Theory of Production Processes

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Lecture – 48
Principle of Resistance Welding

Welcome to the lecture on Principle of Resistance Welding. So, so far we discussed about various types of welding processes. Mainly based on the arc welding processes, we discussed about shielded metal arc welding process and gas arc welding process where the shielding is done by supplying some kind of inert gas in the weld metal zone to shield the joint which is formed from many atmospheric contamination.

Now, many a times we require the joints like in automobile components we require the joints where there is no requirement of you cannot provide the filler metal we require the production rate to be very fast. So, and the sheet is very very thin where the fusion welding processes if normal arc welding processes are carried out that may lead to defects or distortion in the sheet or proper shape may not be maintained for the plates which are joined.

So, this resistance welding concept is used for welding the thin seats basically which are normally used in the automobile components or joining of your thin seats making pressure vessels or making the tanks automobile you know in automobile components like petrol tanks or so. So, in those cases we need to have the joints which have to be very narrow kind of thing and.

It should be done instantly and there should not be much of the heat affected zone and the productivity over all must be quite high. So, this resistance welding concept came in that light. And let us see; what is that resistance welding process.

So, what happens that as we discussed that when we talk about the high production of the sheet metal components which is now normally required in the case of automobiles now, there you require to have quick joints you have to make it very very quickly. So, then in that sheet metal components this resistance welding and concept is being utilized.

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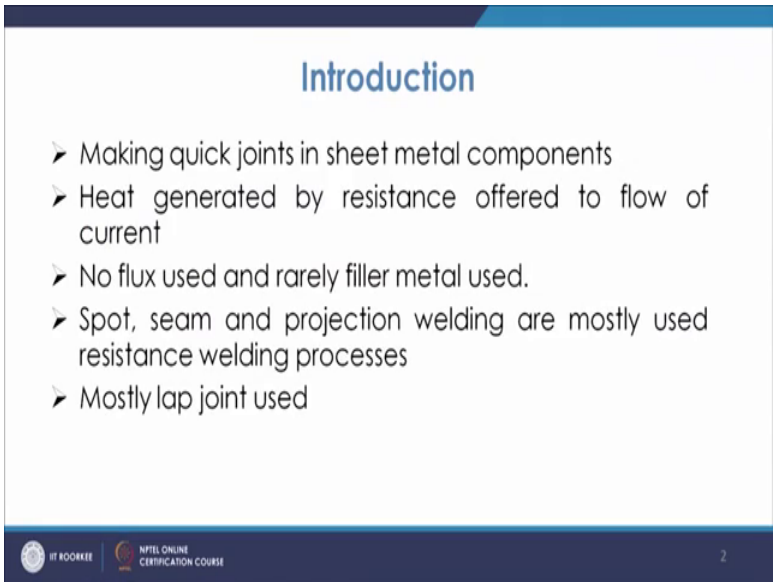

Now, what is the there that you have the two sheets which are to be supposed to you know they are to be joined at certain point or may be along a line in that case the two sheets are faying over each other they are meeting at one over other normally is you have the lap joint and then you put the electrodes from the top and the bottom and then you try to pass the electricity through it.

Now, because at the points where they are meeting you will have the resistance offered to the flow of current. So, flow of current will be there through a conductor, but then it is systems will be maximum where you have a gap now in that gap as the there will be large amount of resistance. So, because of that you will have the heating effect that is joule heating will be carried out and depending upon the value of current voltage I mean current resistance and the time over which this current flows you will have a magnitude of heat which is generated at that particular interface interfacial point and that heat generated is so high that it does the localized collisions of the metal and then the joint takes place.

So, that this since this joining is taking because of these resistance offered to the flow of current at that mating point. So, that is this type of method is known as resistance welding.

Now, what are the advantages in this type of process? The advantage that you have more flux used you have two sheets and the two sheets will be there and then on the top and

bottom sides you will have electrodes and the current will be passed. So, there is no needs they are in intimate contact and when the current as the current passes at that point the because of the high resistance because of the heat generation you know that the generation of heat is so high that the localized fusion takes place or localized collisions takes place.

So, you do not use any flux and that is why the advantage is related to no flux used can be you know seen like when we use the flux you have many kind of you know precautions required to be done. Like when we use flux you have to clean it after every pass.

