat helps to soften the edges of the component to be joined thereafter, and the metallic consolidation through the application of the pressure or the forging like conditions. I developed to develop the weld joint, so whether it is a friction welding or friction stud welding in both the cases lot of heat is generated, that helps to plasticize to soften the base metal components being joined. Further, the forge welding process is also heat is applied from the external source.

Then the component to be joined as are forced together using them external pressure. Similarly, the diffusion bonding is also carried out at considerably high temperature, But below the melting point of any of the components and to be joined so that the diffusion can be facilitated at high rate and the weld bond or diffusion bond can be developed in order to get the desired joint

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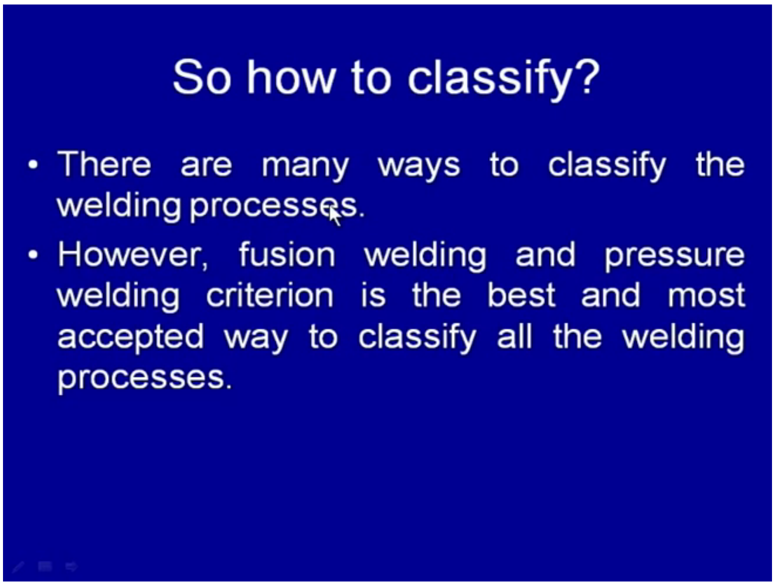

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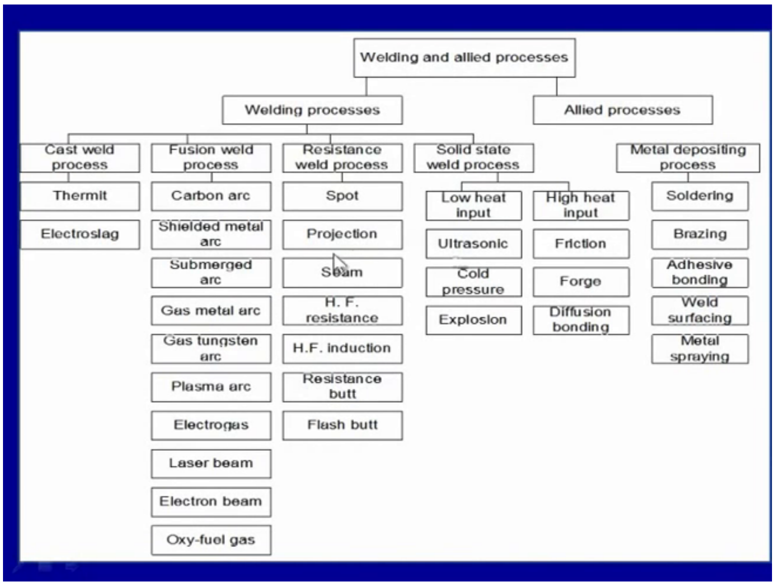

So, there we have seen so many parameters so many criteria's so many the ways through which the classification of the welding processes can be done. However, the fusion welding and pressure welding criteria is the best one and the most accepted way to classify the welding processes.

Here, we can see here this the last grouping of the welding process indicates that the welding processes and allied processes, here we can see the welding processes I have been grouped under one category and the allied processes are under the another category. Under the welding processes, again we have the four different groupings like in cast weld processes, fusion weld processes, resistance weld processes and the solid state. The weld processes is what we have seen just now. So, cast weld processes involves the thermite welding and the electro slag welding; while the fusion weld processes are like carbon arc weld processes, shielded metal arc welding processes, submerged arc weld process, gas metal arc weld process, gas tungsten arc welding process, plasma arc electro gas, laser beam, electron beam, oxyfuel gas weld process and the resistance weld.

The diffusion bonding under the category of the allied welding process, allied processes where some sort of diffusion of the metal or material is carried out in order to either get a joint or to improve the surface characteristics like the metal. These are the mostly metal depositing processes like soldering, brazing, adhesive boding, weld surfacing and the thermal spraying we have seen that a in the welding by the different processes the heat plays a very important role in the development of the weld joint.

