Manufacturing Processes - I
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Lecture - 13
Resistance Welding Process

Welcome students. This is the eighth lecture in welding and this lecture is based on the resistance welding processes. We have seen in the arc welding processes that the heat required for producing the joint is generated by the arc, which is struck between an electrode and the work piece, and in these processes the molten metal is generated. But here, in resistance welding processes, the required heat for producing the joint is generated by the flow of current through the area where joint is to be formed. So, electrical resistance heating is basically responsible in all those processes which come under this category. So, heat required for producing the joint is generated because of electrical resistance heating through the contact interface where joint is to be formed. The need of this process was felt when it was required to join thin sheets at a very high scale. So, if we see the capabilities of this process, this process can produce the joints at very large scale and that too very high at a very high production rate.

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So, here we can say, for a large scale and high production rate of the sheet metal component, it is possible to use the resistance welding processes because it forms the joint in very less time. And whatever joint is formed, that is largely free from the distortion or the distortion is very less, and that is required for producing a successful joint of thin sheets by any joining process. That role is performed by the resistance welding process.

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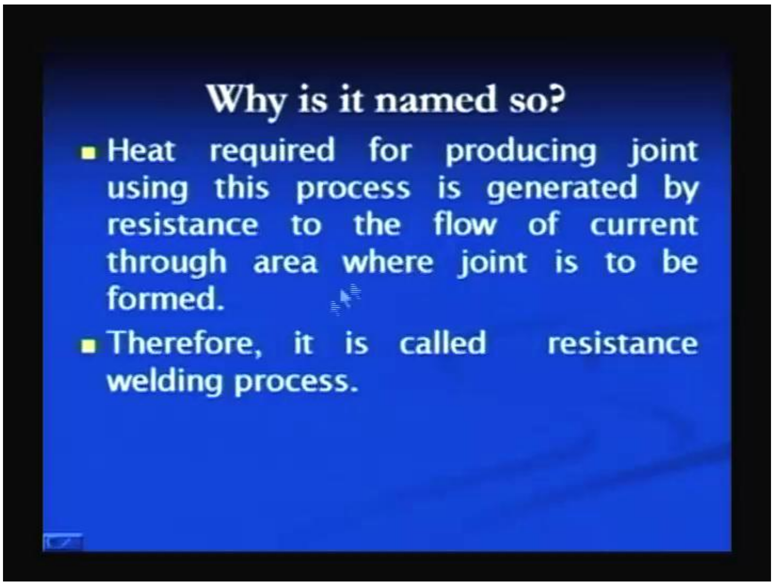

Why it is called so? Because heat required for producing the joint by using this process is generated by the flow of a, generated by the resistance to the flow of current through the contact area where joint is to be formed. And therefore, this processes is called resistance welding process.

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There are various types of the resistance welding processes which are used in different industrial applications, but the eight are the common one, and out of these eights, here the first 3 types of resistance welding processes are the most common and others are used in very specific areas.

The first 3 resistance welding processes are spot welding, seam welding, and projection welding. The application of these 3 welding processes is very expensive in the industrial sectors, while the flash welding, percussion welding, upset butt welding, high frequency resistance welding and high frequency induction welding are used in very localized manner. For example, flash welding is mainly used for joining the rail in the railway industry and upset butt welding is used for producing in the rods in butting position or when ends to ends are joined by the upset butt welding.

High frequency resistance welding and high frequency induction welding processes are used for joining, for the fabrication of the pipes, and therefore, we can say that the spot welding, seam welding, and projection welding we should understand more clearly as these are very extensively used in the industry, while others are used in very localized manner.

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The resistance welding processes are slightly different from the arc welding processes in respect of the many parameters, and if we will see here, the resistance welding processes use pressure, while in arc welding process no pressure is used. Pressure is used in resistance welding processes mainly to consolidate the partially melted metal present at the interface so that sound nugget can be formed. And in terms of rather other factors, like of which the resistance welding process differ from the arc welding processes, is like no flux is used in resistance welding processes and mostly no filler metal is also used; sometimes it can be used. So, these are the 2 main differences which we will see in resistance welding processes compare to the arc welding processes where fluxes are used to remove the impurities from the molten metal and filler metal in normally used in thick sheet welding to fill the groove between the blitz to be joined.

And most of the resistance welding processes are automatic while arc welding processes can be automatic or the manual one. And because of this nature of the resistance welding processes, here the process variables are identified and established first and those are set before proceeding for the welding. And during the welding, the entire process parameters are maintained, while in the arc welding process, those are identified and then as per needs, parameters can be adjusted. So, here, since the processes is mostly automatic, in these resistance welding processes are mostly automatic, and that is why identification of the variables is very important and those parameters are to be maintained for producing this successful joint continuously in production.

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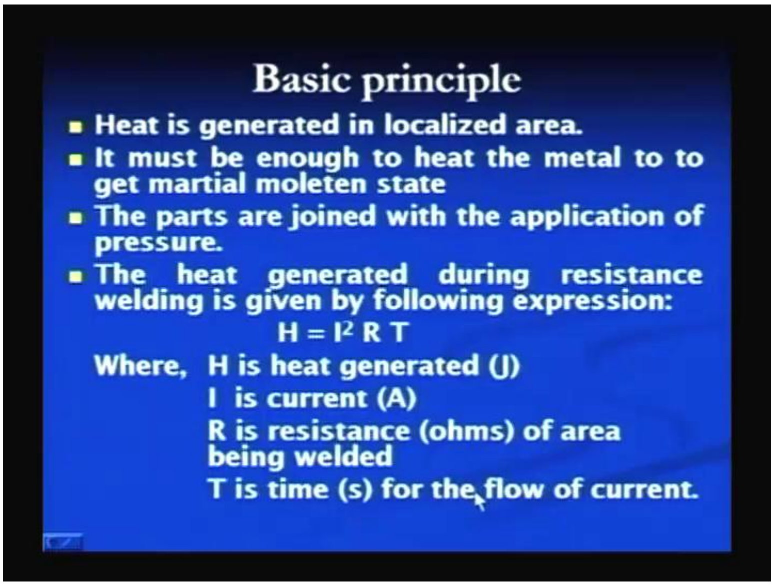

The basic principle of the resistance welding process lies in generation of heat by the electrical resistance heating in very localized manner. Heat is mainly generated in the interface zone where joint is to be formed. And for that purpose, heat is generated by the flow of current through the interface and heat generated must be enough to bring the materials near the interface in the molten state or partially molten state. And here the parts are joined with the application of the pressure.

Once the partial molten state is attained, then they are joined by using the forcing pressure to form sound nugget joint at the interface and heat generated during the resistance welding is expressed by the equation like: H is the heat generated is equal to I squared RT, where I is the current, R is the resistance, and T is the time during which current flows. Here, we can see, heat generated in Joules and I is the current in Amperes, R is the resistance in Ohms of the area of the contact were weld is to be formed and T is the time in Seconds during which the flow of current through the interface takes place.

So, here the role of current and the interface resistance, and the time for which current flows is significant in generation of the heat for producing the sound weld joint. The resistance at the interface depends upon the condition of the work surfaces which are to be joined. Impurities, presence of impurities and rough surfaces cause higher electrical contact resistance compared to the finished and smooth surfaces.

And to generate the higher amount of heat, if the current is set on the higher side, it may lead to the complete melting also or incomplete heating can also take place if the current is not set properly. So, the selection of all these parameters like current and the time is very important for generating the heat which can bring the interface, region, or the contact surfaces to the molten state and then forcing pressure can be applied to produce the nugget for producing the joint between the sheets to be welded. So, here, the role of the current at the time is very important in generation of the heat. When current flows, when flow of current takes place through the interface, the temperature varies across the section of the plate being welded.

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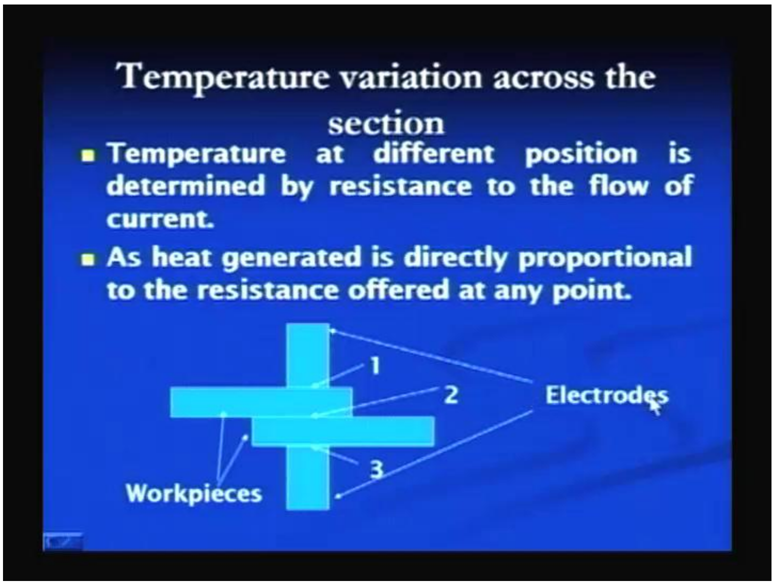

The temperature at different position is found different and it is mainly determined by the resistance to the flow of current in the different zones. As heat is generated, heat generated is directly proportional to the resistance offered by any point in the section which is being welded, and accordingly the temperature of that particular zone is determined; higher the resistance for a given flow of current greater is the temperature which is noticed.

Say these are the 2 plates which are to be welded by the electrical resistance welding, these are the 2 electrodes which are there on both the sides of the plates to be welded, and between these 2 electrodes, the work pieces are placed. And when the electrodes are brought in contact with the work piece, we find the 3 interfaces: one is between this electrode and the upper surface of the one plate that is this one, the region one we can say, and another interface is formed between the 2 plates of the work piece that is the 2 plates of the work pieces like the zone 2 is formed between the 2 plates which are to be joined, and the third region or third interface is formed between the electrode and the lower surface of the work piece.

And at the contact surfaces one, 2 and 3, the contact resistance is found higher compared to the other areas and that is why these, point one, means region one, region 2, and region 3, are subjected to higher temperature compared to the other areas or other region in the electrode or in the work piece or in the other sections of the electrodes.

So, here if we see that how the contact resistance varies from one end to the another one is from one electrode side to the another electrode through the work pieces which are to be joined, and accordingly only we get the variation in temperature at the different zones.

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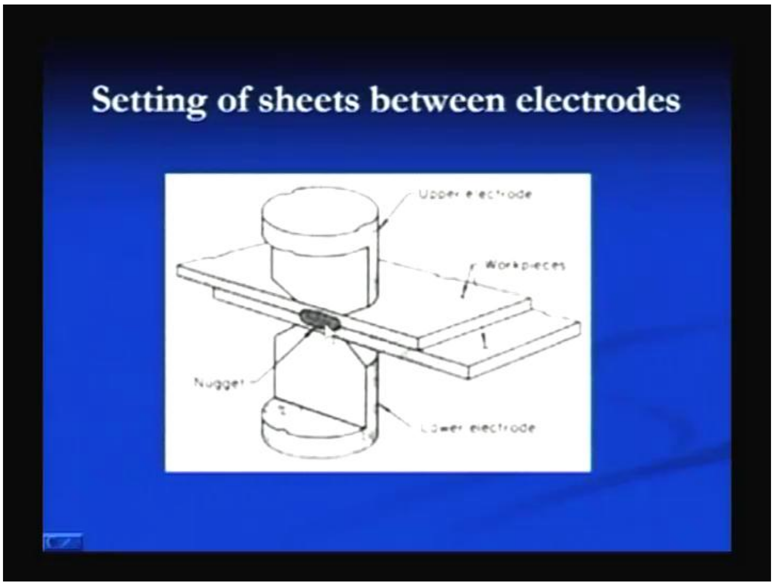

So, here, we can see when the plates are to be welded are placed between the electrodes and flow of current takes place, a nugget is formed at the interface between the 2 plates and this nugget acts as a joint for joining the 2 plates.

