Joining Technologies of Commercial Importance
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Lecture - 18
Fundamentals of Resistance Welding

Hello I welcome you all in this presentation related to the subject joining technologies for the metals. In this presentation, I will be talking about the resistance welding processes.

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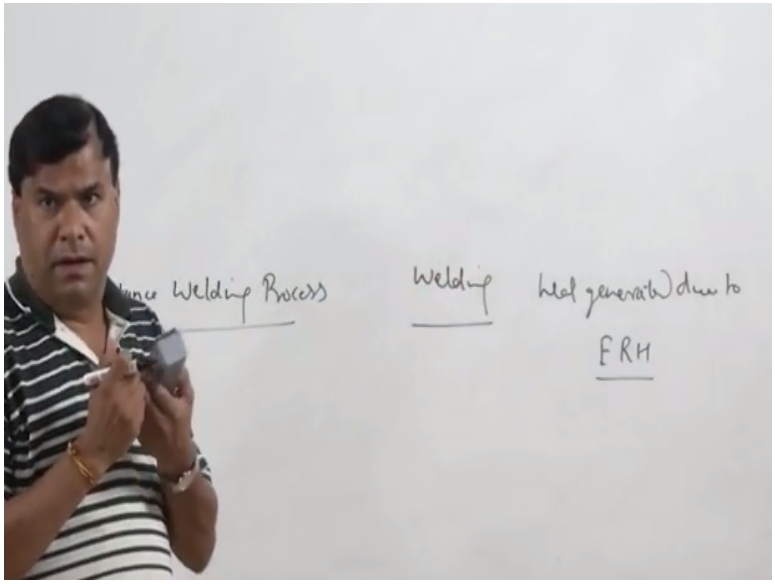

So as the name suggest that the electrical resistance plays a big role in these processes why because the weld joint in these processes is mainly produced by the heat generated due to electrical resistance heating. So the contact resistance between the faying surfaces plays a big role in these resistance welding processes. Resistance welding processes are basically group of the processes.

In all those processes the electrical resistance heating is involved for developing the weld joint.

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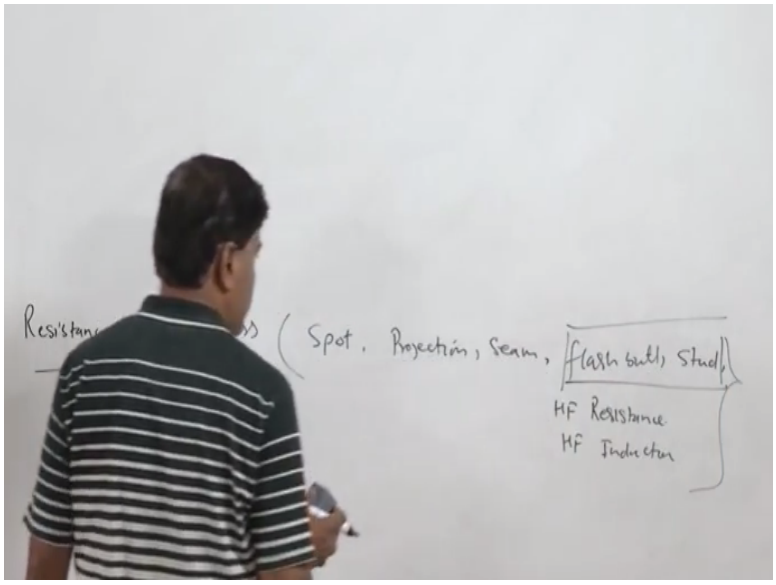

And these are commonly known as spot welding, projection welding, seam welding, flash butt welding, stud welding and then there is high frequency resistance welding and high frequency induction welding. In all these processes, the electrical resistance heating is used in one or other. We will see that some of the processes even arc also comes into the picture, but they have been placed under the category of the resistance welding processes.

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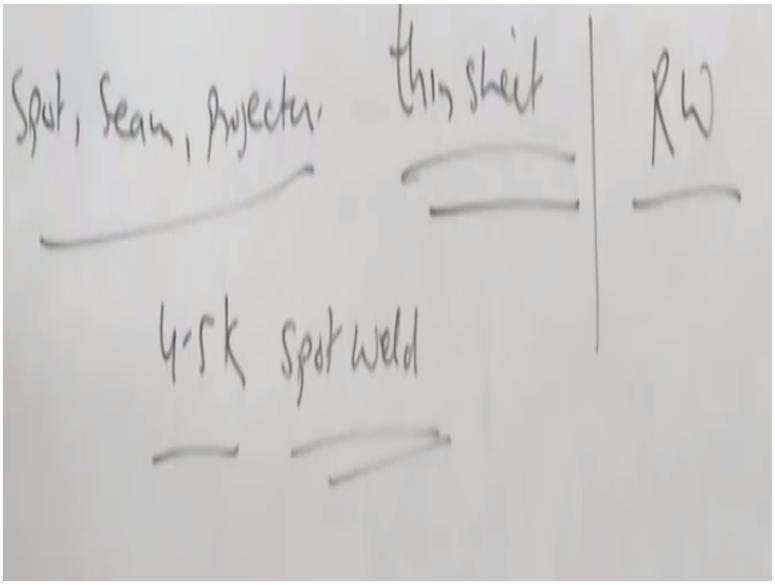

Most of these processes are like say spot welding, seam welding and the projection welding. These processes are commonly used for joining the thin sheets. So like in automotive applications or electronic components wherever very small, small components or thin sheets are to be welded. Will see that the resistance welding plays a big role, for example, in one typical car about 4000 to 5000 spot welds are made.

So it is such a large volume of the spots, which are needed to join the different members in typical automotive car and mostly these are used for joining the thin sheets. So in which way the joint is developed? What is the underlying principle in development of the joint using the resistance welding processes?