Weld processes are like spot welding the projection welding seam, welding high frequency resistance, high frequency induction resistance butt, and the flash butt welding process. Under the solid state weld process category, we have both low heat input and high heat input welding process; where in the low heat input welding process we have ultrasonic cold process cold pressure and the explosion welding process. Under the high heat welding process is a friction welding or friction is steam welding process the forge welding.

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Whether it is being used for melting the faying surfaces of the base metal or to soften the metal metallic components being joined or to facilitate the diffusion the heat is applied in the different ways, during the welding for the different purposes.

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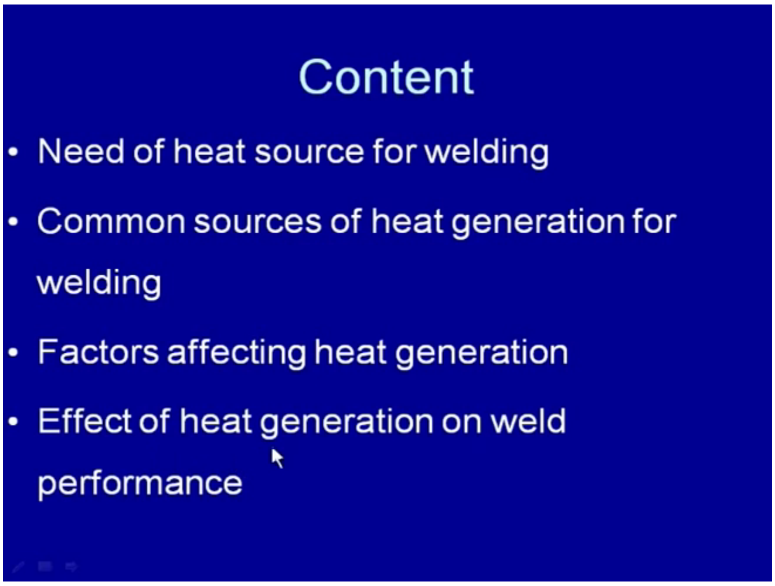

So, in this part first you will see what the various sources of the heat and what for they are applied in the different welding processes are. So in this part we will see the need of the heat source during the welding and then the common sources common ways through which heat is generated for welding purpose. The factors that the heat generation is associated are the welding process, the effect of the heat generation and the heat application on the performance of the weld joints.

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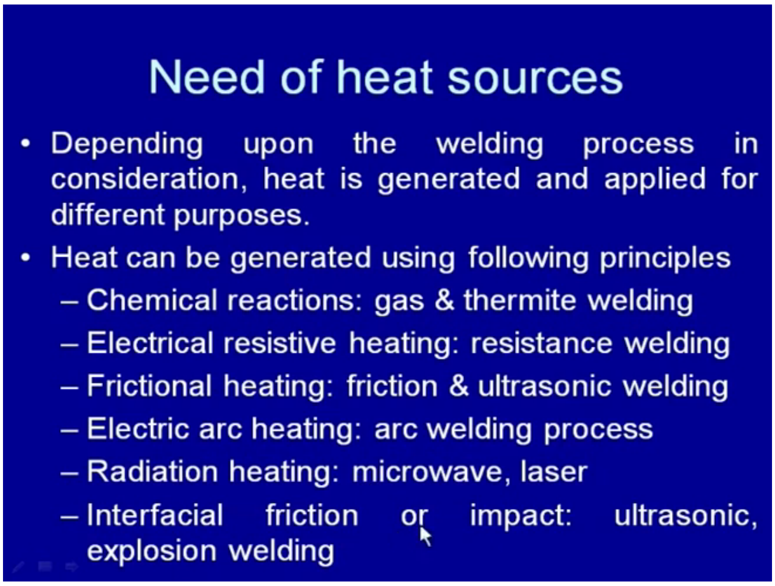

So, these four aspects you will be looking into the greater details like depending upon the welding process. In consideration, heat is generated and applied in different ways for the different purposes like in some of the cases heat is a generated by arc and it is mainly used for melting the faying surfaces. In other cases heat is generated by the combustion of the fuel gases with the oxygen. It is used either for melting the faying surfaces or only melting the filer material or to facilitate the mechanical thermal softening of the material to be joined by the forging pressure.