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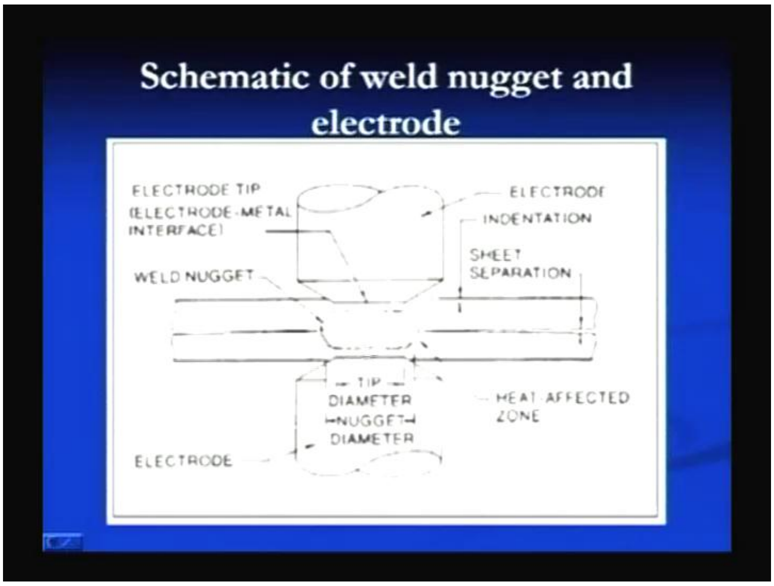

Here, we can see here how the nugget is formed? Say this is one electrode, this is another electrode and this is the tip of one electrode and tip of another electrode. One electrode remains a stationary, another becomes movable. And between the 2 plates, between the 2 electrodes, work pieces to be joined are placed and then movable electrode comes in from contact with the plates to be welded and then flow of current is started. And due to the electrical resistance heating, here weld nugget is formed at the interface between the work, work pieces or the plates to be joined.

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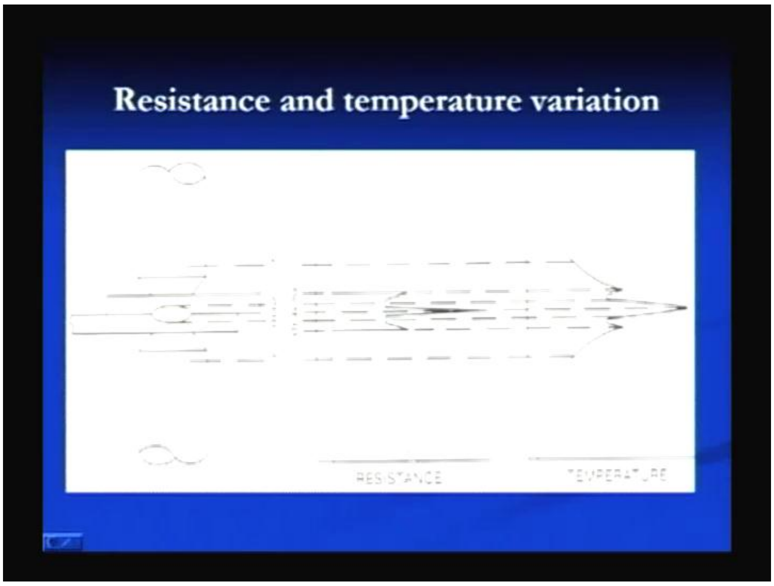

Here, if we see that why joint is formed or weld nugget is formed only at the interface between the work pieces to be welded, to understand that we have to see that how the contact resistance varies from the region one in one electrode to the region 7 in another electrode, through the plates which are to be welded.

Here, we can see, the region one lies in the electrode, movable electrode, and the region 7 lies in the fixed electrode, and here region 3 is in the middle section of the work piece, middle section of the work piece and region 2 is at the interface between the upper surface of the work piece and the electrode. So, this is region 2. Region 3 is in the middle of, somewhere in the middle of the upper plate and the region 4 is the interface between the 2 work pieces which are to be welded. Region 5 again is in the middle of the 2 plates, middle of the lower plate which is to be welded and region 6 is the interface between the lower electrode and the lower surface of the work piece that is this, and the region 7 lies in the electrode. And if we see, the contact resistance at these different regions will find the contact resistance in the electrode, at the electrode, movable electrode and the fixed electrodes is same here; that is the lowest one.

This contact resistance magnitude is shown here and this y axis represents the distance from the region one to the region 7 here. So, across, so, the variation in the contact resistance from one side, one electrode to another electrode can be seen from this diagram. Here it shows that contact resistance at region one and region 7 is the minimum one because these are made of of high electrical conducting materials like Copper or Tungsten or their alloys. That is why the contact resistance of this resistance at region one and region 7 is the minimum one.

If you see the contact resistance at region 2 and region 6 which are indicating the contact resistance between the movable electrode and upper surface of the work piece, and the contact region 6 which is indicating the contact resistance between the lower surface of the plate and fixed electrode, and the contact resistance here is somewhat higher here, corresponding to this value and corresponding to this value. So, here we can say the contact resistance is somewhat higher between the electrode and the work pieces. That is why for given flow of current more heat is generated and that is why accordingly more temperature, higher temperature we find at the interface between the electrode and work piece here between the upper surface of the work piece and the movable electrode.

And the same way, we also find the high temperature between the lower surface of the work piece and the electrode that is corresponding to this one. And if we see that, the contact resistance decreases because we pass through contact resistance at a point, at region 3 and 5 is somewhat lower than the contact resistance at point 2 at region 2 and region 6, because these regions 3 and 5 lie in between the work piece surface in the work piece itself. That is where metallic continuity exist and that is why resistance will be somewhat lower for the flow of the current, and that is why somewhat lesser temperature is generated in the middle of the plates to be welded. But if we see the region 4, the interface between the two plates which are to be joint are subjected to the maximum or they have the maximum contact resistance. And that is why maximum temperature is generated, and this is the reason behind why the melting of the metal is starts first near the interface of the work piece or at the interface of the plates to be joined. So, this is how the contact resistance and the temperature variation from electrode one to the another electrode takes places, and this explains that the maximum temperature is generated at the interface because of the high contact resistance at the interface.

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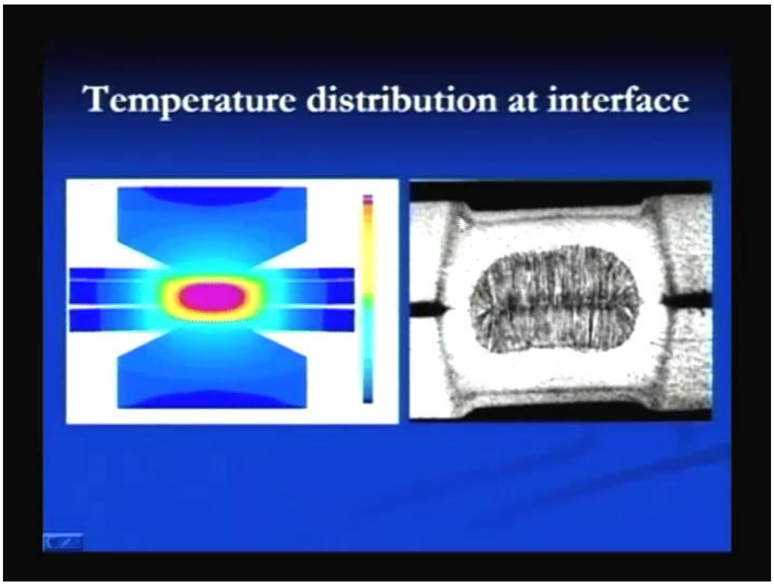

Here, we will see, schematically we can see, here the maximum temperature is generated near the interface. These are the two plates which are to be joined, and the temperature is generated around the interface of the two plates which are to be joined. Then, when under these conditions weld nugget is formed, we find that weld nugget penetrates to both the sides here; partial penetration. We can see penetration of the weld nugget is here in the upper plate side and also in the lower plate side.

So, this is the cast structure which is formed. And the region around it, we can see the area where because of heat the material has been affected, and that region, this entire zone is termed as the heat affected zone. This is the cast zone where melting has taken place. And we can see here, some sort of depression also has been formed because of the electrode pressure.

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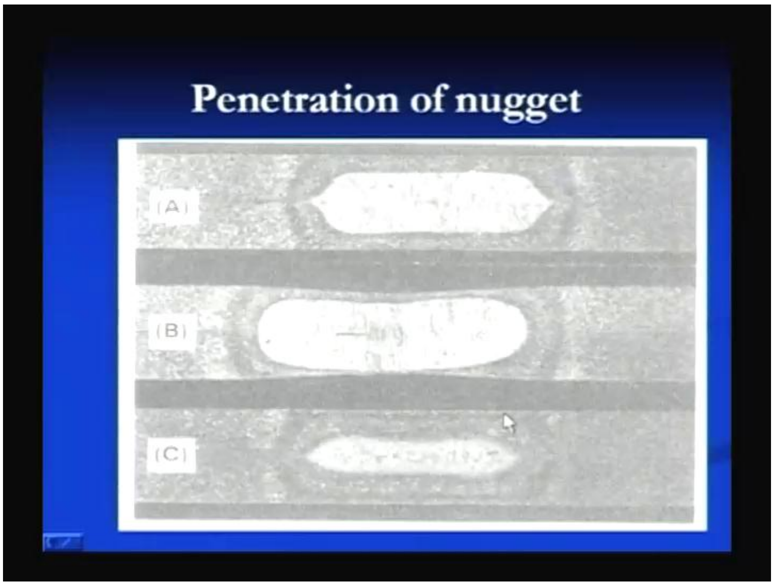

And when nugget is formed, the penetration has to be optimum and not excessive or not less penetration will be required. Here, we can see the penetration; both the sides of the plate is is the optimum one. Here, we can see, excessive penetration of the weld nugget has taken place on both the sides and very thin sheet has left unmelted and here, this may weaken the joint. And here, very less penetration has taken place on both the sides and this extent of penetration will depend upon how much heat is being generated during the flow of current through the interface. So, the setting of the welding current and the time for which current flows is very important for the required penetration to form the sound weld joint by resistance welding process.

The important variables which are to be kept at the control in resistance welding process for a successful welding, it is necessary to see that its current value, optimum current value is selected and then it is allowed to flow for preset, proper preset time. After when the melting has taken place, enough pressure is applied so that molten metal generated at the interface can be consolidated effectively to form sound joint.

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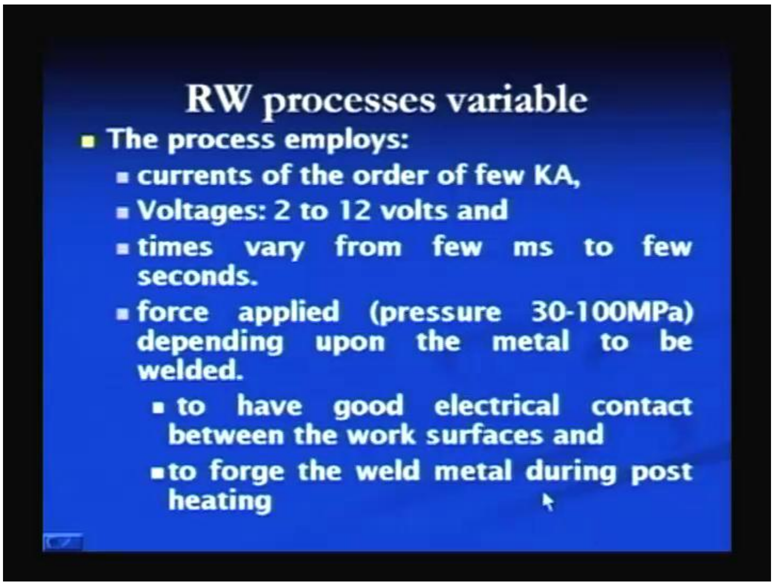

Here, if we see the variables which are to be controlled, current normally selected in the range of few kilo Amperes because these process are known as low voltage and high current. How much current is to be set? That depends upon the material to be welded and thickness of the sheets which are to be processed by the resistance welding process.