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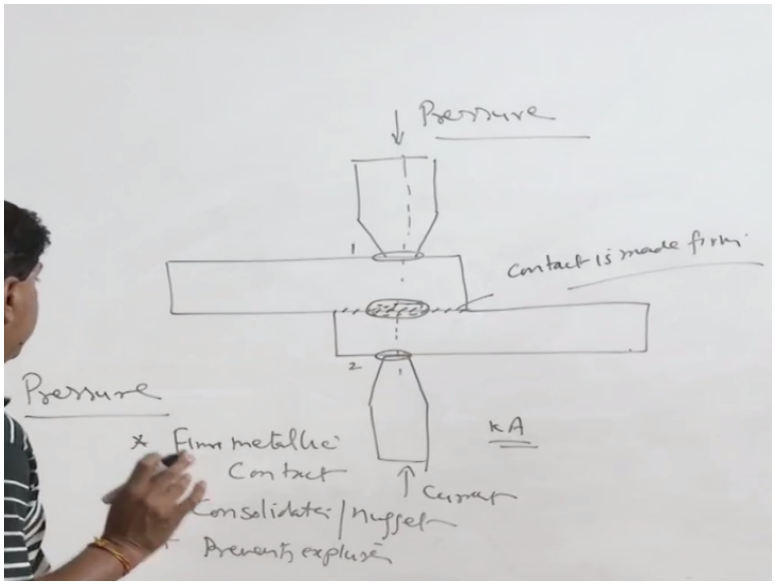

Same this case we take two sheets to be joined, mostly they are kept in lap joint configuration like this and so they will be contacting, there will be one contact interface like this. So if we see the magnified view of the contact interface, the contact is to the peaks and valleys present on both the sides and then during the welding the electrodes are brought in contact with the surfaces like this.

Of course, this needs to be aligned and these electrodes will be delivering the required current and pressure. These are the two purposes of applying using the electrode. So the very heavy current is allowed to flow through this electrode into the workpiece, so it maybe in thousands of ampere like 30,000 or 40,000 amperes. So heavy flow of current takes place through these electrodes and then pressure is applied.

So pressure helps in bringing the faying surfaces together. So contact is made formal with both contact of the electrode with the workpiece surface at location 1 and location 2 which says the heavy current is flowing so the loose contact may result in sparking or arcing between the surface of the workpiece and the electrode, which will damage to both surface of the workpiece as well as to the electrode.

So the firm contact is required first between the electrode and the workpiece and then of course the firm contact s also required with the faying surfaces between the work pieces. And that is why sufficient pressure must be applied so the pressure is one of the important variable related with the process because it ensures the firm metallic contact between the electrode and workpiece and between the faying surfaces of the work piece.

And the second is it helps in consolidation in case of the heating whatever nugget is formed at the interface it will solidify under the pressure. So consolidation and nugget formation after the cooling, at the same time, it also prevents any expulsion of the metal being produced due to the electrical resistance heating.

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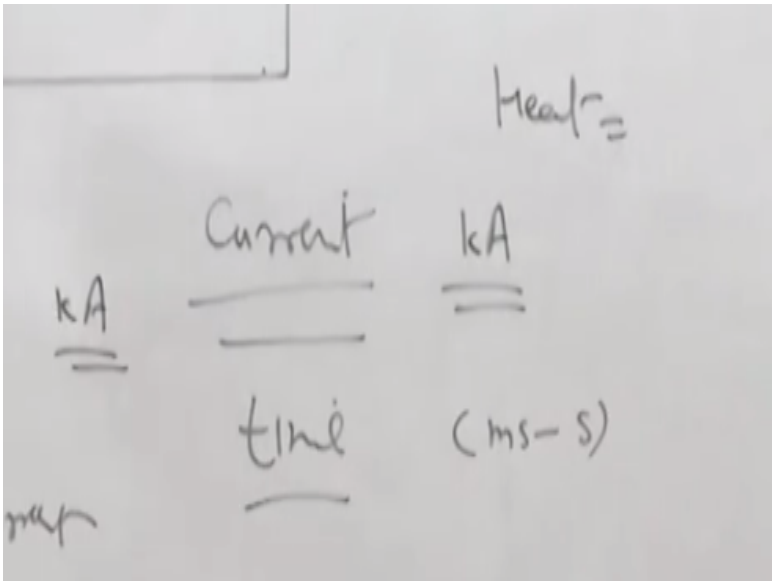

Current I have said definitely very high level of the current is supplied, so that the required heat is generated. Current is in 1000s of the ampere and then time how long that current will be flowing maybe from the milliseconds to few seconds. So the heat generated in this case will be the function of heat at the interface is most important heat will be generated at the contact between the electrode and workpiece also.

So at the contact point 1 and 2 and 3, heat will be generated at all these three locations due to the contact resistance, but the maximum contact resistance is absorbed at location 3, so it will generate maximum heat under the identical conditions of the pressure and the current, which will be flowing.

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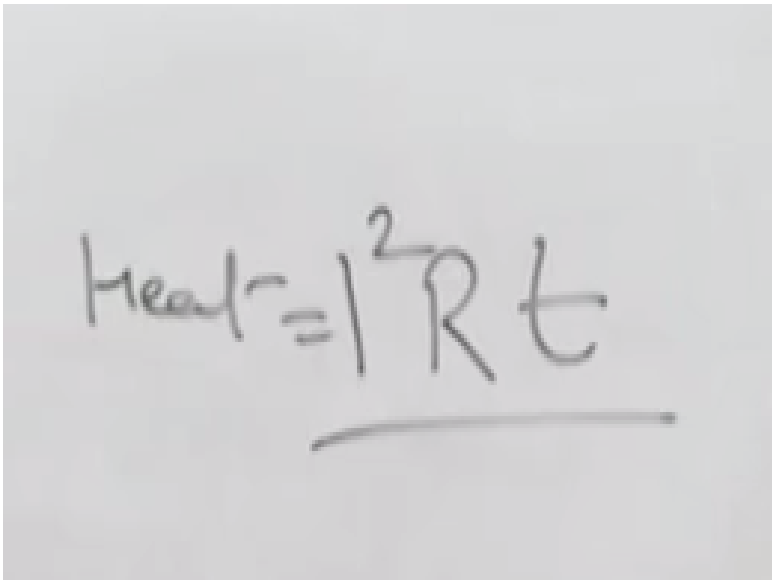

So the heat generated is obtained through the I square Rt where current is in ampere, R is in ohms contact resistance and t is the time in seconds, which will be giving us the amount of the heat being generated. So the heat generation is less at these points at the point 1 and 2 and the maximum heat is there at the interface.