So, in the different welding processes heat is generated in different ways and applied for the different purposes heat can be generated in the using the following principles say the chemical reactions which are mainly exothermic in nature used for generating the heats desired. This approach is sued in full welding and thermite welding processes and the elective resistance, heating electrical resistive heating is mainly used in electrical resistance, welding processes. The frictional heating is used to generate the desired heat for softening and forging the component to get the metallic continuity like in ultrasonic welding although little amount of the heat is generated.

But, lot of heat is generated in friction welding and the friction resistive welding the electric arc heating heat generation by the electric arc is mainly used in the arc welding processes. There are various types of arc welding processes then the radiation heating like microwave and the laser beams are also used to generate the heat for the different purposes whether it is melting of the faying surfaces or thermal softening. Then interfacial friction and the impact is also used although it generates very little amount of the heat like in ultrasonic welding and the explosion welding process.

It is not expected much to soften the metallic interfaces and the faying surfaces through the heat generated by this approach. So, we can see that they are various approaches and the ways through which heat can be generated and applied during the welding. The various welding processes are used particular approach or principle is used for generation of the heat during the welding by a particular process. Each type of approach we will be looking into the greater detail related with the way by which heat is generated are the factors that affect the heat generation by that approach. When the heat is generated it is applied onto the faying surfaces of the component so as to get a metallic continuity by applying pressure or without application of the pressure.

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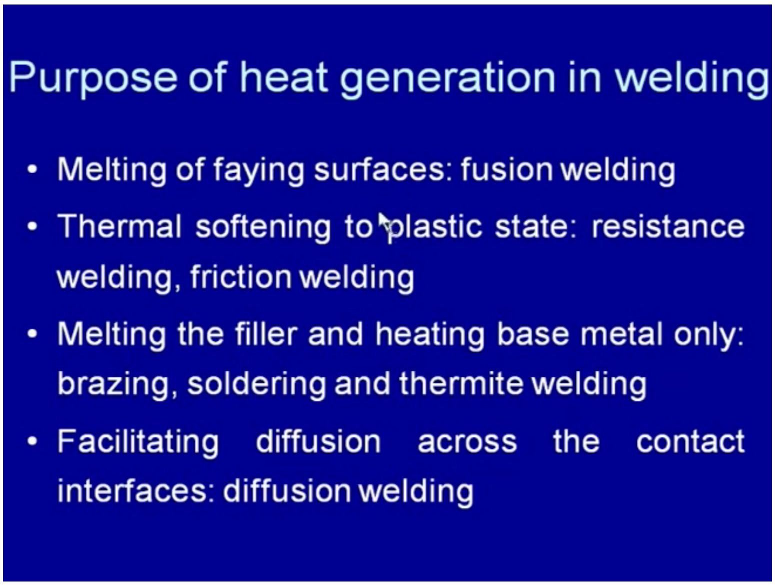

But, this application of the heat is done for the different purposes in the different welding processes. It can be done for melting the faying surfaces like in fusion welding process and the heat can be applied for only for thermal softening to get the plastic state in the components to be joined like in resistance welding and the friction welding process. Heat can also be applied only for say melting of the filler material and heating the base metal to get the good fluidity of the filler material like in brazing soldering and thermite welding. It is not expected that this application of the heat will be to melt the base material.

But, heat is mainly applied in these processes to melt the filler material, so that it can spread and get the spaces between the components to be joined properly for the heat canals. We apply facilitate the diffusion across the contact interfaces in process like diffusion bonding. So, if we see the heat generated in the different welding processes can be used for different purposes, so that the metallic continuity is obtained whether it is melting of the faying surfaces thermal softening of a the metallic component.

The surfaces to be joined or melting of the filler material only or there after heating of the base metal marginally not to the molten state and then to facilitate the diffusion across the interface to get a the diffusion one. So, depending upon the purpose of the heat application different amount of the heat is generated and accordingly the principle of the heat generation is used if melting is to be done. The high energy density sources are used if only the thermal softening is done. Somewhat low energy density processes can be used which can generate the energy at very low rat.

Supply the desired heat to increase the temperature of the material in consideration in equation, so as to get a the thermal softened condition, so as to apply the pressure and get the metallic continuity by developing the weld joint. So, depending upon the purpose the different amount of the heat generation may be required and for those different principles can be used and accordingly the selection of the welding process is made. For example, in heat generation by the chemical reactions in case of the gas welding, involves the use of the hydrocarbon gases, where like gases like acetylene propylene propane hydrogen and natural gases can be used.

When these gases are burnt the combustion is facilitated in presence of the oxygen with the optimum amount then it performs the exothermic reaction and generates lot of heat. When this combustion takes place combustion of these hydrocarbon fuel gases in the oxygen takes place typically the two or three zones are formed in the flame. Accordingly these are termed as the primary and the secondary zones in the flame.