The voltage can range from 2 to 12 volts and the time can vary from few micro seconds to few seconds, and the force to be applied for the consolidation purpose may vary to generate a pressure in range of 300 MPa. And the amount of pressure which is to be used will depend upon the thickness of the sheet to be welded, the welding current which is to be used, and the material which is to be welded. Purpose of applying pressure is to have the good electrical contact between the surfaces of the work piece and the good contact between the electrode and the work piece surfaces itself. And also, to force the weld metal during, after the welding or when molten metal is formed, it has to be consolidated formally by using pressure so that there is no expulsion of the molten metal. And for that purpose, to force the molten metal and form sound nuggets, the required pressure is to be applied, which can range from 30 to 100 MPa. The welding current is an important parameter and it has to be selected after giving the due considerations related to the material which is to be welded and the other related factors.

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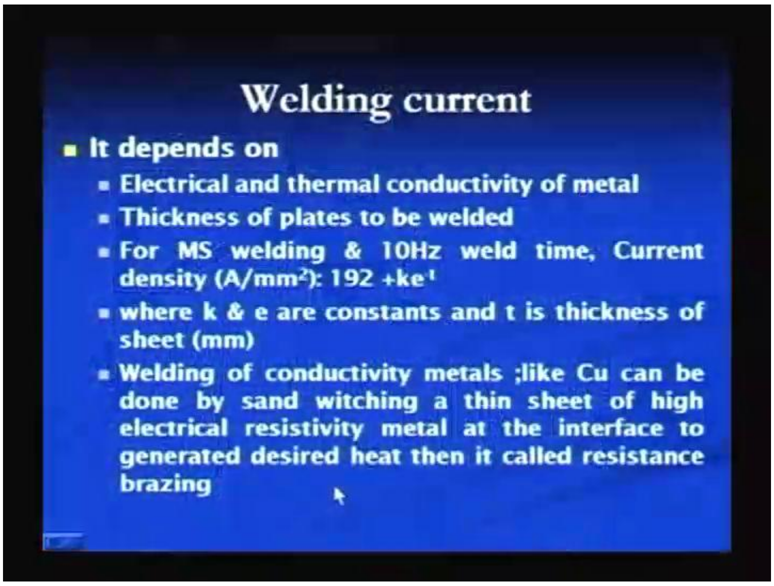

Out of the factors which significantly affect the selection of the welding current are electrical and thermal conductivity of the metal. If the electrical and thermal conductivity of a given metal is high, then we will require higher welding current because whatever heat is generated at the interface, that will be dissipated easily because of high thermal conductivity. And due to the high electrical conductivity, the heat generated at the interface will be less.

So, if the material is having high thermal and electrical conductivity, we will have to set the higher welding current and the same is applicable here also. Thicker the plates to be welded higher will be the welding current required for producing the sound nugget. And like that, for welding of the mild steel, the current can be selected in such a way that the current density that is Ampere per mm is square lies in range of 192 plus minus K into e raise to the power minus t, where K and e are constants and t is the thickness of the sheet in mm to be welded.

This helps to get some idea about the current density which should be there for welding of the mild steel sheets at 100 for 10 hertz weld time. And the weld, conductive welding of the high conductivity materials like Copper can be done by sand witching the thin sheet of high electrical resistivity at the interface to the generate the required heat.

Actually welding of the high electrical and thermal conducting materials like Copper becomes the difficult by using the conventional resistance welding process because the amount of heat generated becomes less and whatever heat is generated because of a high electrical conductivity that is dissipated rapidly from the interface to the base metal region rapidly, due to the high thermal conductivity. That's why it becomes difficult to get the molten metal in the interface region to produce the weld nugget. That is why the welding of the Copper and other high conducting electrical and thermal conducting materials becomes difficult. And to make the weld joint possible of these materials, normally a thin sheet of high electrical resistivity material is placed between the plates to be welded and then the flow of current generates high heat which is required for producing the joint. But in that case, such process is not termed as electrical resistance welding, but it is termed as resistance brazing.

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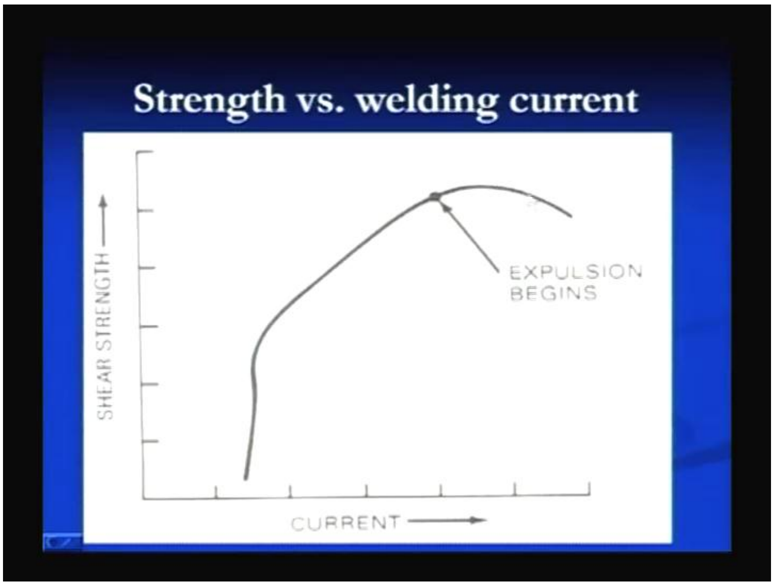

And if you see the relationship between the strength of the joint and the welding current, then we notice that increase in welding current increases the shear strength rapidly and it goes on increasing up to a certain critical level. There after reduction in strength takes place with the further increase in welding current, and this is direct attributed to the increase in weld nugget area.

If we increase the welding current, then it increases the heat generated and it also increases the amount of the molten metal which is formed at the interface, which in turn increase the size of the weld nugget, and increased size of weld nugget helps to increase the shear strength.

So, increase in shear strength is attributed to increase in diameter of the weld nugget. But after reaching to a critical value, due to the excessive heating, the expulsion of the metal from the interface region extorts and because of which reduction in shear strength of the metal takes place.

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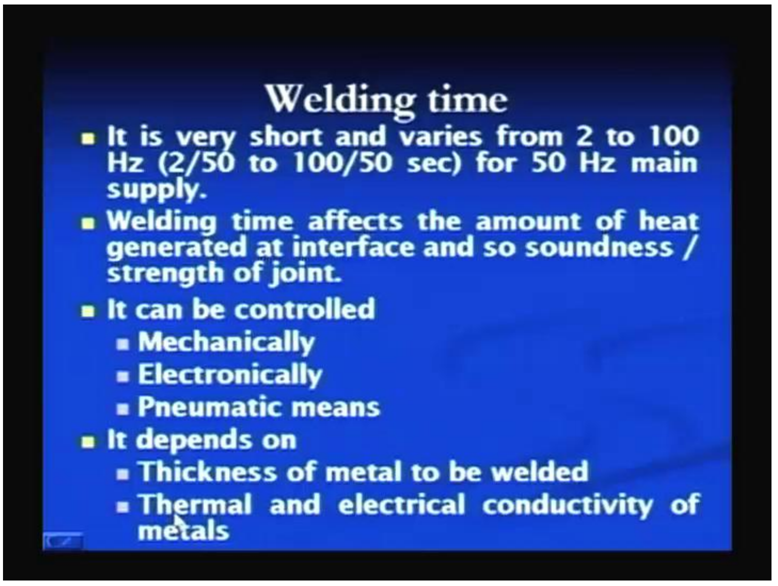

Another important variable of the resistance welding process is the welding time. Welding time normally is very short in resistance welding processes. It can range from 2 to 100 Hertz for 50 Hertz main supply and the welding time affects the amount of heat generated at the interface and so their strength and soundness of the weld joint. Because heat generated is found proportional to the time for which current flows through the interface; longer the time, greater than the heat generated. And accordingly, there will be increase in strength of the joint. And actually, this weld time is controlled through the various means like the mechanically, electronically and pneumatically.

And for how long time, flow of current should be there? It depends on thickness of the metal to be welded. Thicker the plates to be welded, greater will be the requirement of heat. And accordingly, longer should be the time for which current should flow through the interface for producing the desired heat. And the thermal conductivity and electrical the weld time are the time for which the current should flow. Increase in thermal electrical conductivity also needs the longer time for the flow of current.

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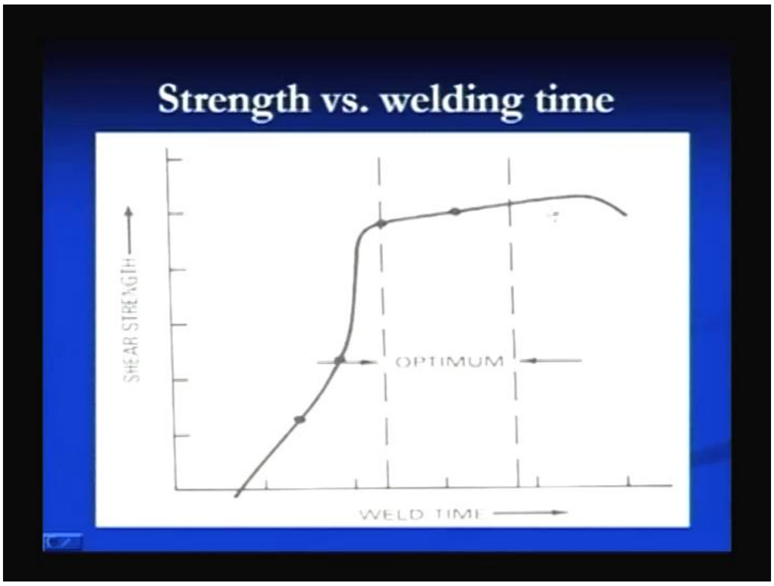

Here, if we see the relationship between the strength and the weld time, then here also we can notice that increase in weld time increases the shear strength of the metal, and this increase in shear strength of the metal up to a certain level, is attributed to the increase in weld nugget diameter due to the increased heat input. When heat input is increased, that increases the weld nugget diameter due to the increased melting of the metals at the interface, but beyond the limit, here also expulsion start and the reduction in shear strength of the weld joint takes place.

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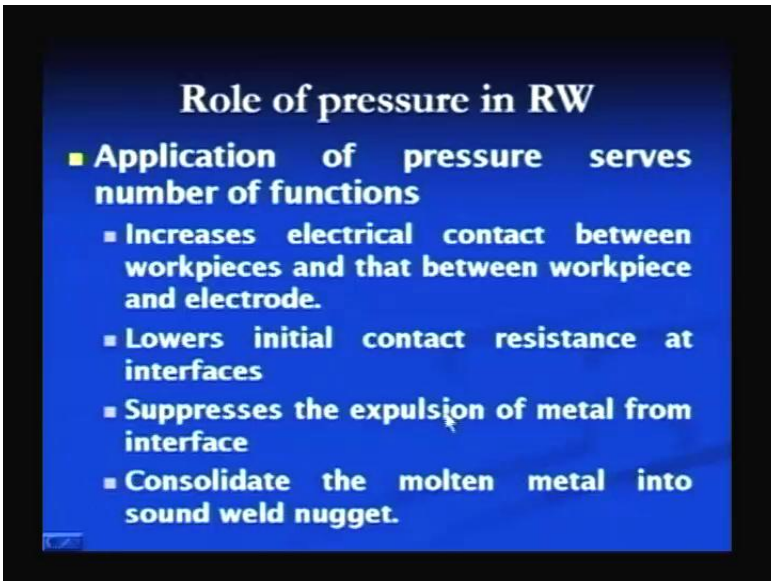

The pressure is the another variable which play significant role in producing the successful weld joint by resistance welding process and pressure is used to perform certain functions like the pressure increases the electrical contact between the work pieces, work piece and electrode, and between the work piece's surfaces which are to be joined, to avoid the arcing between these components and at the interfaces, the initial and it also lowers the initial contact resistance at the interface. Otherwise, there would not be any flow of current due to the very high, due to the large gaps between the plates or the electrode to be joined. The pressure also suppresses the expulsion of the molten metal which has formed due to the heat generated during the welding. And when molten metal is formed, it is consolidated under the pressure to form sound nuggets which is free from the defects.