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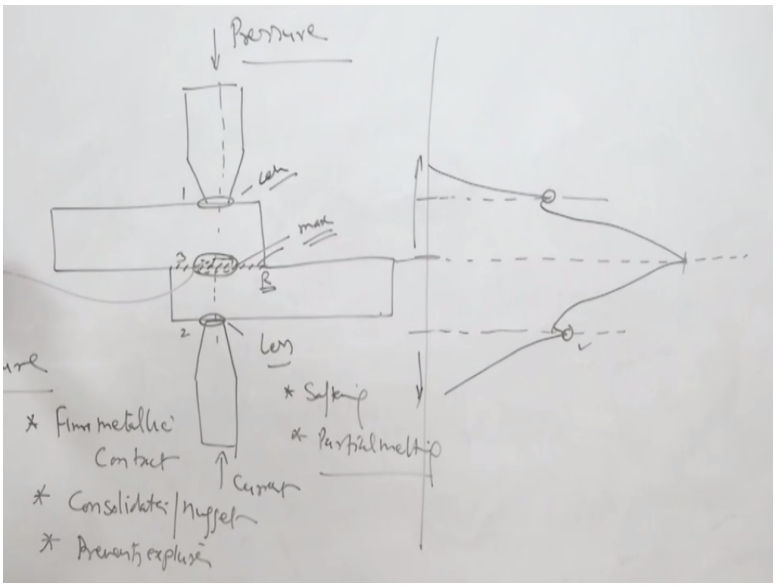

And because of this if we try to see the temperature variation at this point and at the contact interface and as well as the interface at the faying surfaces. So here we will see the temperature will increase and it will go like this. Thereafter again it will increase, reach to the peak value then it will start coming down then it will be somewhere here then again it will start coming down, so some peak is observed at the contact interfaces.

This temperature corresponds to the temperature at both the electrodes and the workpiece surfaces and the maximum temperature is generated. So this you can say this is the distance from the faying surfaces this is on the electrode side and this is on the another electrode side and maximum temperature is of course generated at the faying surface or contact surfaces of the workpiece.

So here because of the maximum current and the heat generation because R value at the contact interface is maximum so it is at the maximum heat and this in turn causes this heat results in the softening as well as sometimes even partial or little melting also takes place and after this melting what we will see that the solidification will result in the formation of the joint.

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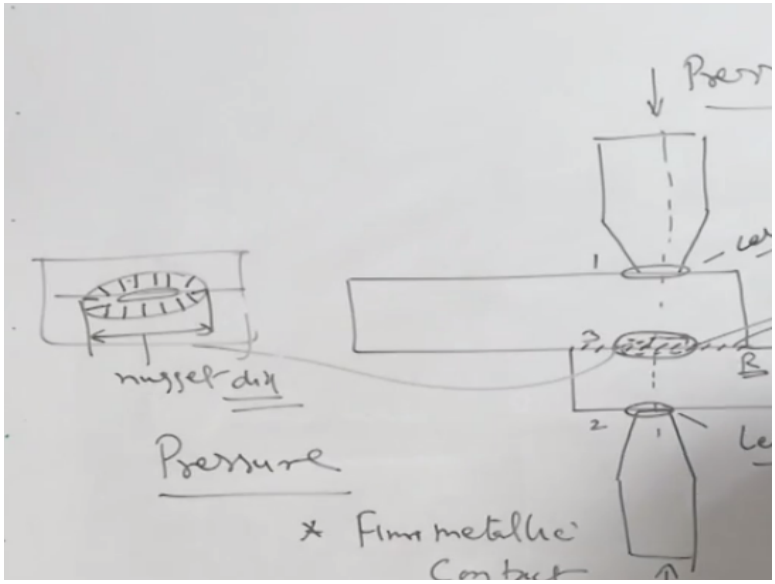

So this portion if you see in magnified form like this. So this is the fused portion, which will solidify and this solidification takes place through these columnar grains normally and here will see that Equestrian structure is formed so this diameter of the melted portion after the solidification result in form of the weld metal, which is called nugget and this dimension is termed as the nugget diameter and this significantly determines the load carrying capacity of the weld joint.

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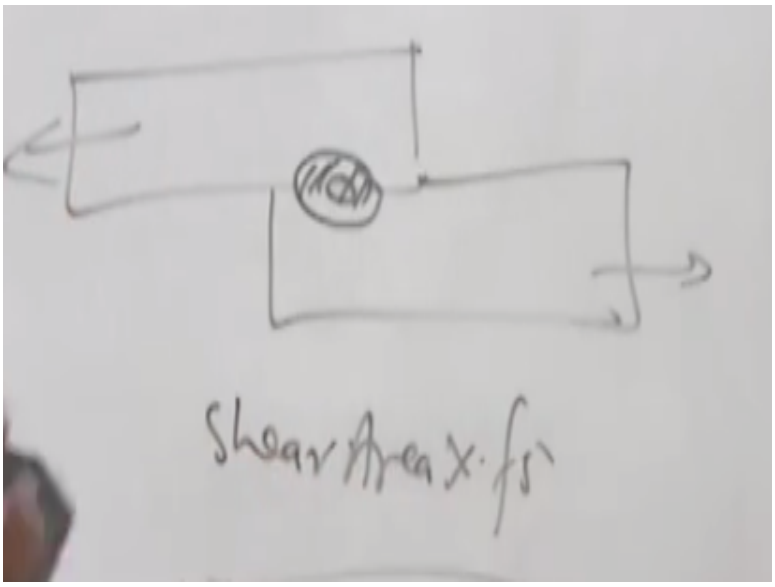

So if you see in this configuration in this kind of joint if the nugget size is small, the load carrying capacity of this joint will be lesser as compared to the case when the nugget diameter is large, larger nugget diameter in general increase the load carrying capacity or the shear area multiplied by of course shear strength will give us in this lap joint configuration, the load carrying capacity under the shear conditions.