So, this way the productivity is hampered every time you have to if you put the specimen under further welding or next pass then you have to clean it or if the flux you know if it is entrapped in the weld pool then that may lead to the deterioration of mechanical properties corrosion resistance may be you know affected.

So, basically this effects so, this since because of no use of the flux the productivity is improved also you do not use the filler metal mostly in most of the cases. So, no use of filler metal it is simply joints. So, there are many kind of the resistance welding variations like spots seam, projection flash, there are many, but normally this spot welding, seam welding and projection welding these are the main three kinds of resistance welding processes which are used for the automotive applications. And as we discuss that in most of the cases the joint which is used in these resistances welding is the lap joint. So, we use the lap joint.

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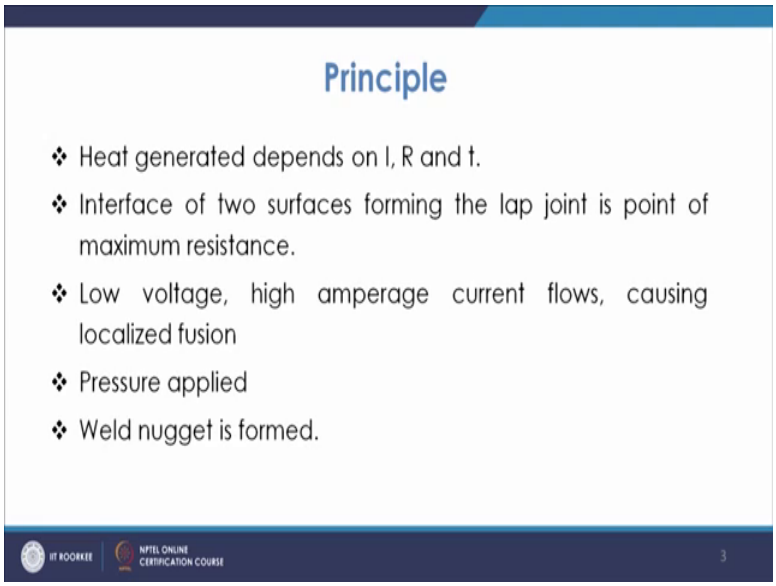

Now, what is the principle? So, as we discussed that it is based on joule heating so the depending upon the magnitude of the current and then the resistance of the current conducting path and time over which the current is flowing now this heat generation basically will be depending upon these three parameters. So, as we know that once we know the amount of current which is being flowing and then the resistance and the time.

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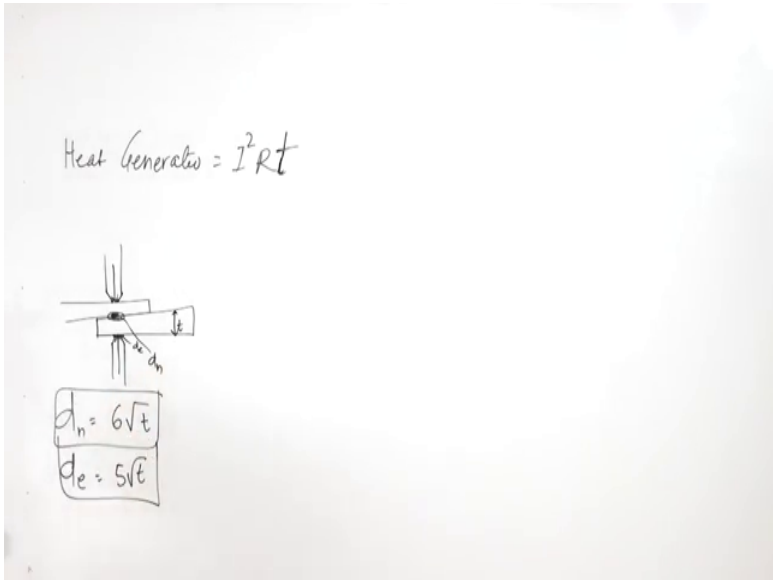

Then we know that we have heat generated will be I square RT. So, it means the heat generated is proportional to I square and heat generation is proportional to R and heat

generation is proportional to T. So, as we see that is proportional to the square of the current, proportional to the resistance and the proportional to the time over which this current flows. So, this is T.