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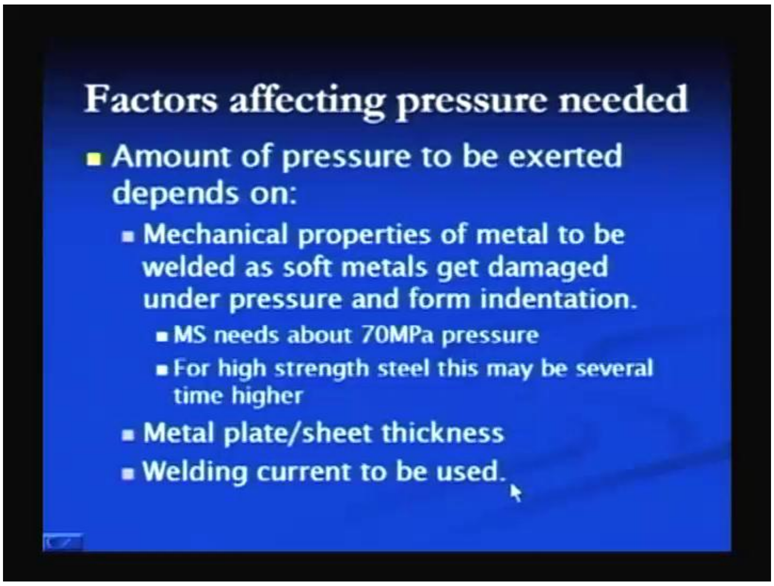

The amount of pressure which is to be exerted depends upon the mechanical properties of the material to be welded; stronger the material greater will the pressure required for producing this sound joint. Mechanical properties of the metal to be welded affect the pressure which is to be used for producing the sound joint. Soft materials may get damaged under pressure and form the indentation.

For example, mild steel needs about 70 MPa pressure for producing the joint. And for high strength steel, this magnitude of pressure can be the number of times higher than that of required for mild steel and the metal plate thickness or those thickness of the sheets to be welded also affects the pressure to be used. Thicker the sheets, greater will be the pressure required and the same is for the current; if the higher is the current is to be used, then the pressure requirement decreases. But there is a limit up to which increase in pressure can be used to reduce the pressure requirements. Excessive pressure with the soft materials particularly can lead to form indentation at the surface of the work piece which can damage at the interface.

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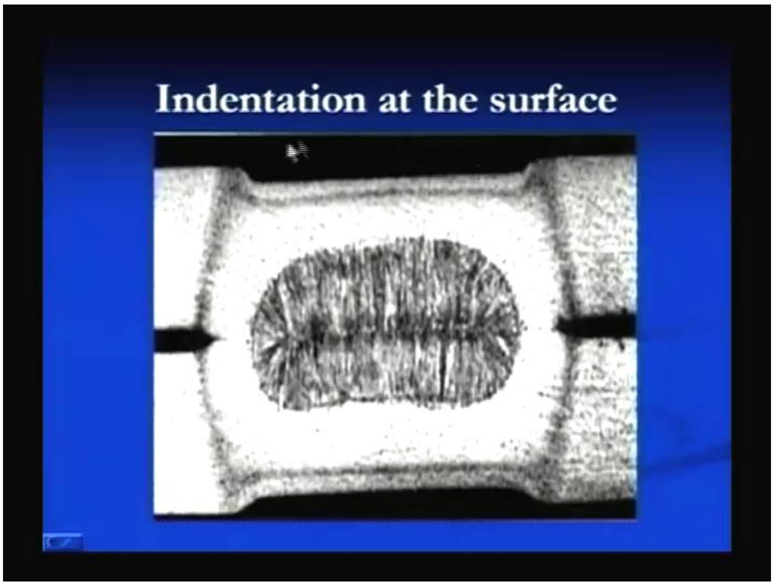

We can see here, the depression formed or the indentation formed at the surface of the work piece due to the heavy pressure transferred from the electrode to the work piece surface. This indentation can reduce the steam value of the product or can damage to the surface of the work piece.

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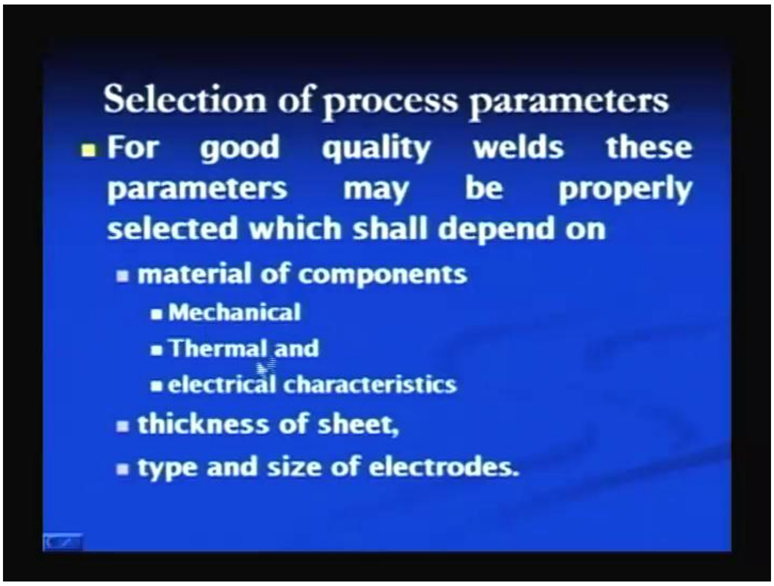

So, the process, parameters selection like welding current, welding time and the pressure are important for the selection of the weld metal for the successful joint, for producing the successful joint. The selection of these parameters to a great extent depends upon the material of the component to be welded, in terms of the mechanical thermal and electrical characteristics of the plates to be joined, thickness of the sheet to be welded, and the type and size of the electrodes which are being used for producing the joint.

The steps which are used in spot welding for producing the joints starts with the firm contact between the electrode and the work piece, and the firm contact between the work piece interface. So, under the pressure, the electrode surface is a the pressure is applied through the electrode on the surface of the work piece to have the firm contact between the electrode and work piece, and the firm contact between the work piece surfaces

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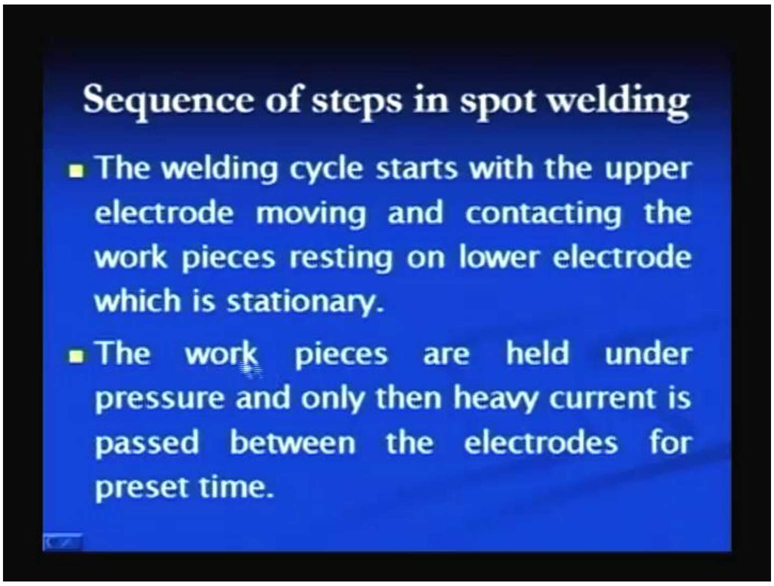

So, weld cycle starts with the upper electrode moving and contacting the work piece, resting on the lower electrode which is stationary and work pieces are held under pressure and then flow of current is started for preset time.

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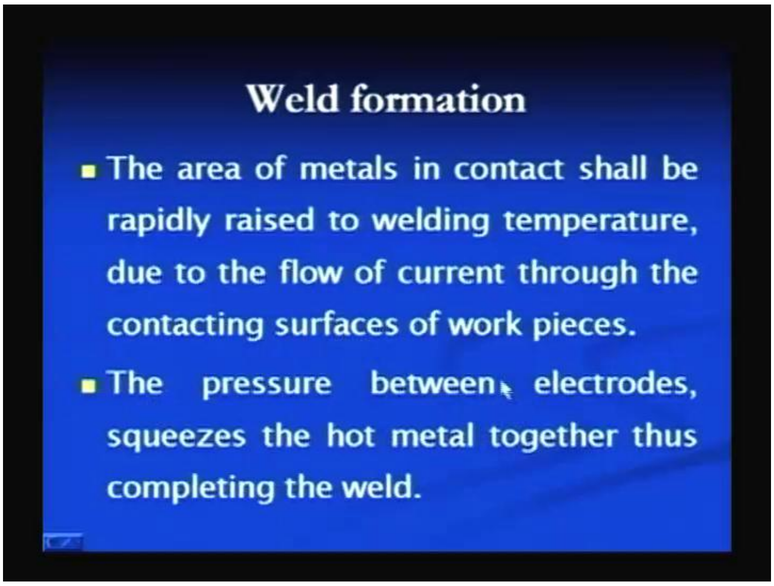

And when flow of current starts, it generates heat at the interface and the maximum heat is generated at the interface and which leads to the partial melting of the work pieces of surfaces at the interface. And under pressure, the molten metal is squeezed and consolidated to form nugget.

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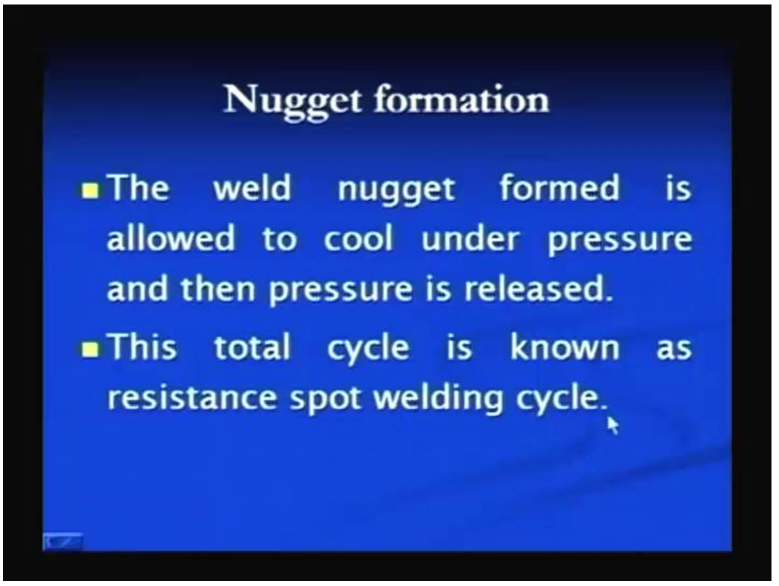

And when the nugget is formed, weld nugget is formed, it is allowed to cool under pressure and then pressure is released gracefully. These are the four steps in producing the joint by spot welding, and the entire, all these four steps are termed as resistance spot welding cycle.

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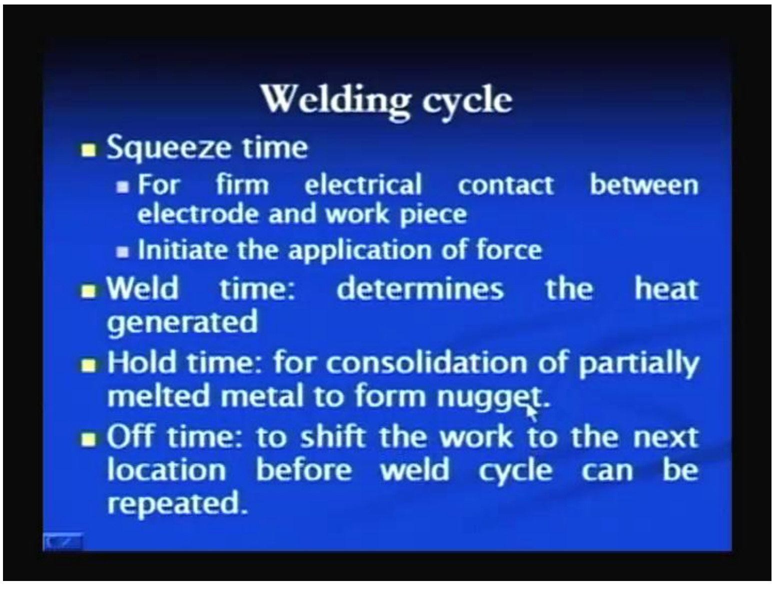

If we have to see, then it includes the squeezing times; the time for which the initial pressure is applied and during which pressure increases from zero value to the maximum squeezing pressure. This is applied for firm electrical contact between the electrode and work piece and initiate the application of the pressure. So, means, when there is no pressure. Pressure application is started in squeezing time and until it reaches to the maximum level. Welding time is the time during which flow of the current take place and it determines the amount of heat which will be generated at the interface.