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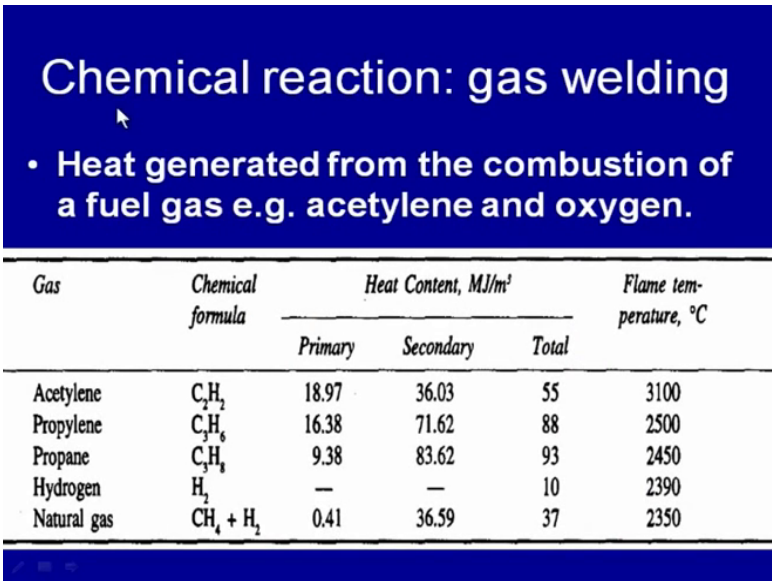

Gas	Chemical formula	Heat Content, MJ/m³			Flame temperature, °C
		Primary	Secondary	Total	
Acetylene	C_2H_2	18.97	36.03	55	3100
Propylene	C_3H_6	16.38	71.62	88	2500
Propane	C_3H_8	9.38	83.62	93	2450
Hydrogen	H_2	—	—	10	2390
Natural gas	$CH_4 + H_2$	0.41	36.59	37	2350

So, primary zones generate the lesser amount of heat as compared to the secondary zone. Secondary zone is the outer envelope of the flame which is bluish in nature. The inner portion which is whitish in colour is termed as the primary cone or primary zone, where comparatively lesser amount of the heat is generated as compared to the outer zone. The total amount of the heat generation by the combustion of unit quantity of the fuel gas and the oxygen, results in the different amount of the heat generation. For example, the acetylene on complete combustion results in 18.97 units of the heat for unit quantity of the fuel gas combustion.

In secondary zone, it results in 36.03 mega joule per meter cube of the fuel gas consumption. Thus, the total heat generation by the combustion of a 1 meter cube of the acetylene results in the 55 mega joule of the heat while the peak temperature in general it results in the range of 3000 to 3300 degree centigrade. But, on average the temperature around 3100 degree centigrade is generated, this combustion of the acetylene with the oxygen in optimum amount results in the highest temperature among all these the full gases which are shown in the table. This in turn results in very effective welding and the cutting processes because high heat higher temperature of the flame results in the rapid melting of the faying surfaces in the faster welding speed. The other welding, the fuel gases like propylene, propane, hydrogen and the natural gas results in somewhat the lower amount of the heat generation and the peak temperature.

So, the peak temperature or generated within the flame is more important from the welding and the fusion point of view of base metal as compared to the heat generation. As we can see the heat generation by the propylene and the propane are higher than that of the acetylene, but the peak temperatures are significantly lower than that is generated by the combustion of the acetylene. So, this temperature difference decreases the rate of the melting, decreases the rate of the welding, its speed and therefore other fuel gases are not that popular then the acetylene.

But, all other gases are very cost effective, so for somewhat low production rate conditions the cost effective fuel gases are also used. There is certainly difference in the peak temperature which is generated in the flame and the heat generated so we can see that the different the fuel gases on combustion results in the different peak temperatures in the flame. So, acetylene results in the maximum, is highest temperature among these gases as compared to the other gases accordingly this use of the oxy acetylene flame results in the higher welding speed and the cutting speeds as compared to the other gases. If we see further the heat generation in the primary zone in general is lower than the heat generated in secondary zone.

But, the peak temperature is found maximum in primary zone which is inner zone and that lower temperature is absorbed in the outer zone all the more heat is generated this happens primarily because of the difference in the surface area related with the secondary zone which is much wider and bigger. It is in direct contact of the atmospheric air at very low temperature, so lot of heat losses takes place from the secondary zone and that in turn results in the lower temperature of the secondary zone. However, the more heat is generated in the secondary zone, but the peak primary zone is of very small in size and covered with the secondary zone.