So, as the value of I will be larger, that is why we use the large amperes of current which is about to flow which is made to flow, so that you have large quantity of heat generated and as the large quantity of heat is generated and it is focused at the particular area because once you have the. So, you have if you have two points two sheets are there and you know the here in this place you will have the electrode. So, from here the electrode will be you know apply this for there will be applied with force. So, there will be force also applied on the electrode. So, and then the current is passed.

So, at this point where there is a interface at this point there will be large amount of heat generated and then this. So, you though your electrode will be like normally this. So, it will be like normally this now, what happens that from this point. So, there will be a point here there will be it point here which will be in indentation mark will be there and then you will have. So, in that you know dimension itself proportional to this dimension of indentation or the nugget dia you will have the nugget formed here. The zone which is basically collapse or where the fusion is taking place or this you know because of the heat these local material basically fused to each other.

So, they are you are finding a bound and that form is called a nugget. So, that nugget formation is taking place. So, normally you go for having a low voltage high amperes current and once it flows then it is causing the localized fusion.

Now, as we discussed that the pressure is applied from here and the pressure is applied, so that you have an intimate contact between them then also so that they are held and then. So, that once you have the because of the fluid because of the heat they melt in a in the localized area and then because of the pressure they are hold for some time so that they are bond to each other. So, there is a bonding developed at this point. So, that is how the joining takes place and weld nugget is formed. So, so this mass which is formed is known as well nugget.

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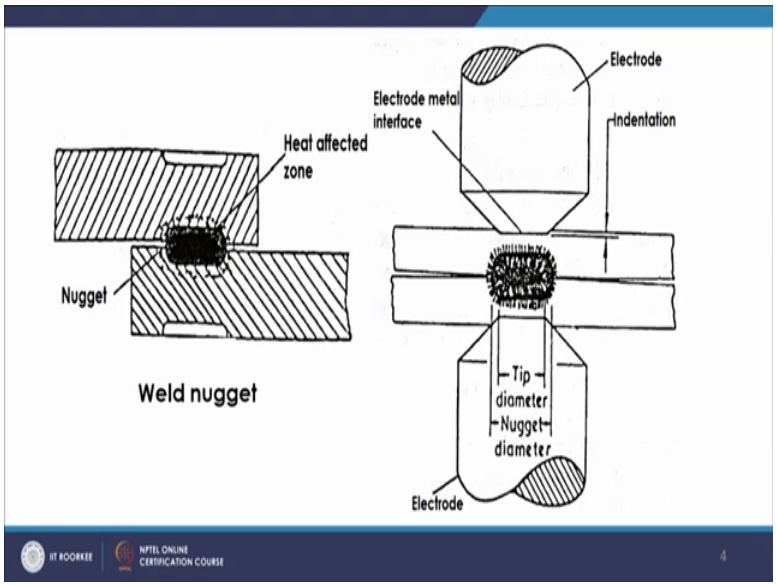

Now, you can see the formation of weld nugget how it works here. So, as we see that you have this is the point you have this is known as the indentation zone. So, from this indentation zone you have the electrodes as we see this electrode which is having this much of contact to this work piece. So, this electrode will be there and they will be connected to the power source and now once the electricity is passed. So, once that circuit is completed in that cases they are there is having a gap here. So, in this case here a large amount of heat is generated.

And, this heat being generated they will fuse the material from both the sides and then a zone will be there which will be formed by the of collisions of the metal from both the parts which are to be welded and this way this weld nugget is formed now we also see that since there is temperature involved a very small amount of heat affected zone also is seen because certainly when the this is melted or this is zone which is found by the collisions of the metal on both the sheets. So, the temperature will be higher on.

The two sides and there will be a small heat affected zone also be form on these two sides now what we see that is here also the same thing that you have the this is the electrode metal interface where which forms that indentation mark and then you have two things here there is one is tip dia and another is nugget dia. So, that that you see that this is the nugget dia and this is the tip dia electrode dia.

So, basically it has certain empirical formulas by which depending upon the nugget dia or depending upon the sheet thickness basically we try to have certain you know this electrode dia tip dia or nugget dia. So, that basically normally empirically it has been calculated using experimental investigations that it should be a function of the thickness some root square root or thickness multiplied by some quantity or maybe depending upon the different kind of empirical relationships have been suggested by different researchers. So, you will have this way the formation of the weld nugget.