Hold time is the time during which pressure is maintained, but current is switched off. And during this period, the consolidation of the partially melted metal takes place to form weld nugget. Off time is the period during which the shifting of the work piece from one station to another station takes place before the weld cycle can be repeated.

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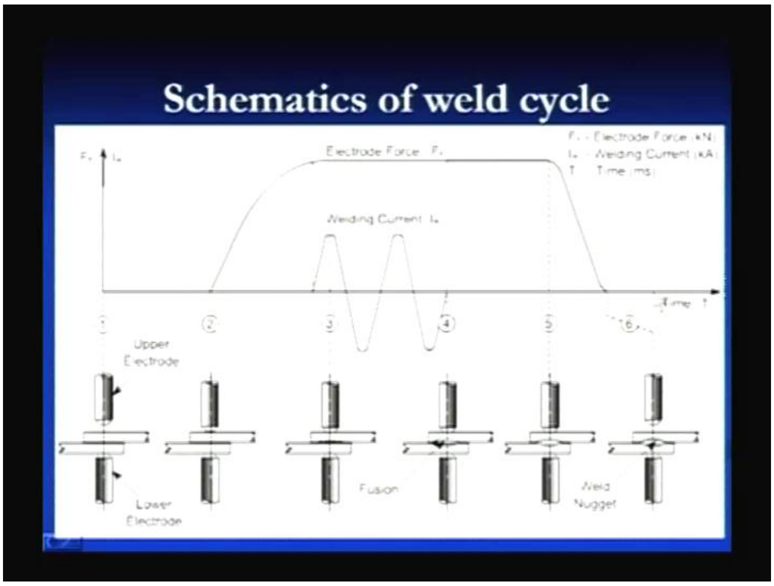

Schematically, we can see these four steps like this, represents to the off cycle period, where shifting of the work piece form one station to another station takes place. And in this case, there is no firm contact between the electrode and the work piece. At the location 2 here, here squeezing starts and the electrode comes in contact with the work piece and pressure is increased gracefully. Here, in this period, in this squeezing period or squeezing time, the electrical pressure is increased gracefully so that the electrode and the plates come in firm electrical contact with each other and then this maximum pressure is maintained.

Here maximum pressure is maintained and the flow of current is started so that the time, this period during which flow of current takes places is termed as weld time and after that current is switched off, this pressure is maintained for some more time and this pressure as known as force time. During this period only consolidation of the molten metal takes place and then pressure is released is gracefully. So, here, this way we can see again we reached to the same stage when there is no contact between the electrode and work piece. So, this way, four steps are repeated for producing the joints continuously. First squeezing, then welding, then holding and then off period, during which the electrodes are not in contact with the work piece.

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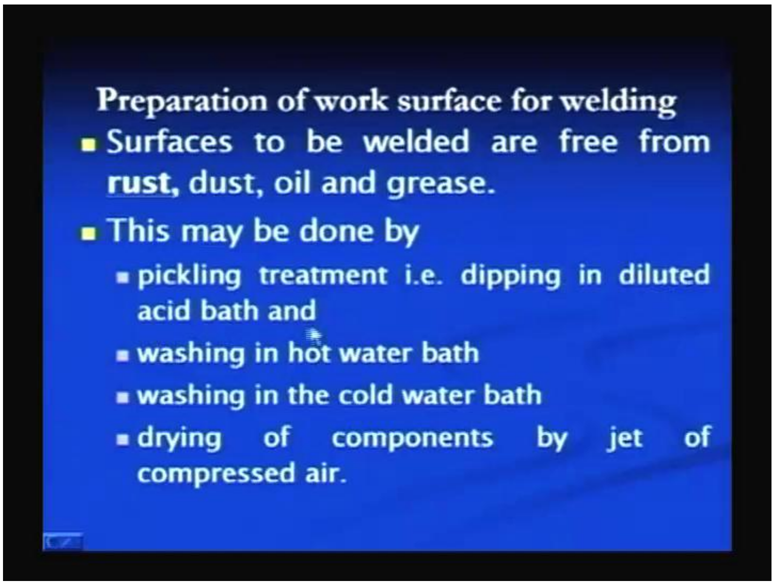

For producing a successful joint, sound joint, the surface must be free from the impurities and the dust and dirt. If the rust is present, or dust and oil and grease is present, these must be removed by using the suitable techniques. If the rust is present at the surface, we should follow this procedure like, pickling treatment is done first by dipping in dilute acid bath and then washing in hot water bath, washing in cold water bath and followed by drying using the compressed air jet.

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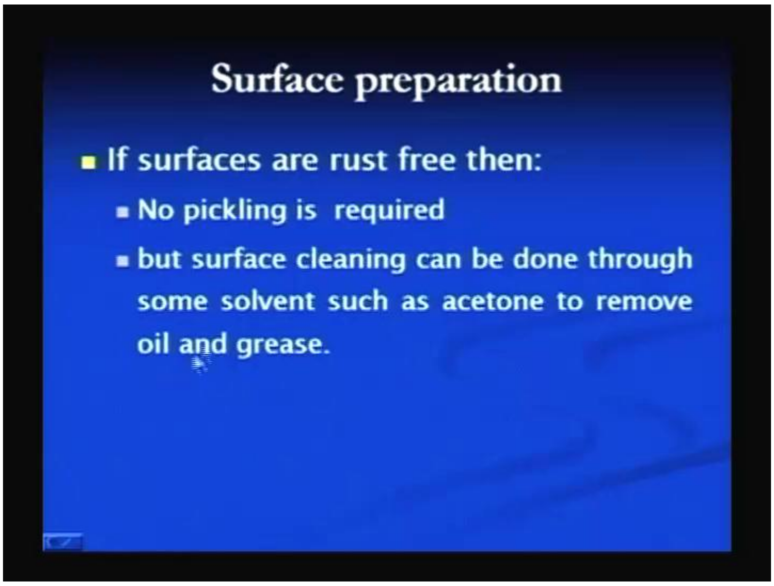

And if the surface is free from the rust, then pickling is not required. But only surface cleaning is done using the acetone to remove the oil and grease from the surface.

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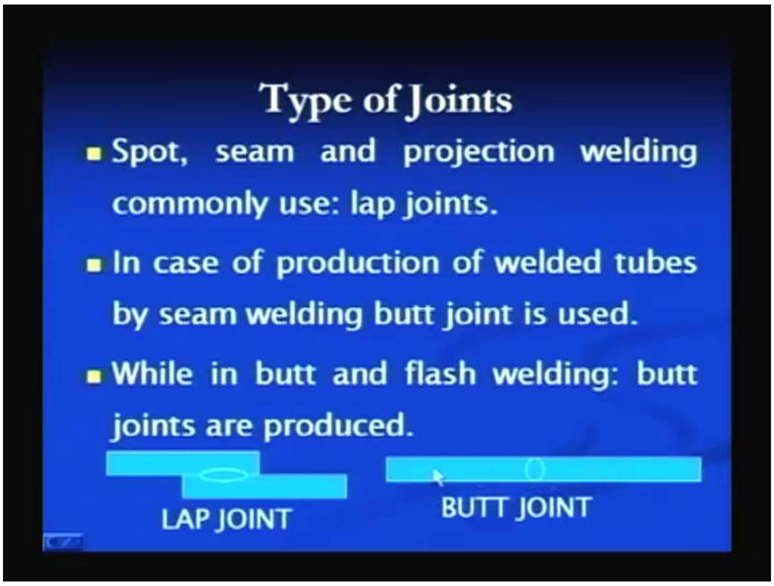

The different types of the joints which are produced by the resistance welding processes like a spot, seam and projection welding, the most common one is the lap joint; however, butt joint can also be produced. In some cases, in resistance welding process, like in case of production of the welded tubes by seam welding, butt joint is used, while in butt and flash welding process, butt joints is produced for joining the rods where ends are butting together. Here, the lap joint is formed in this manner when one plate overlaps another and at the interface joint is formed. In case of the butt joint, ends are touching each other and they are aligned, and then joint is formed between them.

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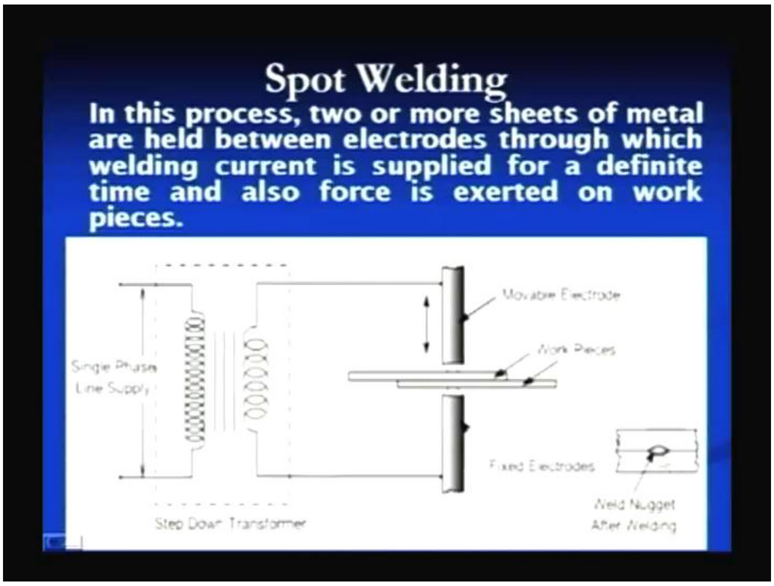

The spot welding process is the first and most important resistance welding process which is most extensively used. In this process, 2 or more sheets of the metal are held between the electrodes through which welding current is supplied for a definite period and then force is exerted on the work pieces to produce the joint. This is how power is supplied and the work pieces to be welded are kept in between the two electrodes and by the flow of the current heat it generated for a limited period, and then weld nugget is formed like this at the interface.

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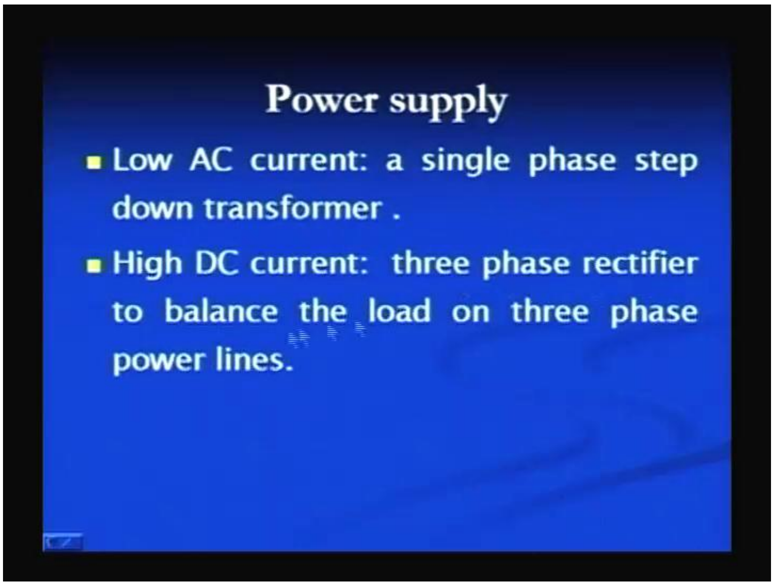

And power supply for the resistance spot welding process can be of low AC value or the high DC value. Low AC current is supplied using a single phase step down transformer and the high DC current supplied using 3 phase rectifier to balance the load of 3 phase supply.