So, despite of having the low heat generation in the primary zone peak temperature generation generated in the primary zone is much higher than that is in the secondary zone. So, we can see those typical reactions which take place in the flame in the different zone as I said depending upon the oxygen and the fuel gas ratio we can have.

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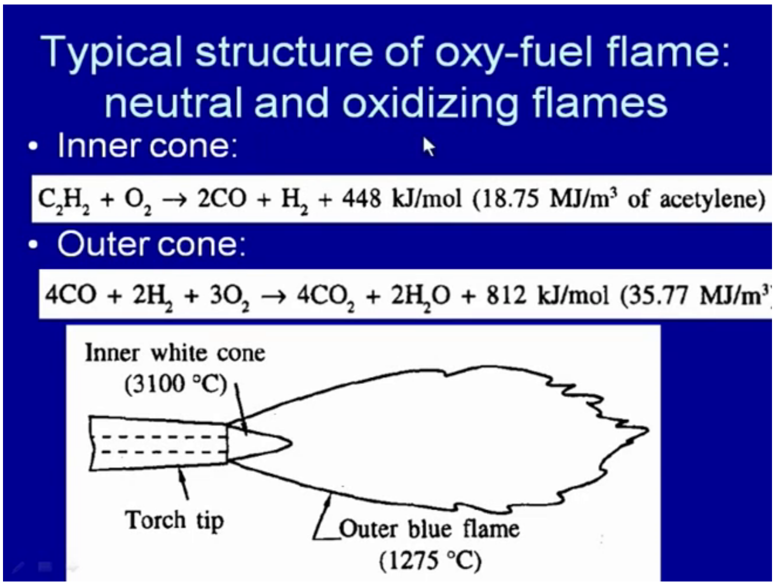

The three different types of the flames these are neutral flames, when oxygen acetylene ratio is almost equal. When the oxygen ratio is greater than the fuel gas then it results in the oxidizing flame and the fuel gas ratio of the fuel gas and oxygen is greater than one then it results in the carburising flame. So, the schematic structure of the neutral and the oxidizing flame is shown in this diagram, where the inner cone is this one where the peak temperature is generated in this zone.

Although, lesser amount of the heat is generated by this reaction where the acetylene reacts with the oxygen to form the carbon monoxide and the hydrogen and the heat generated is around the 448 kilo joule per mole. That is about 18.75 mega joule per meter cube combustion of the acetylene. In the outer cone outer cone this kind of reaction takes place where carbon monoxide and hydrogen again reacts with oxygen to form carbon dioxide and the water vapours.

But, at the same time it results in another vapour, but at the same time it results in another exothermic reaction by generating lot of heat to produce huge quantity of the heat in the secondary zone. But, if you see the size of the inner cone is much smaller although heat generated is also lower than the heat generated in the outer cone. Because of its small size and since it is covered by the heart secondary zone the temperature generated in the inner cone is much higher than that is of the secondary zone.

The temperature in the secondary zone is around 1275 degree centigrade while it is maximum around 3100 degree centigrade in the inner cone. So, it is always desired that the, if the welding is being done then the faying surfaces are brought in contact with the inner cone. So, that the heat is transferred very rapidly and the melting can be facilitated at faster rate to ensure the higher welding speeds. So, this is important while deciding the torch tip distance from the base metal so this is an important point to be kept in mind while deciding with decision about the torch tip distance from the base metal you will see the carburising flame it happens.

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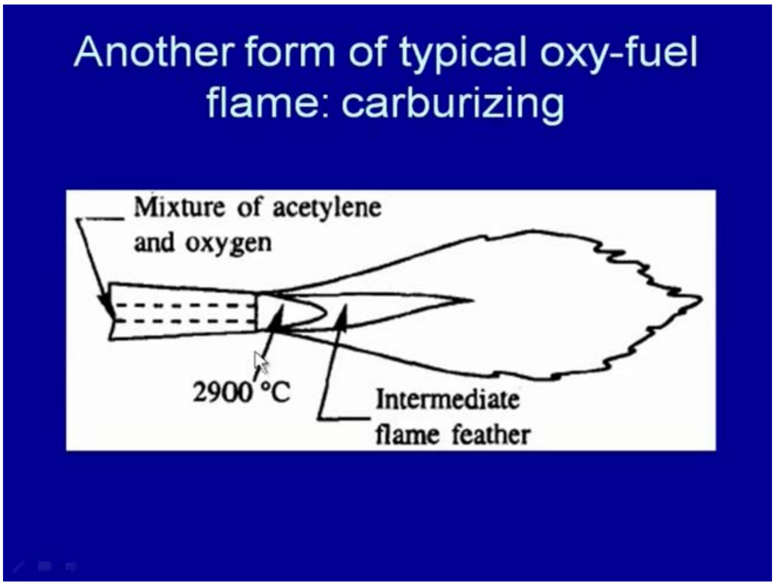

When the fuel ratio of the fuel gas and the oxygen is greater than one and under these conditions we get lot of unburned fuel gases, which in turn results in the third flame in the inner cone and the outer cone this is called the feather. The length of this feather is found proportional to the amount of the excess fuel gas which is present with the fuel gas mixture which is being used.