So increase in diameter of the nugget directly determines the load carrying capacity and the size of the nugget diameter is governed by the amount of heat being generated so we need to see what are the parameters that affect the heat or the individual effect of the welding parameters on the heat being generated. So as far as that effect is concerned, before going into that let us see the kind of cycle which is followed in resistance welding processes.

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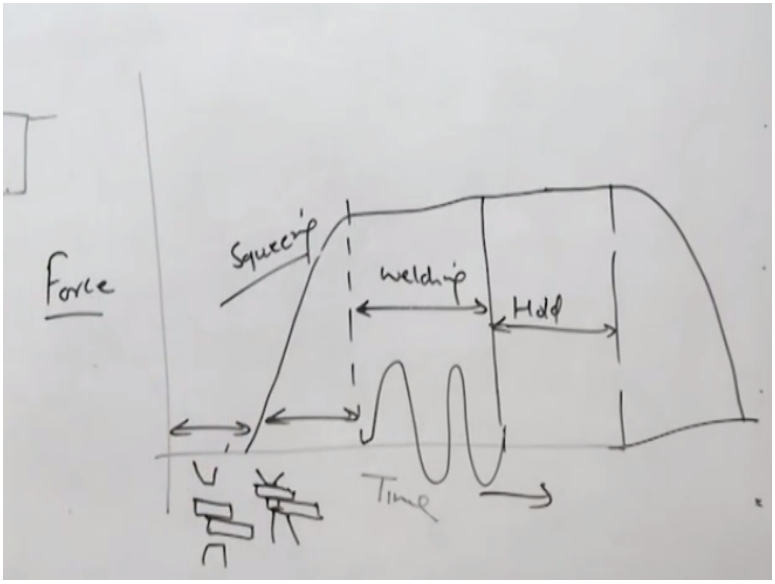

So that cycle goes in like this as a function of time how the pressure and current varies so here if it is force, which is applied through the electrode and as the function of time. So initially when the electrodes are far apart from the surface of the workpiece like this. So the electrodes are far apart and the pressure is 0 and then the pressure is increased as soon as they come in contact with the surface of the workpiece pressure is increased.

So like this so here they are brought in contact, pressure is increased then pressure is increased gradually then it is kept constant like this and then slowly it is brought down as a function of time. So this axis shows the variation in pressure as a function of time and here as soon this is the portion where squeezing is taking place and when this squeezing is over, the electrode will be in firm contact with the surface of the workpiece after this only the flow of the welding current is started.

So once the flow of current is over, heat is generated, melting of the faying surfaces will be taking place so this is the time when the current is allowed to flow known as welding time, first is squeeze time and here no pressure zone, welding time and thereafter under pressure it is kept for some time, this is called hold one in which the nugget which is being formed will be solidifying under the pressure.

And thereafter once the solidification is over, the release phase comes in, the pressure is reduced gradually and then the sheets are taken off and this is how the cycle is repeated. So basically squeezing, welding, holding and then off this is the kind of cycle which is followed in most of the resistance welding processes like spot welding and projection welding. Now we will see the kind of requirement or expectation from the electrodes, which are being used.

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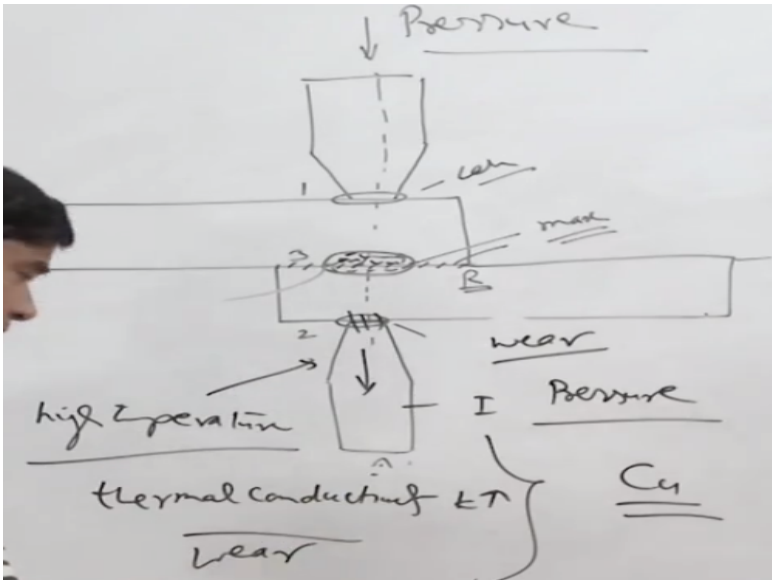

So the heavy current flows through the electrodes and the pressure is also applied through these electrodes. So electrodes are supposed to withstand under the conditions of the high temperature. So this is one requirement that electrode material must have the high temperature strength. Another is, it comes in contact with the surface of the workpiece very frequently so repeated contact, repeated relative motion between the surface of workpiece and the electrode causes the wear.

So it must be wear resistance since heat is generated to the contact interface with the workpiece so this heat must be transported away to avoid unnecessary damage to the electrode material. So the conductivity like thermal conductivity of the electrode material must be good. So the K must be high and to satisfy all these requirements normally the copper based alloys are used.

So these electrodes are normally water cool also to maintain the safe temperature limit, but since they have to handle the heavy current so the good electrical conductivities needed, high temperature resistance is needed, high thermal connectivity is needed and good wear resistance is needed.