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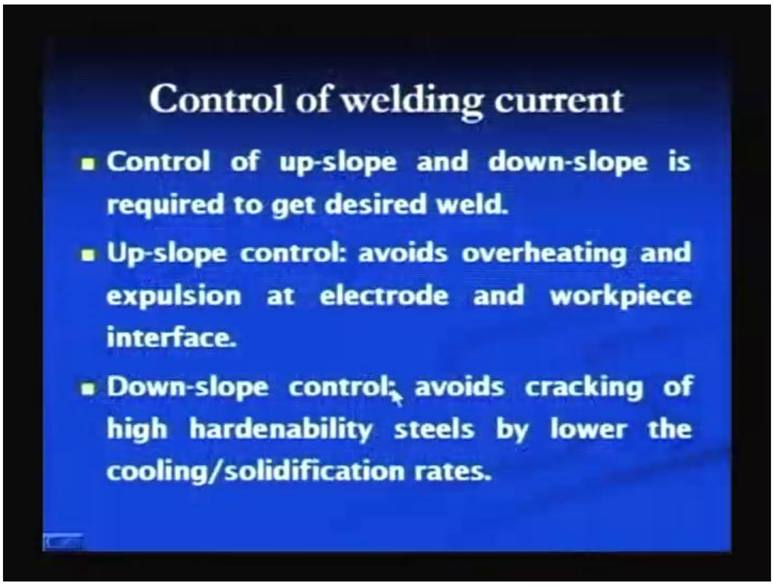

Welding current is to be controlled properly to avoid the defects and to form the sound weld joint like the rate of increase in current and the rate of decrease in current, that is termed as up slope and down slope should be controlled to get the desired weld. Up slope should be controlled to avoid the overheating between the electrode and the work piece surface, and also to avoid the expulsion between the interface of the work piece and interface between the electrode and the work piece.

If the rate of current rise is very high, then it can lead to the excessive heating between the electrode and work piece surface and which can ultimately lead to the expulsion between the electrode and work piece interface. The down slope is controlled to have the slow cooling rates. If the current is switched off rapidly, then the high cooling rate can lead to the cracking in the materials, particularly which are having high hardenability like high hardenability steels can show tendency to get cracks if the current is switched off rapidly. So, that can be controlled, means this cracking can be avoided by controlling the down slope by low and which in turn lowers the cooling rate and also lowers the solidification rate.

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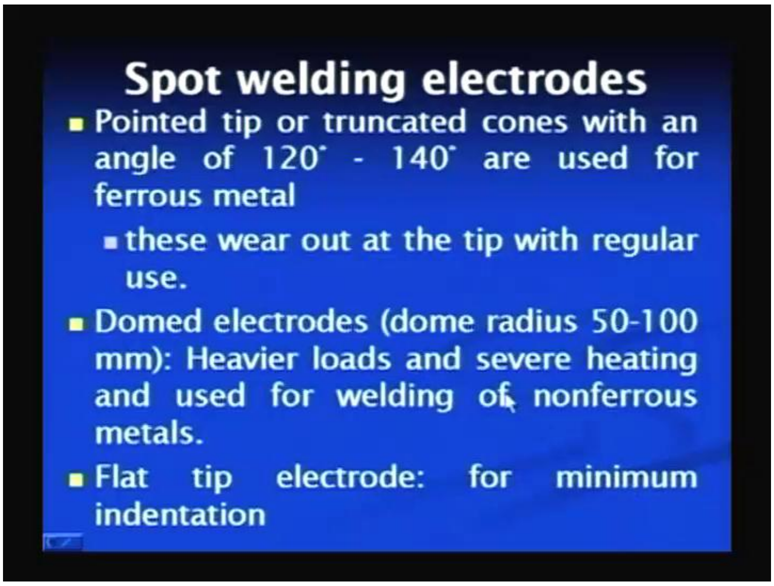

Electrodes which are used in a spot welding can be of different shapes. The pointed type or truncated pointed type or which are also truncated cones in shapes having the angle from 120 to 140 degree are used for the welding of the ferrous metals. But these show tendency to wear out rapidly and that is why are to be reshaped regularly. Dome shaped electrodes having the dome radius from 50 to 100 mm used for the heavier loads and where severe heating is to be used for producing the weld joint of the nonferrous metals and the flat tipped electrode are used where minimum distortion is required in the plates to be welded.

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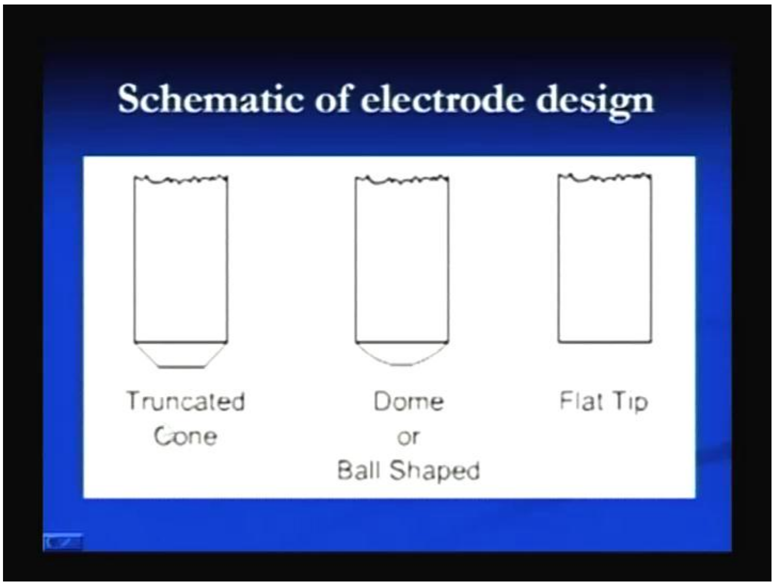

We can see 3 different shapes of the electrodes which are used in spot welding truncated cone, dome shaped or flat tipped electrodes.

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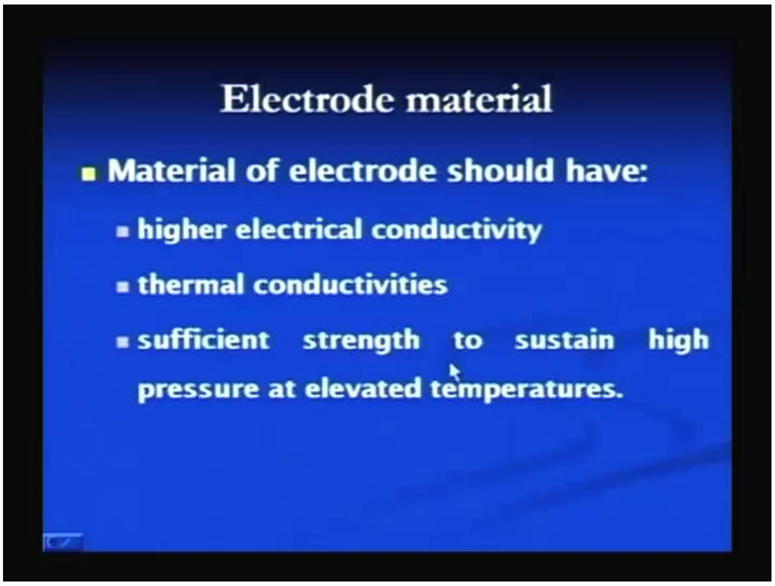

Materials of the electrode should have certain characteristics; means these electrodes are made of certain materials which can offer very good thermal and electrical conductivity, and having ability to withstand under the pressure because pressure is to be transferred through the electrode onto the work piece. So, these electrode materials must be strong enough to sustain high pressure at elevated temperature.

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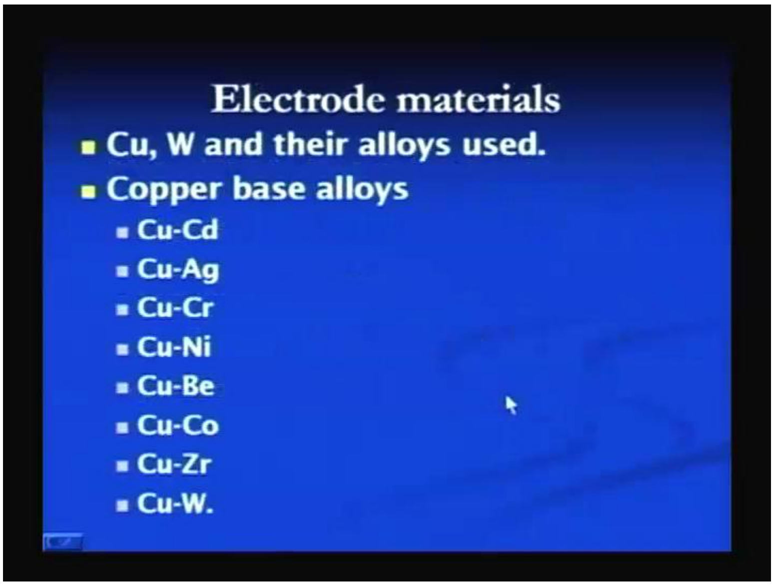

These are the common materials which are used for making the spot welding electrodes. These are basically Copper or Tungsten base alloys because both these materials show good thermal conductivity and electrical conductivity, but addition of the alloying elements in turn reduces the electrical conductivity, but these additions are frequently used to increase the strength of the Copper base alloys particularly.

The Copper base alloys which are used for making the electrode for their spot welding system can be of the Copper, Cadmium based Copper Silver, Copper Chromium, Copper Nickel, Copper Beryllium, Copper Cobalt, Copper Zirconium and Copper Tungsten. The Tungsten base alloys are also used for making the electrodes.

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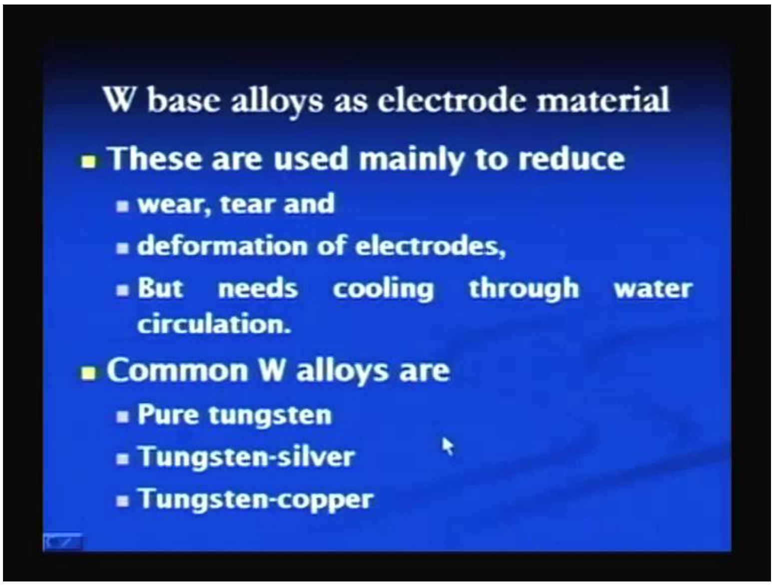

These are mainly used where it is required to have a very low wear rate and the deformation tendency to the electrode is more. So, here, if the deformation is to be controlled and wear is to be controlled, then these tungsten based electrode are used, but the cooling is the problem with these electrodes. These needs cooling through using water circulation to maintain the temperature within the limits. The common Tungsten alloys which are used for making the spot welding electrodes are pure are made of pure Tungsten or Tungsten Silver, and Tungsten Copper alloys. This is how cooling is done in Tungsten in the spot welding electrodes to maintain their temperature within the limits.

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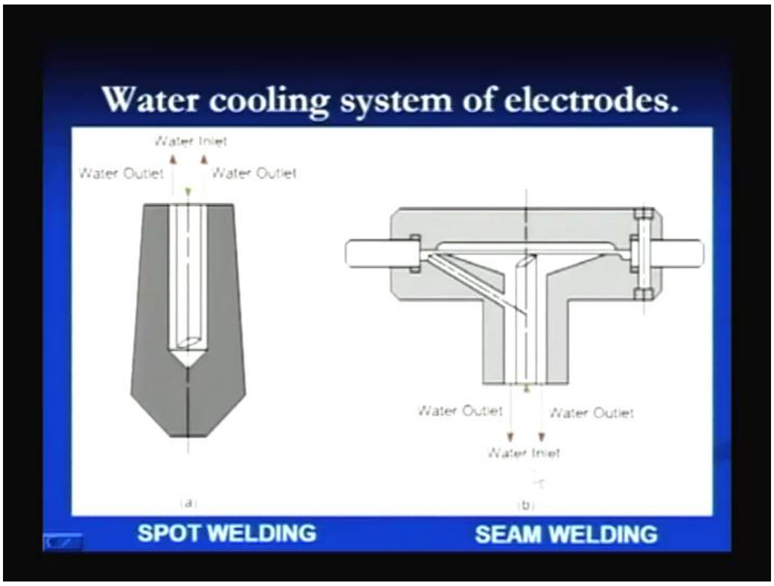

Here, water is supplied from one side and it is taken out from another side. This is the case of cooling for a spot welding purpose. If the electrodes for seam welding has to be cooled and these are used in form of rollers, and the water is supplied from one side and it is taken out from the other side to maintain the temperature of the electrodes within the same limit.