This carburising flame is normally not used when the hardening steel are welded because these gas these flames frequently supply the carbon to the steel and which in turn increases the hardness and the crack tendency of weld joint further. The temperature generated in these flames is also lower than the oxidising and the neutral flames another process where heat generate heat generated by the chemical reactions is a thermite welding.

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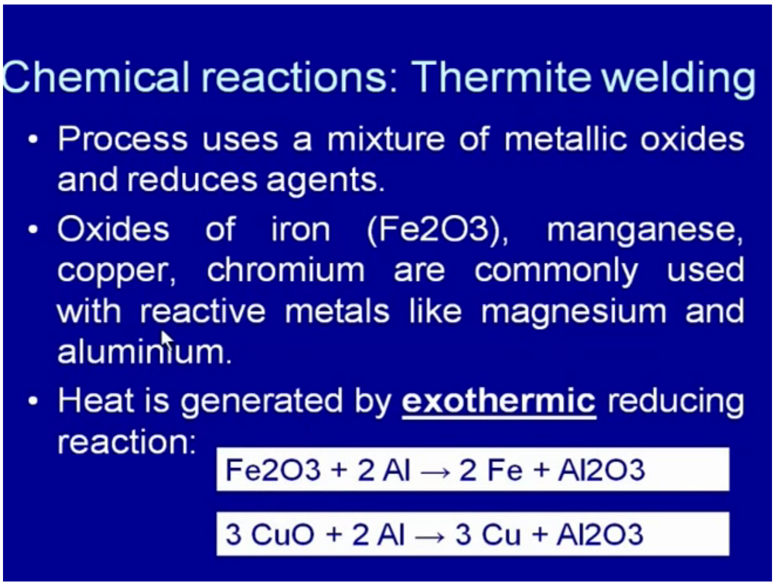

In the thermite welding, this process uses metallic oxides and some reducing agents. So, the basically the reduction of the metallic oxides is some reducing agents happens with the exothermic reaction which in turn generates lot of heat oxides that are used for generating the heat to the chemical reactions are like oxides of iron very commonly used for thermite welding of the rarely steel. The oxides of the manganese oxides of copper chromium are also used for generating heat so that the filler material can be melted outside. Then it can be fed between the components to be joined and for performing the reducing reactions.

The other the metallic reactive metals are also added with the oxides and these are manganese and the aluminium any of these metals system form of ribbons or powders can be used to initiate the ignition so that these oxides can be reduced. So, heat is generated because of the exothermic reactions, which is reducing in nature. So, here the iron oxide say make sure of iron oxide is and the aluminium powder is being used for thermite welding process. It results in the reaction of the reducing reaction of the iron oxide with the aluminium to produce the iron and the aluminium oxide.

This reaction occurs with the liberation of lot of heat that helps to melt the iron powder and this molten the metal is then fed between the components to be joined. Similarly, if the copper oxide is used then it is reduced with the aluminium to produce copper and the aluminium oxide this is also associated with the exothermic reaction and liberation of lot of heat.

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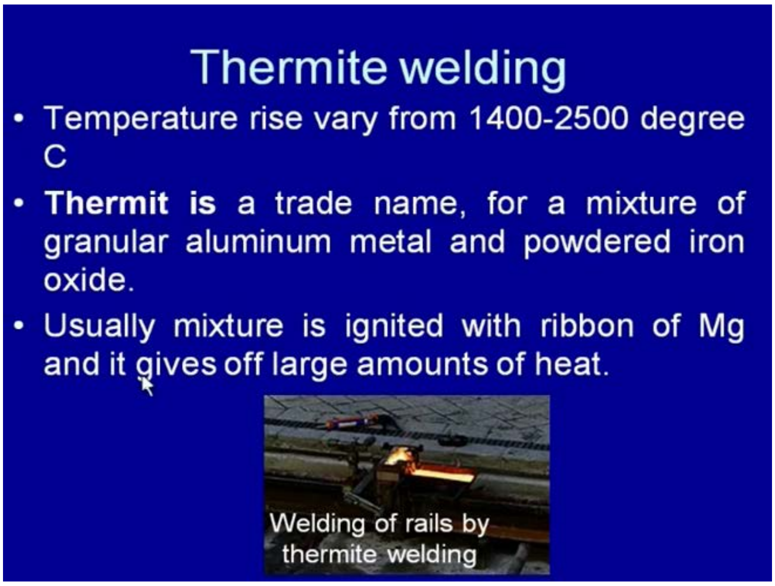