Now, we will also discuss that there are certain mechanism of when cooling these electrodes because they will be getting heated a lot. So, and then as you see that from here you will have the pressure applied on the sides from the electrode you will have the pressure applied from top and the bottom. So, that also have I means it is the whole process is completed in a cycle and that cycle has many steps so that we will discuss later on.

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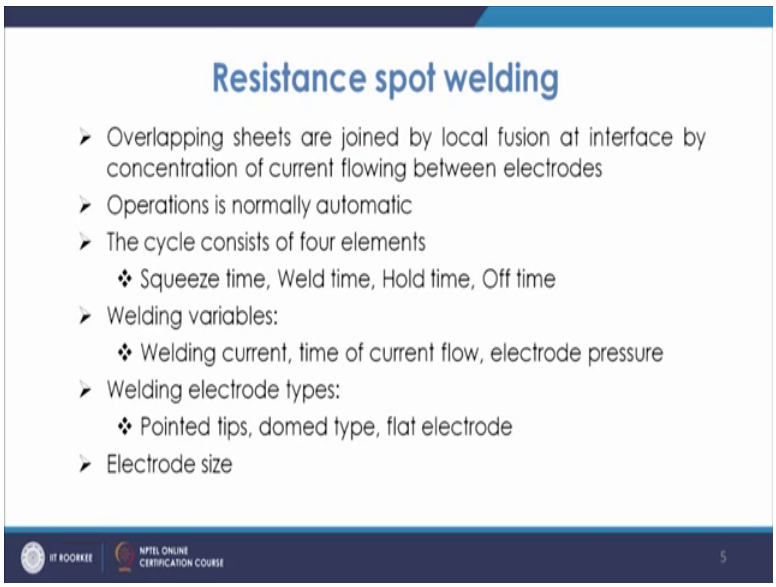

Now, if you look at this. So, we discuss about the resistance spot welding. So, this is resistance spot welding is basically the most important type of resistance type of welding is it mostly I used. Now, resistance of spot welding as the name indicates that the welding is done at a spot. So, the sheets which are the overlapping sheets are there and this overlapping sheets are basically joined by the local fusion at interface by concentration of current flowing between electrodes.

So, that is what it is clear that you have the sheets which are overlapped and then you have the current concentration of current which is flowing between the electrodes and then you will have the localized fusion at the point and because of the large heating according to the joule heating formula and then this joining takes place because of the pressure also which is applied at that movement of time itself.

Now, most of these operations are basically automatic. So, you know the variables which are normally used they are preset and normally constant because you know this is a very high productive type of process and for how much time you will have to apply the pressure of how for how much time you have to switch on the current then when to switch off the current all these things are basically very much you know important variables and if the proper you know values are not maintained then that may lead to the spoiling of the joint quality.

So, basically these values are normally preset and mostly constants. So, that is needed to be operated and mostly that is why these operations are normally the automatic type of process. Now, there are few operating variables and these are and a terminologies so that we will discuss. So, first is the welding cycle. Now, what is so, in that basically we are going to discuss mostly as we discussed that among the resistance welding varieties we have three kind of resistance welding processes which are mostly common that is spot welding, seam welding and projection welding.

Now, so, what happens that in these cases you have a cycle welding cycle and the each cycle has four elements? So, what are these four elements one is the squeezed time. So, what is squeezed time now squeezed time as we know squeezed time it will be the time interval between the application of electrode pressure. So, once we start the pressure by the electrode to the work so, and then switching on the welding current so that time interval that is known as the squeezing time. So, that we are squeezing. So, that is why that is known as especially you apply the pressure and before and the time at which you start flowing the current before that that time is normally known as the squeeze time.

Similarly, you have the weld time now weld time means the time for which the current is flowing. So, that is known as the weld time. So, for that time the current will be flowing through the workpiece and that will be basically melting. So, that will be basically fusing it. So, or melting will take place. So, that time is known as weld time.

Then, you have the whole time. Now, whole time is that the time for which these electrodes are kept in position after welding. So, then after the welding the electrodes are kept in it is position you know because when the current is switched off, but they are just kept at it is position hold to it is position just to assure that there is application of pressure. So, that during that time the nugget is consolidated. So, even if the current is not flowing, but then you are having it at it is own place. So, that the nugget which is which is to be formed that consolidates in that time. So, that time is known as the whole time.