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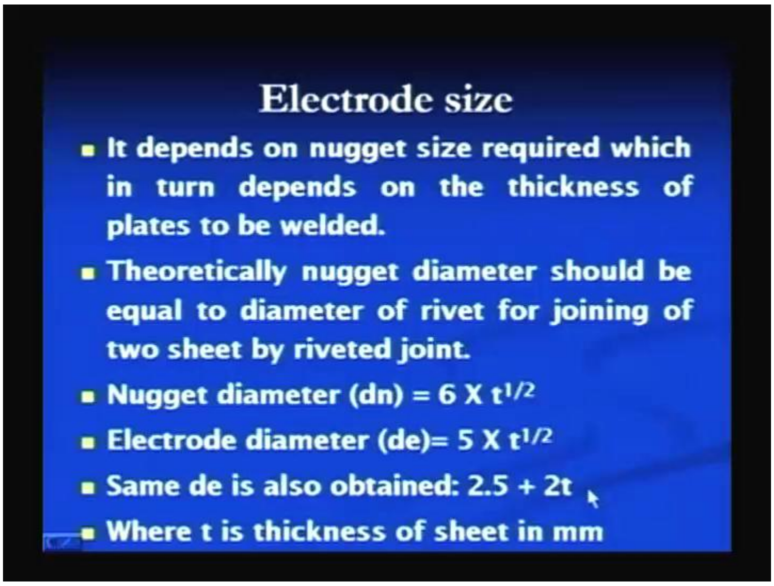

Electrode diameter affects the size of nugget which is produced and the nugget size is determined by the thickness of the plates which are to be welded. If thicker plates are to be welded, we will be going for the larger nuggets size, and to produce lager nugget size we have to supply large amount of heat and for that we need large electrode size. So, the selection of the electrode size to great extent depends upon the nugget size which is to be the produced, which in turn depends of on the material’s thickness which is to be welded.

Theoretically, nugget diameter should be equal to the diameter of rivet which is to be used for joining of the two sheets by riveted joint to get the equivalent strength. So, the diameter of the nugget and diameter of the rivet which is to be used for producing the joint by the riveted joint, these two should be equal. And here, you see the nugget diameter which is normally used or which is normally produced for welding of a particular thickness of the plate. It is 6 times t raised to the power 1 by 2 or square root of t. Here, where t is the thickness of the plate and the electrode diameter can be the 5 into the t raised to the power 1 by 2.

Same, for same, the de also; means, that is the electrode diameter can also be obtained by using equation 2.5 plus twice of the t, where t is the thickness of the sheet which is to be welded in mm.

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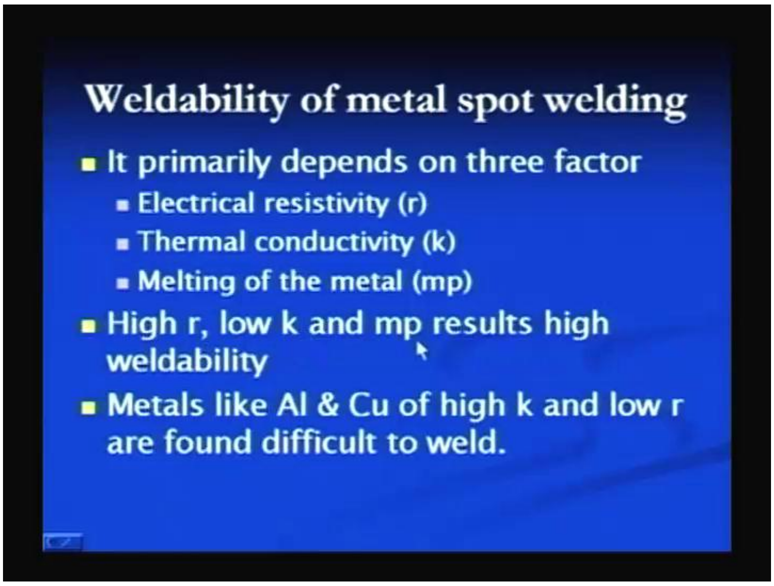

The weldability of a given material by the spot welding to a great extent is determined by the electrical resistivity, thermal conductivity, and the melting point. These are the 3 main parameters that affect the weldability of the metal by spot welding and that is why weldability of the metal by spot welding is calculated using equation which is based on the electrical resistivity r, the thermal conductivity k and melting point p.

For a given material, if the electrical resistivity is high, thermal conductivity and melting point low, and then we will get the good thermal, good weldability of the metal by the spot welding. Say here, high electrical resistivity, low k and low melting point results in high weldability. For metals like Aluminum and Copper, which show high thermal conductivity and low electrical resistivity, are found difficult to weld. That is why if the weldability is calculated, then these materials show very low weldability.

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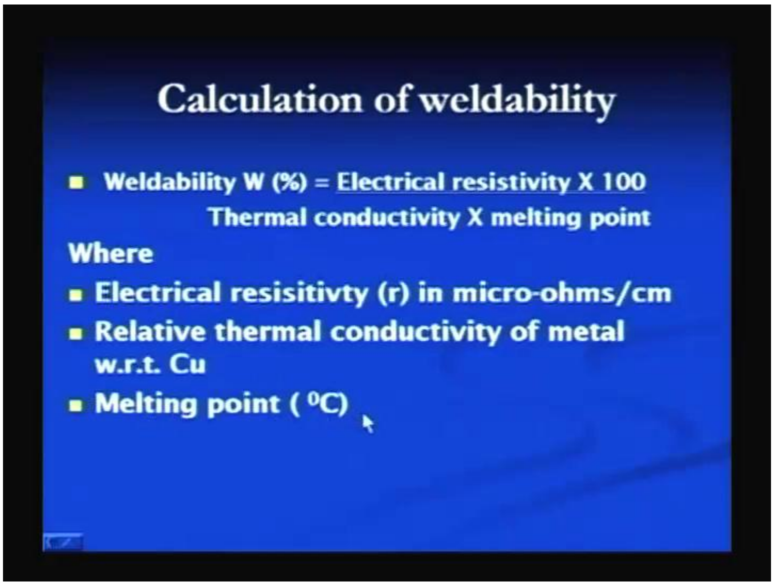

The weldability can be calculated using equation like this weldability expressed in terms of percentage like is equal to the electrical resistivity into 100 divided by thermal conductivity of the material multiplied by the melting point where electrical resistivity r in micro Ohms per Centimeter, relative thermal conductivity of the metal with respect to Copper has been quantified and it has been tabulated in handbooks can be obtained and the melting point in degree Centigrade.

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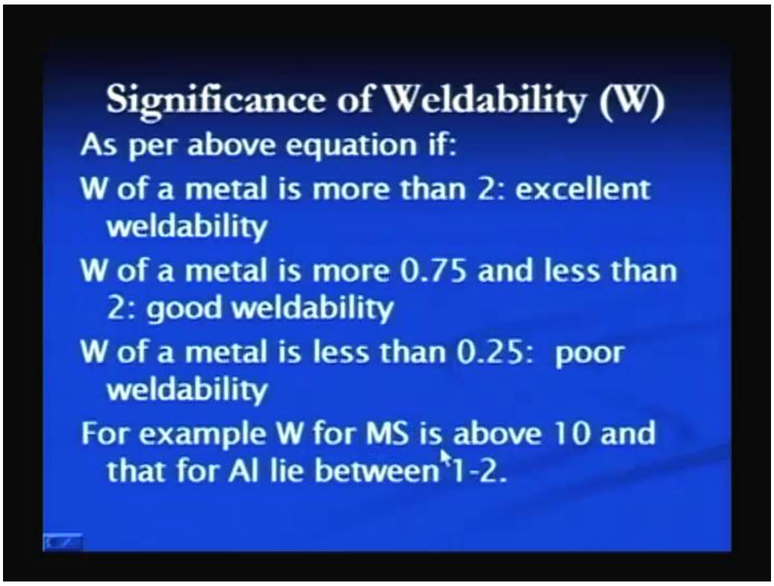

The weldability W can be calculated using above equation, can be interpreted in terms of the how easily we can weld a given material by this spot welding process. If the W of material comes more than 2, it shows the excellent weldability and if the W of material is in between 0.75 and 2, then it is considered a good weldability. If the W value becomes less than 0.25, then it is considered of poor weldability.

For example, the weldability in terms of percentage for mild steel is found in range of or above the 10 which indicates very good weldability of the mild steel by the spot welding, while that for Aluminum lies in between 1 and 2. For the different alloys, this W will be different. For Aluminium alloys, this will be in range of 1 to 2; means, it is fairly good. For Copper alloys, further it is found less.

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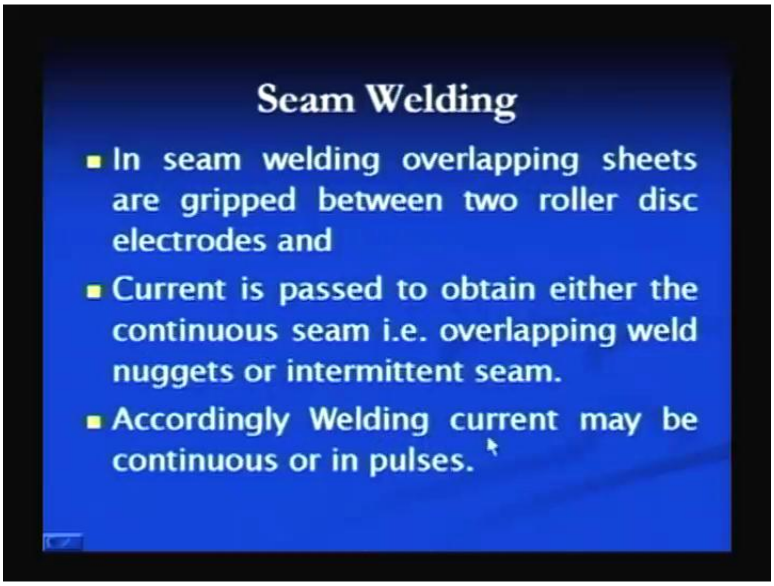

And if you see the applications of the spot welding, it is widely being used in electronic, electrical, aircraft, automobile, and home appliances. In electric and automobile industries, particularly it is used for joining the body parts of the automobiles; car body parts or the trucks and buses body parts are joined, and the tanks, petrol tanks which are to be made are normally produced by this spot welding process.

The seam welding is another important resistance welding process which is normally used to produce the leak proof joint. And in this process, overlapping sheets are gripped between the two roller disk which acts as a electrodes and the current is passed through these rollers, and this current can be supplied continuously or in intermittent manner to form nugget. Means, the sheets to be welded are passed through the rollers and the rollers will be rotated continuously, through which sheet will be passed and these sheets are to be joined. When current passes through the work pieces to be joined, heat is generated and the nugget is formed at the interface of the work plates or the sheets to be joined, and the supply of the current can be continuous or intermittent.

When continuous current is supplied, we get the overlapping welds or nuggets; otherwise, we get the intermittent nugget. So, accordingly, as for the needs, the intermittent nuggets are to be formed or the overlapping nuggets are to be formed; according to that the current is supplied in pluses or in continuous manner.