That temperature rise in the thermite welding can vary significantly from 1400 to 2500 degree centigrade. This temperature is found enough to melt the iron and the other constituents which are used as a filler metal and so as to get the weld joint. Thermite is typical trade name for a mixture of a granular or powdered form aluminium metal and the powdered iron oxide. This is the reason this process is called thermite welding because it uses the thermite, which is basically a mixture of aluminium iron oxide powder.

Usually, this mixture is ignited with the help of the magnesium ribbons, when it is burnt it gives of a lot of heat for melting the filler material. This filler material and then is applied between the components to be joined and the rail steel is one of the common example where thermite welding is used heat generation.

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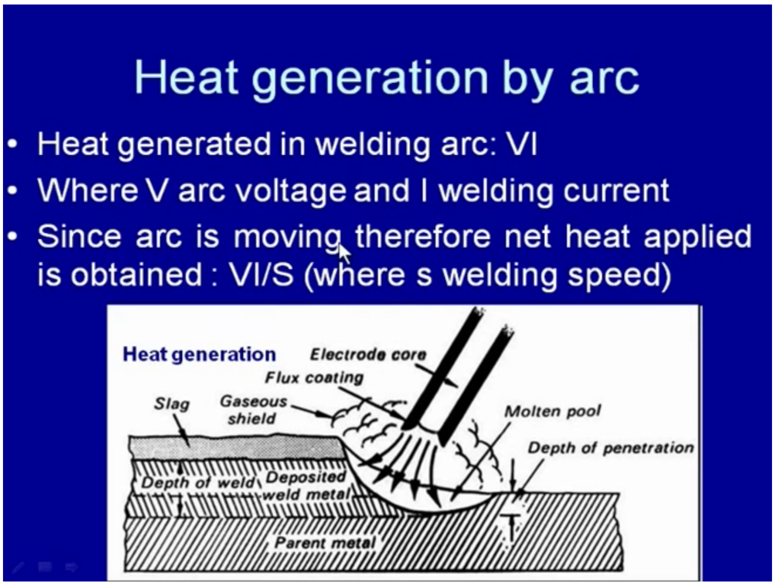

By arc welding, heat generation by arc welding this is another approach for generating the heat using the electric arc and this can be used for melting the faying surfaces. So, this heat generation by the welding arc is basically governed by the flow of current through the arc. When arc is established the flow of current that is welding current in the arc voltage with across the base metal and the electrode, this product of the welding voltage and the welding current results in the heat generation. This heat is basically generated because of the resistance to the flow of current through the plasma region between the plasma region between the electrode tip and the base metal.

So, here basically the product of the arc voltage in the welding current indicates the power of the arc and since the arc is continuously moving during the welding. So, it is therefore, it is important to find out the net amount of heat applied to the basement metal for melting process. This is done by dividing v the power of the arc that is V I with the welding speed that. So, this helps to give a get us the net amount of the heat being supplied to the base metal and unit of this is going to be kilo joule per m m.

So, when arc is established between the base metal and the electrode the there is particular arc voltage and there is flow of current that helps to generate the heat. This also results in melting of the base metal and the filler material, these filler material becomes very active and frequently it reacts with the gases present all around. This is why the protection of the weld pool from the surrounding gases becomes important the amount of the heat generation by the arc welding is governed by basically the two factors that is arc voltage being used.

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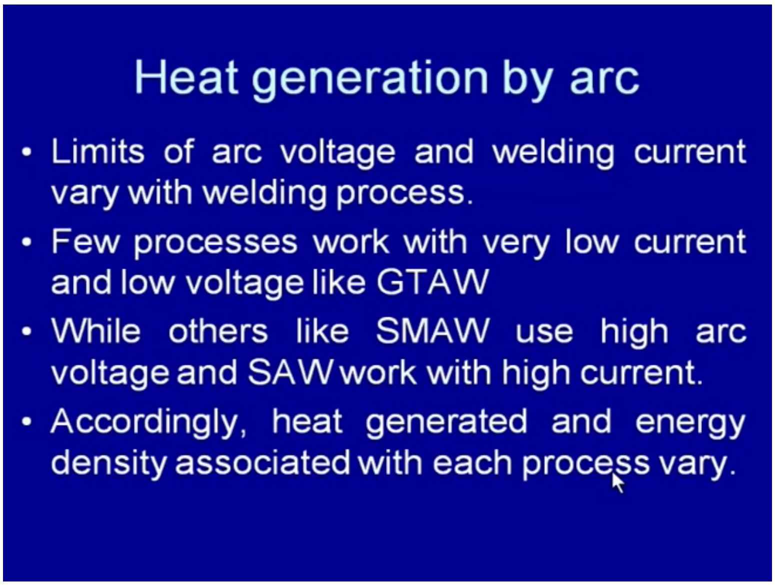