And, then you have the off time now whole time is very important because how much force is to be applied you cannot apply even larger kind of pressure. So, you do not you have to have optimum pressure because you apply the large pressure at that time there may be expression also taking place.

Then you have the off time and off time is defined as the time allow to shift the work. So, that is the I mean the we are allowing to shift the work to next location before the cycle is repeated. So, that is known as the off time. So, because electrodes are kept of the work during this interval that is why it is known as the off time. So, these are the four elements in a particular welding cycle.

Now, we have different welding variables. Now, if you talk about the different welding variables and the welding variables which are normally used are the welding current time of current flow and electrode pressure. So, as you know that the current value is the most critical value in the case of this resistance welding because the current is basically the most important parameter in generating the heat. So, this is I square RT. So, that is the most critical value of these resistance welding parameters.

Now, the size of nugget which is being formed or it will not be formed. It depends upon the value of current which is being used. So, normally we use the AC current that is 50 hertz main frequency that type of AC current we use and we also can use these DC currents where we require very heavy current. So, in those cases we require we go can go for even the dc currents and with DC the advantage is that the rate of current rise or fall that can be programmed. So, that is another characteristics when we go for the either AC or DC or in case of DC you have some other you know characteristics.

Similarly, the other variable which is given is the time of current flow. So, time how much for how much time this current has to flow. So, you know and then you have the electrode pressure. So, the pressure control is also important and the pressure basically can be controlled or pressure is applied by many ways like hydraulic mechanism maybe there or mechanical you know or the pneumatic type of mechanism maybe there.

So, there are many means by which the pressure has to be applied and pressure also plays a very important role while you know showing the quality of these you know welding you know quality or the nugget quality.

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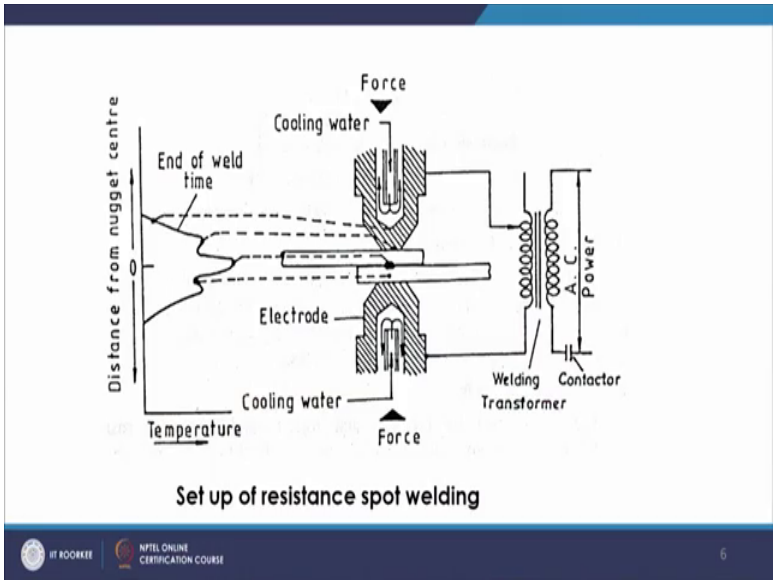

Now, coming to if we look at the setup of the resistance of spot welding if you look at the figure this figure shows that setup of the resistance spot welding. So, as we have seen that you have.

The nugget formation here you have the electrodes which are basically from both these sides you apply the pressure from both the sides. So, that there is intimate contact between these two work pieces which are to be joined at this point then if you look at this is the power source by which it is you know connected. So, you will have now once it is the circuit is on then in that case the current will flow and that process will start.

Now, there is cooling water also going on because the welding this electrode is subjected to very high temperature. So, this cooling water is passing through it, so that it is life is

you know increased or it is life is maintained in that case. Now, if you look at the different points from the nugget this graph tells that this is distance from nugget centre. So, as you look the different points from this nugget you see that how this temperature is varying your maximum temperature is at the nugget and then as you go on and that temperature will be going on lesser and lesser and then that way the temperature drops.

So, this way the temperature variation is taking place in the case of resistance spot welding. So, the thing is that it is very clear that you have the as the current passes because of the resistance the melting takes place here.