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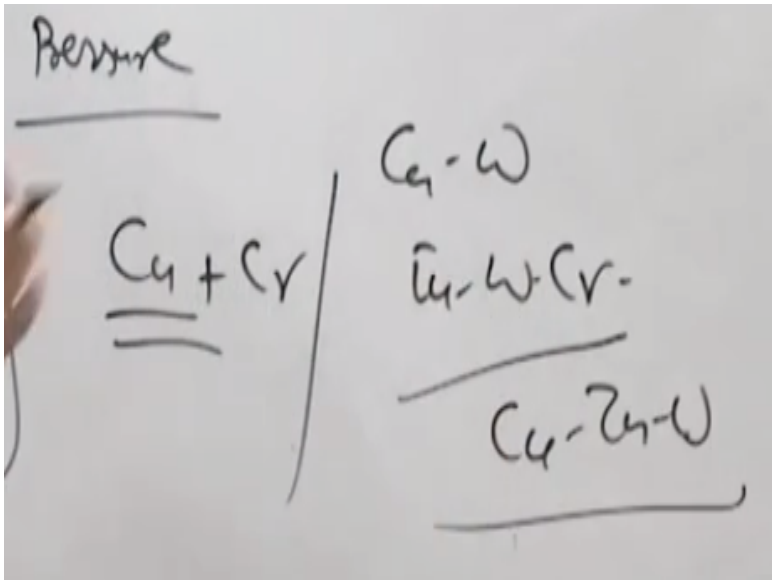

So the copper is normally alloyed with the various alloying elements like copper chromium and copper tungsten or copper tungsten chromium, sometimes copper zirconium tungsten systems are also used. These alloys offer very good resistance to the thermal softening, good wear resistance without much compromising on the electrical conductivity of the electrode. However, alloying will definitely be reducing the thermal connectivity as well as electrical conductivity, but they provide enough value of these properties so that they can be used effectively for the purpose of developing the joints.

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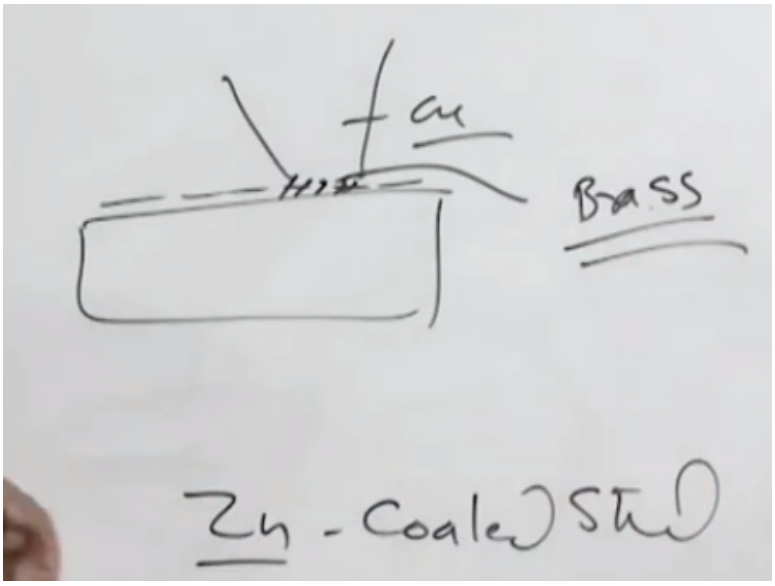

Especially in some of the cases like if the electrode is of particular shape and size, gradually these wear out in course of the operation so diameter increases, increase in diameter is actually reduces the current density and because the current is allowed to flow through the

larger area so reduced current density results in the reduced heating and so the nugget diameter sometimes gets reduced.

This problem is mainly encountered when we weld the zinc coated steels. So the zinc coated steels like the steel sheet having the coating of the zinc and when it comes in contact so the copper due to the continuous heating interacts with the zinc and it forms the brass. So this brass being hard and brittle and continuous under the adhesive conditions causes the wear of the electrode at much faster rate.

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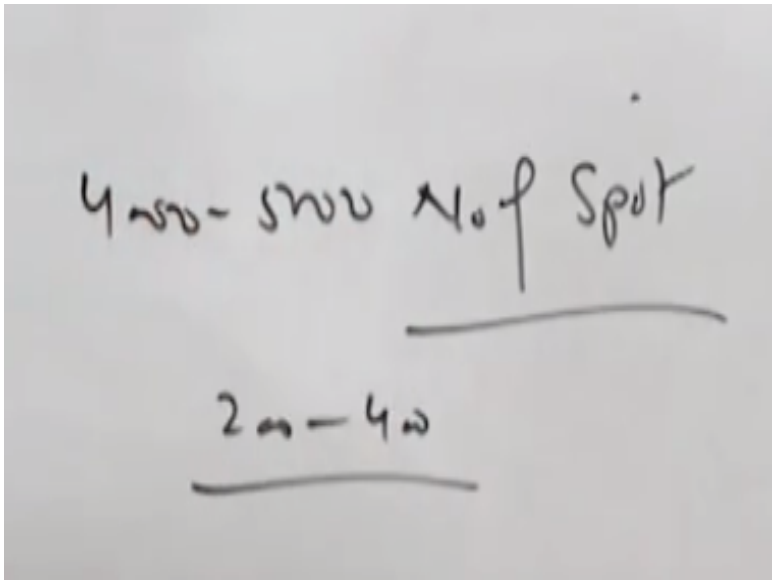

So normally the electrode, which can produce the joints of 4000 to 5000 in one go, 4000 to 5000 number of the spots without compromising in the nugget diameter when the zinc coated steels are spot welded (()) (18:28) 200 diameter gets modified and it is enlarged to certain extent that it needs the replacement or the refurbishing so that it the same size of the nugget diameter can be achieved.

So significant reduction in the number of spots, number of the welds, which can be made spot welds, which can be made in case of the zinc coated steel sheets that is reduced significantly because the formation of the brass at the electrode surface reduces increases the wear rate, which in turn reduces the life of the electrode significantly.

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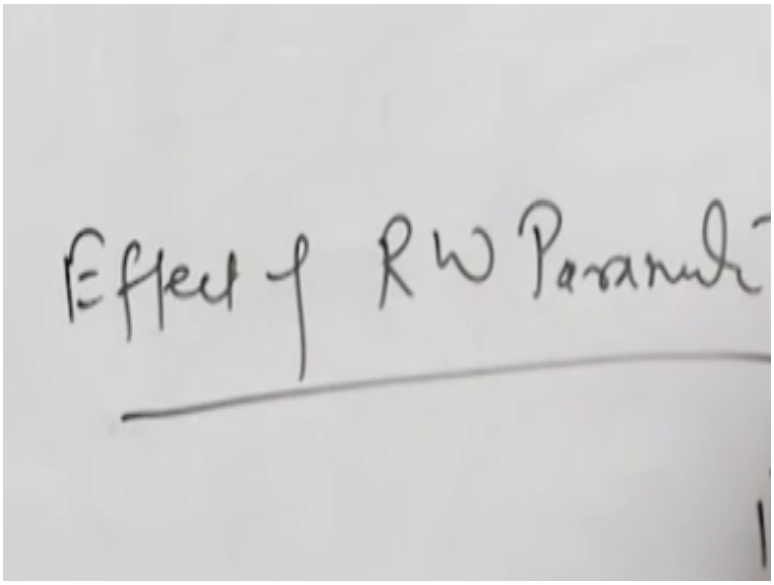

Now we see the effect of the individual parameters, effect of the resistance welding parameters on the joint performance.