The welding current and the magnitude of arc voltage by a particular for a particular process or the current very significantly with the type of welding process are being used. So, they are the upper and lower limits of the arc voltage and the welding currents which are associated with which welding process few welding processes, work with very low current and the very low voltage. For example, it is common to use the current in the range of 50 ampere to 150 or 200 amperes with the tungsten inert gas and the voltage to the tune of 15 to 20 volt.

In case of the submerged arc welding high arc voltage is common which may vary from 50 volt to the 80 volt while in the case of submerged arc welding current can vary from 200 to 2000 amperes. So, this variation in arc voltage and the welding current associated with the particular process can result in the significant difference in the heat being generated during the welding. So accordingly, the heat generated the energy density associated with each welding process very significantly because the welding current becomes different and the arc voltage becomes different.

At the same time the size of the arc or the area over which the heat is applied through the arc, these things very with the each welding arc welding process and therefore, the significant difference in the energy density associated with the each welding process is found to vary significantly.

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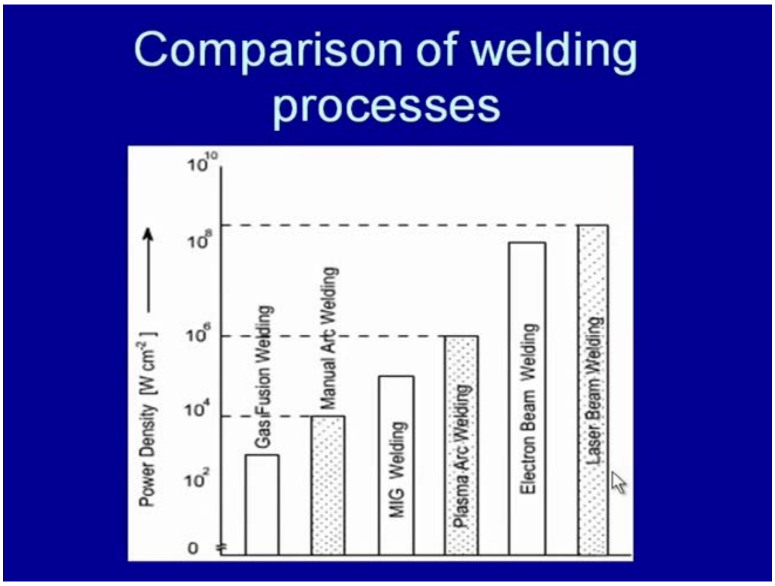

We will see here a typical comparison of the energy density related with the each welding process. If we see here in this plot in addition to the arc welding process, the other welding processes like gas welding and the electron beam welding and laser beam welding also has been given. We can see here power density related with the heat source very low with the gas welding and it is in watt per centimetre square. In case of the manual metal arc welding is somewhat higher then further higher with the metal inert gas welding. Then so the higher with the plasma arc welding and then electron beam welding and the laser beam welding.

In difference in the power density associated with the each welding processes, primarily due to the factor that the area, over which heat is applied and the rate at which heat is delivered to the base metal. It’s very low rate of the heat generation and very wider area is covered during the welding in case of the gas welding. This is why it results in very low power density while in case of the arc welding although energy density is high but, not as high as in case of the plasma takes or electron beam. But, it further results in the higher temperature of the arc say around 500 to 600 degree centigrade and the arc here size is also very small.

So, this in turn results in the higher arc higher energy density, then the gas welding and this is the same logic is applicable in all other welding processes. The rate at which heat is generated and the area over which it is applied during the welding onto the base metal results in significant preference in power densities associated with the each welding process. So, here we have seen that they are very different ways through which heat can be generated and in this part further we have observed what are the different how heat can be generated through the chemical reactions.

The heat generation through the arc and the factors associated with the each welding process. In the coming presentations we will see the other approaches through which heat is generated for the welding purpose and what is the need of protecting the weld pool from the atmospheric gases. What are the various approaches available with the different welding processes to protect the weld pool? We will see in next lecture.

Thank you for your attention.