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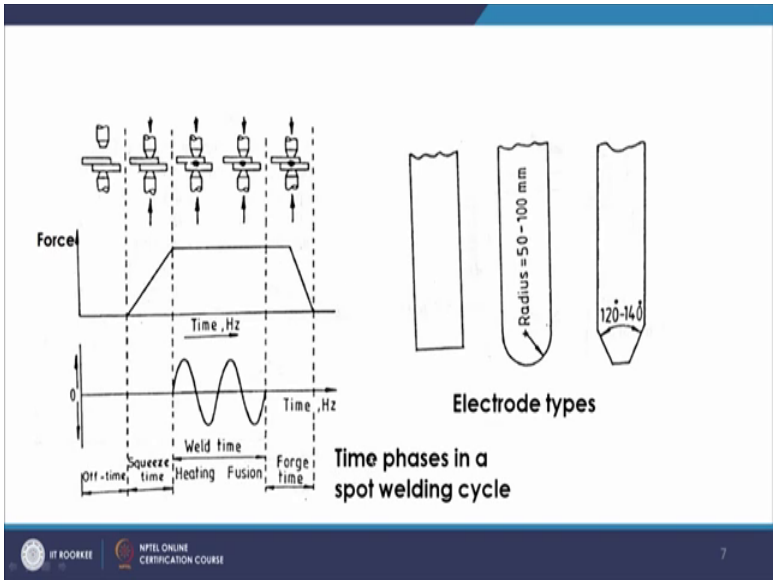

Now, this is about the time phases. So, how we apply the pressure if you look at as you see that you started the this is off time and then once you go from here it is the squeeze time as you discussed you have the different you know stages in different the cycle elements. So, here this is the squeeze time where you apply the pressure so that this force is increased in from here.

Now, at this point you once you start come to this reason then you start the current. So, in this zone you have the current flowing. So, heating taking place and as you see that this nugget is starting forming and then here the nugget is formed and then after the formation after that where we have switched off the current. So, even after that we have still maintained that pressure at this point. So, pressure is maintained up to this point and

then you release the pressure at this point. So, this is at this point you ensure that if the nugget is completely formed.

Now, we will discuss about other points like we have electrode types. So, the different types of electrodes which are being used in these cases now first of all the what should be the quality of these spot welding electrodes, because they are going to conduct the welding current. So, then also they are you know they have to be strong because they are they are applying the pressure on the work piece. So, they need to be also very strong in that case.

Also they have to dissipates the work I mean the heat which is generated to the workpiece. So, part of the heat from the work they are they are basically to dissipate. So, from the work it will come to them. So, that way also they must have those qualities by which basically should make them suitable for its use in that particular orientation.

So, now, the electrodes are used are of different types. So, you know the types are basically based on what kind of you know this structure is add it is tip. So, the tip may be a truncated tip which is also known as the pointed tip. So, the pointed tip is nothing, but it is like this. So, this is the pointed tip in the case of the electrodes then you have the domed shape of electrodes. So, as you see that normally this is 120 to 140 degree of included angle is used in these cases. So, this is a most widely used type of electrodes.

Then we use also the domed electrodes where radius is kept from 50 to 100 mm. So, there the attribute of these type of domed shape of electrodes are there they withstand high amount of pressure. So, and basically based on the severe heating also they do not mushroom the problem with these type of electrodes or normally the electrodes fail by mushrooming taking place at the tip of the electrode. So, that though take place here in the case of the domed shape of electrodes.

And, then you have the flat electrodes which are used for the invisible which we do not see on speakers type of whales where you have a also the minimum indentation which is where it has to be. So, in those cases the flat whales are flat type of these electrodes are used. Then you have different kinds of offset electrodes are also used for the use in different positions like maybe at the corners or so. So, you have may have and mechanism of electrode, so that you can do the welding or spot welding at different places.