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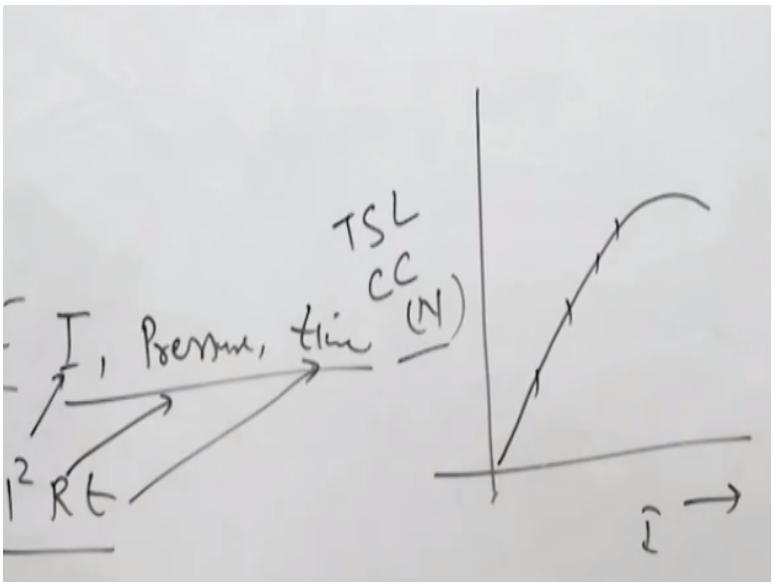

So there are three important parameters like current, pressure and the time for which current is allowed to flow. So all these factors in fact govern the heat in one way like I square Rt, t is directly proportional to and heat generated is proportional to the square of the current being supplied and pressure in fact effects the contact resistance.

So now we will see that when the current is increased like the tensile shear load carrying capacity in kilo newton increases with the increase in current and then it starts decreasing after reaching to the maximum.

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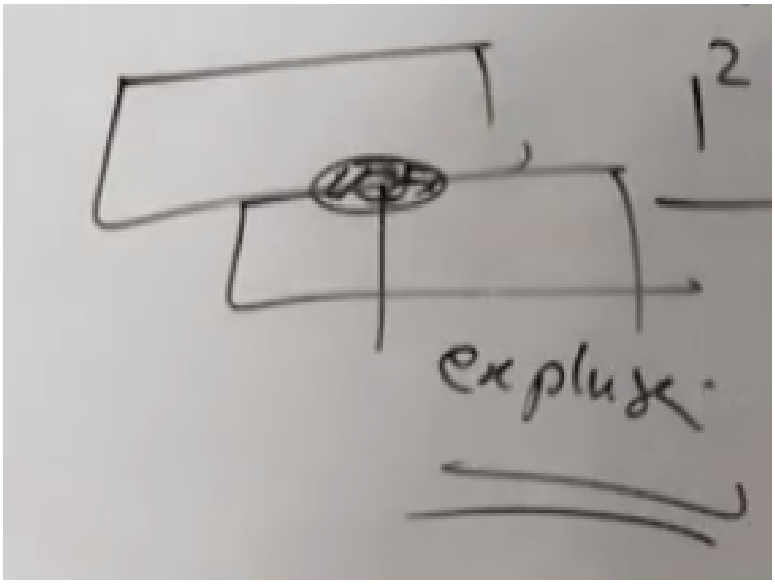

We know that increase in current will increase the heat generation, which in turn will increase the size of the nugget, which will be made and that is good from the shear strength point of view. For low current, nugget size is small and as the heat generation is increased with the increase of welding current, nugget size will keep on increasing that in turn will increase the tensile shear load carrying capacity.

But after reaching to a particular value will see that excessive development of the excessive molten metal due to the too much heat generation expulsion of the molten metal starts.

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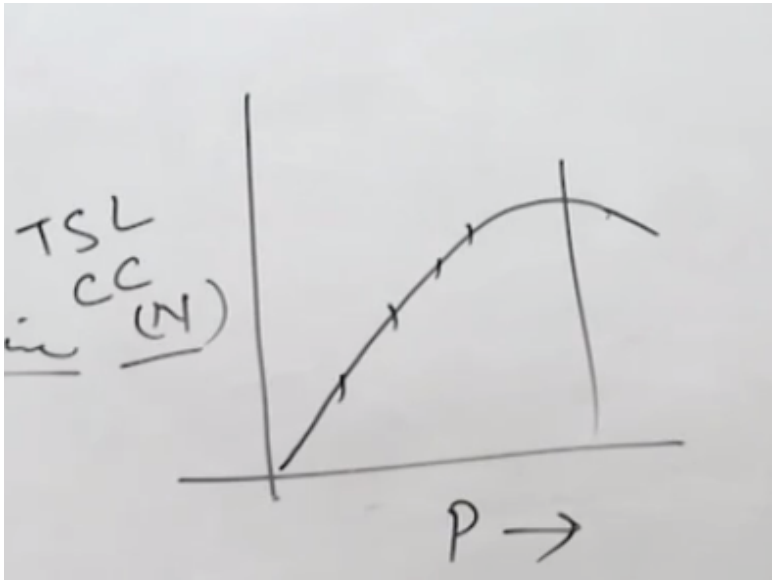

And in that case strength starts decreasing after reaching to the peak value. Similar kind of the trend is also absorbed in case of the pressure variation. So the increase in pressure are the load initially so of course we need some minimum contact pressure in order to have the good

current flow through the workpiece without sparking and thereafter will see that initially when the pressure is lesser.