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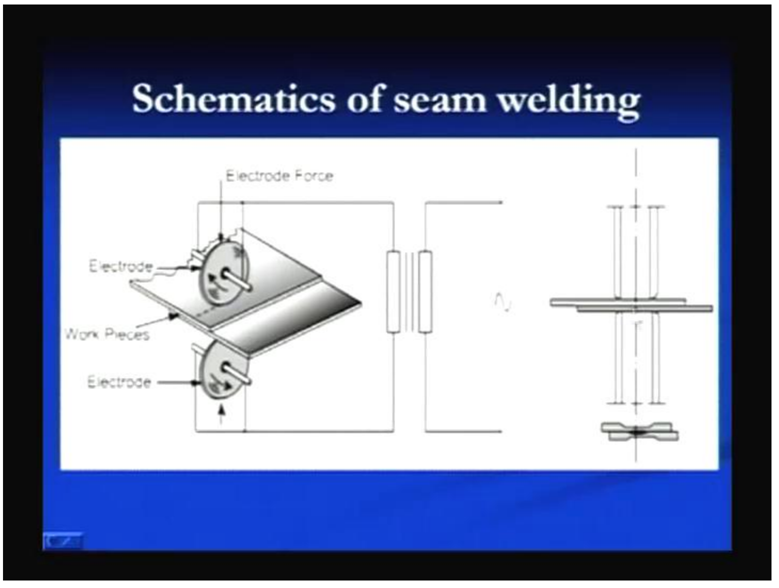

Schematics of the seam welding can be seen here. These are the two rollers which acts as a electrode and one electrode is fixed and another is kept movable. Fixed means both rotate during the operation, but one can be adjusted vertically to accommodate the plates to be welded. During the rotation, the plates will, rotation of these rollers, the plates will be passed through these rollers and these rotating rollers will also be acting as a electrode to supply the current to these plates which are to be welded.

Schematically here we can see. From the side view if you see the section of this arrangement, these are the, this is upper roller and these are the lower roller and these are the two plates to be welded. Flow of current through these plates form the nuggets between them like this.

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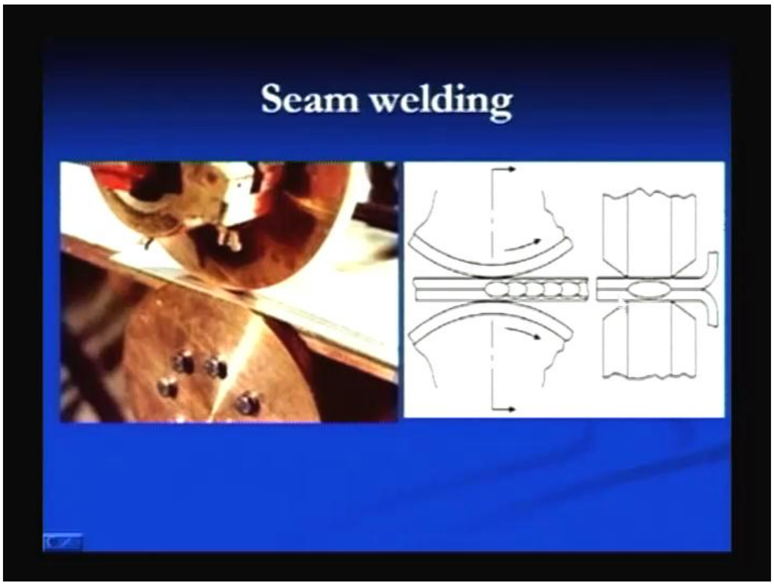

Here, we can see more clearly. This is a upper roller, lower roller, and these are the two plates which are to be welded, and this seam is formed along this line here. And if you see this diagram, the rollers are rotated and the nuggets are formed in series in overlapping manner. This is the side view of the same diagram which shows that the interface weld nugget is formed.

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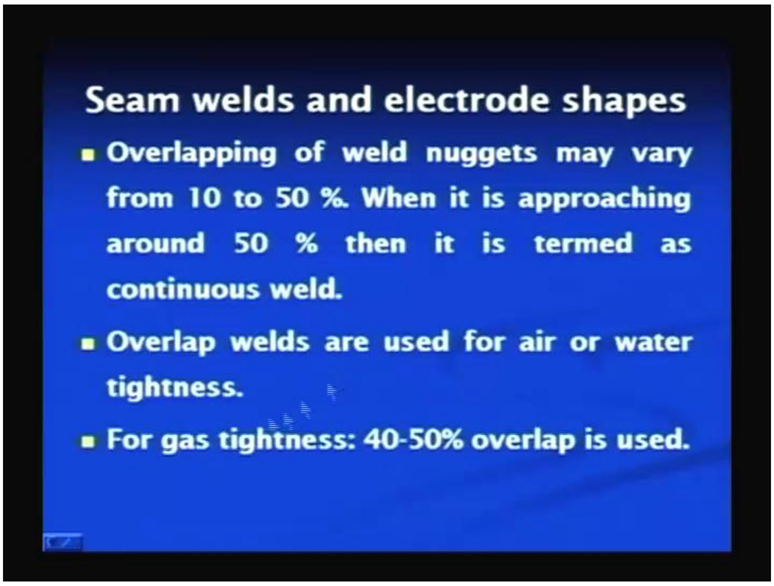

This overlapping of the nuggets may vary from the 10 to 50 percent. Depending upon the purpose of the joint, the nuggets can overlap from 10 to 50 percent, like a for gas tight joint, the overlapping can be 40 to 50 percent over for water and other flit tight liquid tight joints, it may vary from 10 to 40 percent. So, when it is approaches around 50 percent means when overlapping approaches about 50 percent, it is termed as continuous weld and overlapping welds are used for air and water tightness. For gas tightness, it can range from 40 to 50 percent.

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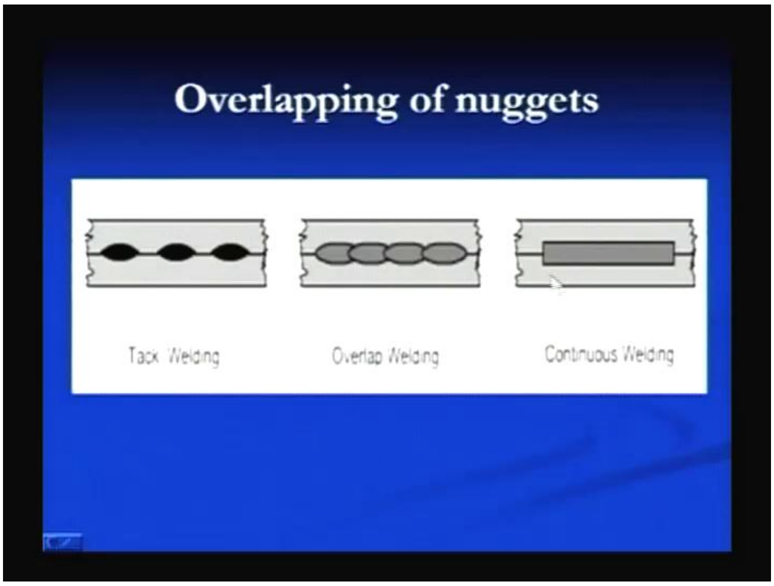

Here, we can see that the nuggets are intermittent and here the nuggets are overlapping. Here the overlapping is more than 50 percent. You can say there is so that the nuggets is formed continuously.

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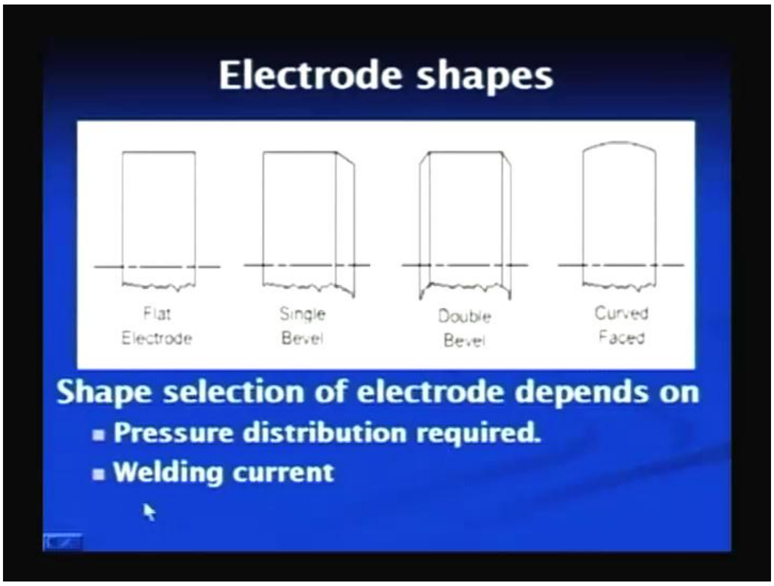

These are the different shapes of the rollers which are used in seam welding and these are the points which are to be considered, the kind of pressure distribution required, and the welding current which is to be used based on that we select a particular geometry of the roller to be used for.

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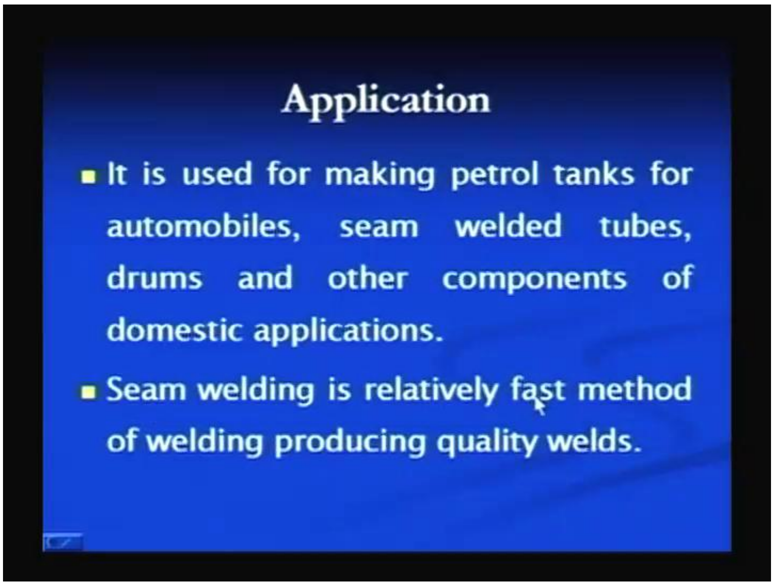

The application of the seam welding includes like a making the petrol tanks for automobiles, seam welded tubes, drums and other components for domestic applications and seam welding is relatively fast method for producing the high quality welds.

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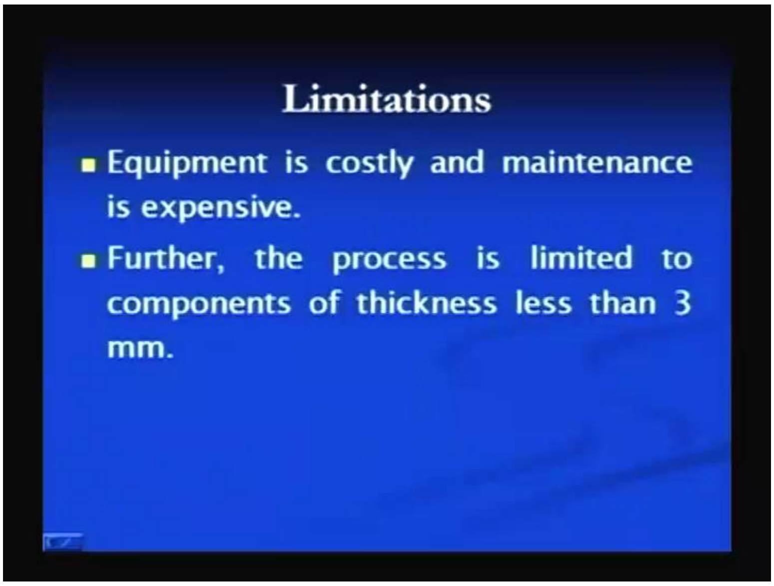

So, here, now we can see that some of the limitations also there with these equipments. Like equipments are costly and maintenance is also expensive. For these processes are limited to the thin sheets, very thick sheets cannot be processed by the resistance welding processes, particularly seam welding and a spot welding.

So, now, here I can summarize this lecture here. In this lecture, we have seen the basic principle of the resistance welding processes and some of the technical aspects related to the spot welding and seam welding. We have seen that these processes can be successfully used and are being successfully used in production of the components which are to be made by using thin sheets; however, these processes cannot to be used for producing the joints of very thick sheets.

Thank you for your attention.