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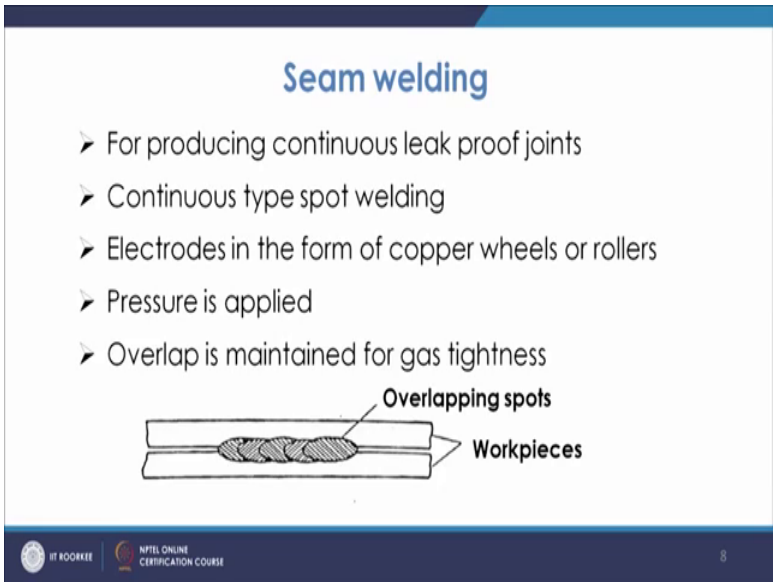

Now, coming to the seam welding now, before that let us discuss another aspect of the as we discussed that you about the electrode type we discussed about the electrode types then will be the pointing electrode size what should be the electrode size. So, basically size means where it is in contact with the plate. So, as we there, where the indentation taking place and then depending upon that the nugget is formed.

So, normally what is seen is that depending upon the thickness your nuggets should be 650. So, d n will be. So, nugget diameter d n is normally given as 6 root t. So, t is the thickness of one plate. So, that is how nugget diameter is there and similarly the electrode tip diameter that is basically 5 root t. So, that is d e that is 5 root t. So, these are the empirical correlation shapes by the different researchers. Some of the researchers have also given like 2.5 plus 2 t where t is basically the single sheet thickness in mm.

If the if is a t then this is basically this is the d e this is the nugget will be like this and this will be d e. So, this will be de and this will be d n. So, this way d n and d e can be. So, that way you can control the size of the electrode.

Now, coming to the other varieties of the resistance welding the seam welding; so seam welding here also it is a it is nothing, but it is a similar type of spot welding, but it is continuous. So, here the continuous spot welding taking place the welding take takes place in such a way that you have overlapping of these spots. So, as you see in the picture you have the welding taking place, but again starting here again starting here. So,

that is there is overlapping. Now, overlapping is maybe 10 to 20 percent or even 40 to 50 percent depending upon the overlapping you will have the strength increase increment.

So, this is normally required whenever you require a very gas type of container oh or there should not be any leakage. In the case of spot welding there may be leakage it is not gas tight because there will be a small amount of gases which can pass through it, but in this case when the requirement is that there should not be any type of gas leakage even in those cases there is seam welding is done.

Now, here basically this is not much of difference again the heating is on the same concept, but the electrode is basically in the form of wheels. So, it may be in the form of copper wheels or rollers. So, there will be passing and then because of that the current will be at those places that current will be passed and in the during that time the current flows there will be resistance heating and that that is how the nugget formation will take place and overlapping to each other.

So, this way there will be seamless type of you know the continuous type of joint is you know found and that way that is that type of joining is known as seam welding. So, normally you have thickness normally is maintained as the thicker sheets are I mean thinner sheets are normally welded using this process of seam welding. So, normally 3 to 6 mm of thin thickness is the higher limit.

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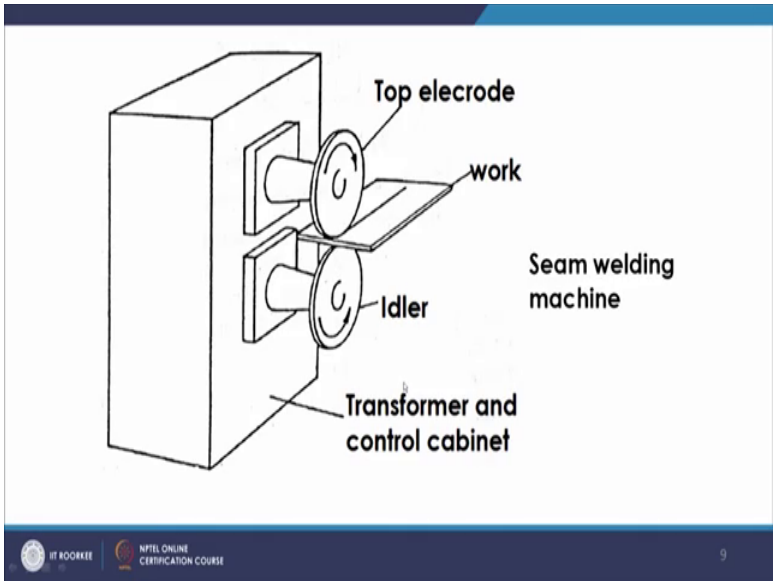

Then the as you see that this is the schematic on this you have the that the top electrode which is treating by the power drive and then this way of work. So, as it rotates and since being that these two electrodes being the one here the heating takes place and then the continuously this joining will take place.