The current will not be flowing without this sparking so minimum current is needed.

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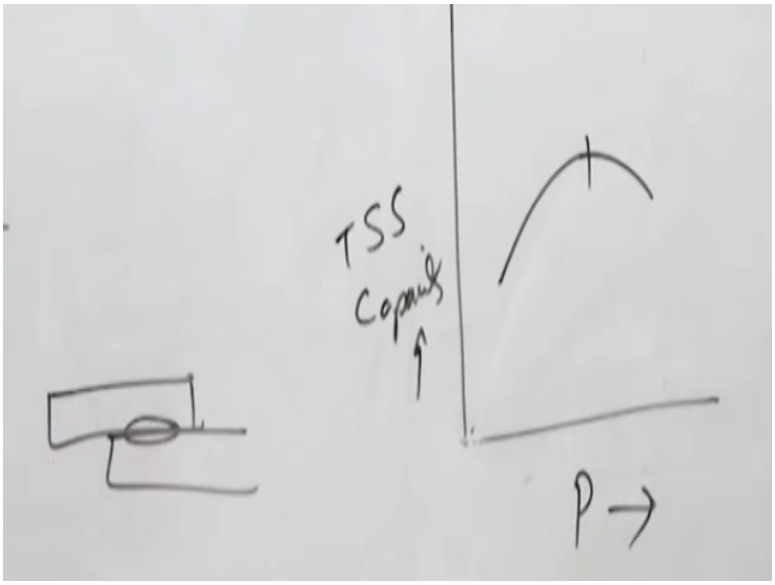

So initially the increase in pressure helps in better consolidation, proper solidification and thereafter but too much increase in pressure starts decreasing the tensile shear strength capacity of the nugget or of the joint and this decrease is attributed to the reduction in contact resistance say for if the pressure is too high then increased metallic intimacy at the faying surfaces will be decreasing the contact resistance.

So under identical pressure conditions, the amount of heat being generated will get reduced and that in turn will reduce the nugget diameter, but we need to have a reasonably good pressure to avoid this sparking and use of the two high pressure will reduce the contact resistance, but little marginal increase in pressure helps in effective consolidation as well as the solidification of the metal at the interface.

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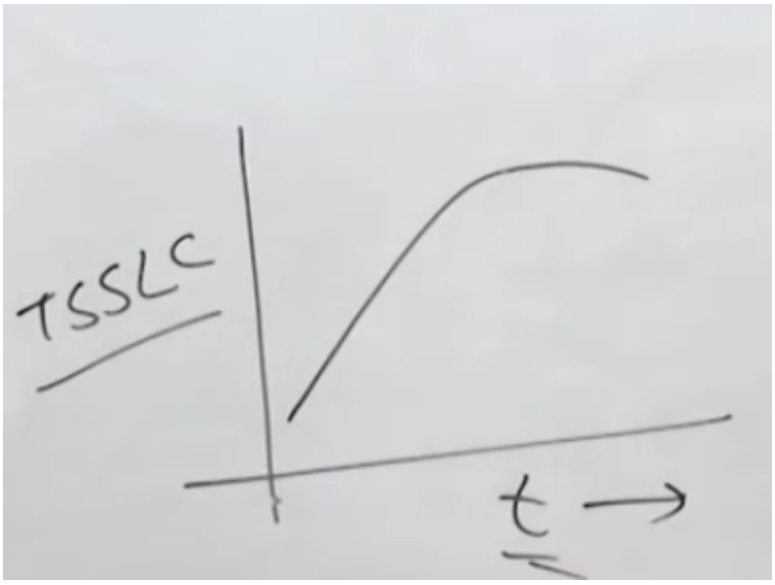

And similar to the current increase in welding time also increases the strength and thereafter it becomes almost constant. So basically the load carrying capacity of the joint increases linearly with the increase in the time for which current is flow. So basically increase in time increases the heat generation, increases the nugget size and thereby it increases the load carrying capacity of the nugget.

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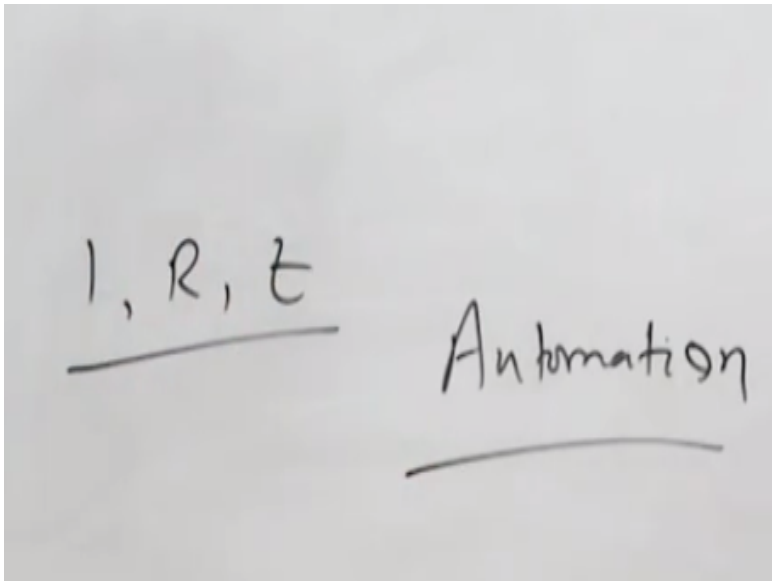

So this is how the welding parameters effect the joint strength and it is necessary that proper control over the current I and t is maintained. Once these parameters are obtained, automation of the process is very effective. After optimization once the process is activated later production is very high in case of the resistance welding processes.

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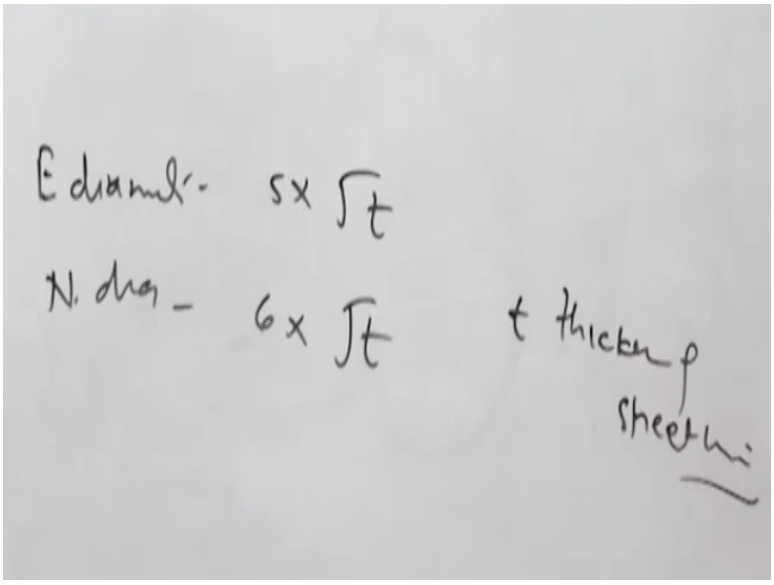

There are certain requirements related to the nugget diameter and electrode diameters, which as required for developing the weld joints like the electrode diameter requirement is likely five times of the root of the thickness, t is the thickness of the plate in mm, thickness of sheet in mm and the nugget diameter is six times of the thickness of the plate. So this is about the requirement side.

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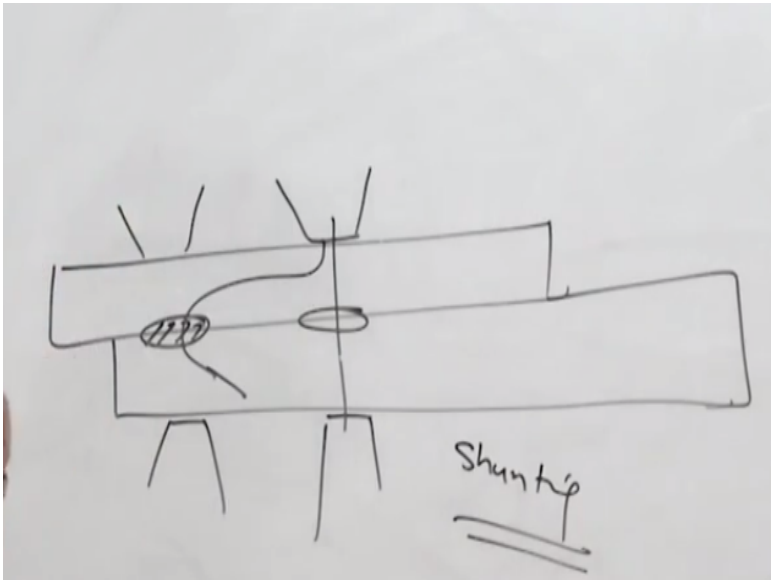

Now will see once the one spot has been formed in spot welding, if the number of spots are to be made for higher load carrying capacity so once the one spot is made here by applying suitable electrode and having the flow of current through this. So heat will be generated and that nugget will be formed. Once the one nugget is formed for developing, another nugget it is required to use the higher level of current.

Because since already metallic connection is established between the two plates so the current starts flowing through this metallic connection and because of this the flow of current through from one electrode to the another electrode directly through this one gets reduced because already metallic connection exist in. So current instead of flowing directly from the high contact resistance zone it starts flowing through the low contact resistance zone and that is why we require higher level of the welding current.

This one is called shunting effect so shunting effect means some of the current will be flowing if some of the spot welds have been made then some of the current will be flowing so already developed nuggets and therefore the current requirement increases for making the further nuggets in case of the spot welds. To overcome the shunting effect, the magnitude of the current is normally increased so this is what happens in case of the spot welds.

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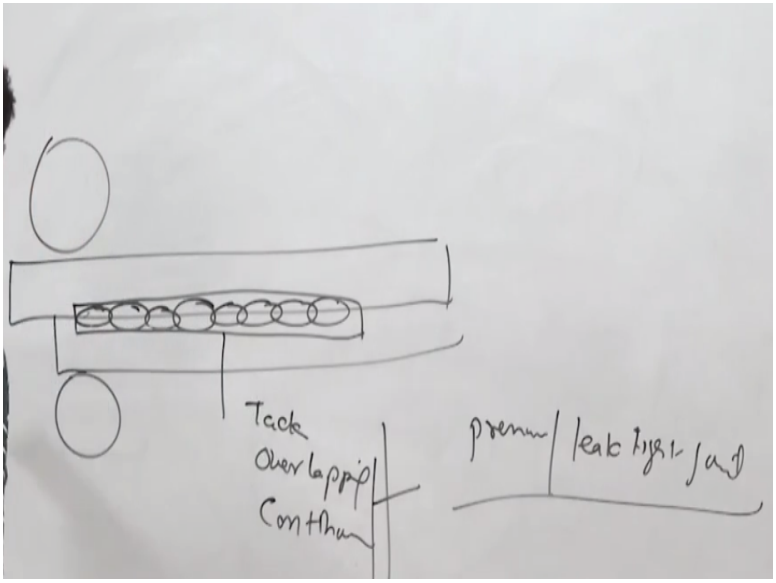

Similarly, in case of the seam weld now will see. The seam welds are made in three ways, seam weld means continuous just like they are made with the help of the rollers, which will be rolling continuously and current will be fed. So here the seam can be made like this one spot, another spot, another spot this is likely tack welds are made or they can be made in like overlapping kind of the tacks like this.

So this is overlapping weld or instead of overlapping if the weld is made continuously rather than just like intermittent or overlapping weld so continuous. So there are three types of the one is tack weld, overlapping or continuous kind of the seam welds. So these type of the

arrangements continuous or overlapping type of the seam welds are normally used for making the pressure or leak tight joints of the sheets mainly for the tanks.

And wherever it is required that the joint is leak proof, the seam weld is made that also works in the same way like contact resistance heating principle. So now I will summarize this presentation. In this presentation, I have talked about the basic principle of the resistance welding processes, effect of the different parameters, the role of the electrodes and how the joints can be made effectively using the common resistance spot welding processes. Thank you for your attention.