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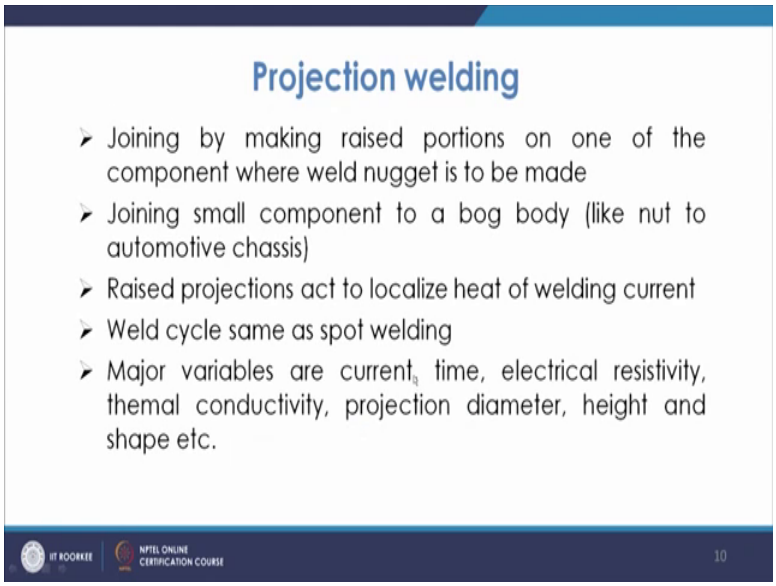

Then, another variety is the projection welding. So, as the name indicates you will have the projection at places specified places and once the electrode you know the current passes through it you will have the projection points fair that resistance welding takes place and this way these are basically used for joining for making raised portions on one of the component while where weld nugget is to be made.

So, basically normally used when you have one very flat type of component very small component is to be you know joined like not to automatic chases. So, those type of cases you use this projection welding. So, raised projections act to localize heat of welding current and weld cycle will be same as the spot welding and you have the different type of variables.

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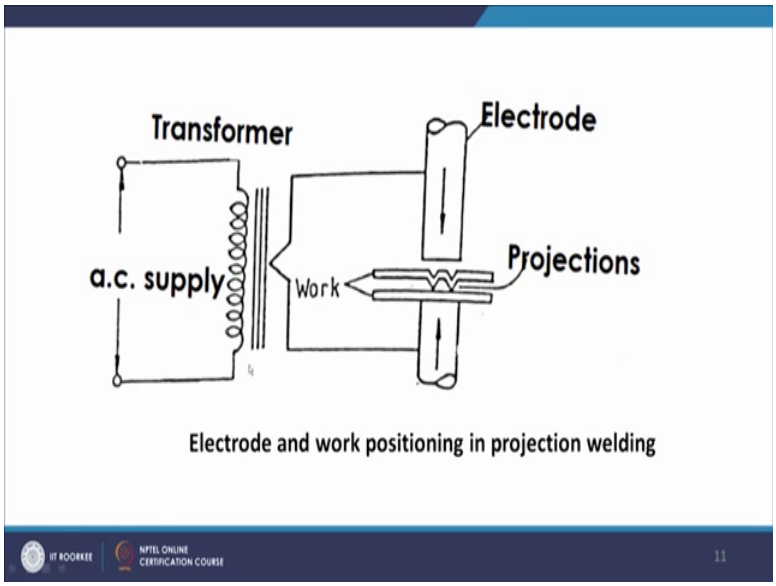

If you look at this process as you see that these are the projections. So, as the current passes the at these projections basically localized heating taking place and then the welding will be taken at will be done at these points. So, this way your welding will be finished. So, these are the projection welding and this is the electrode and what positioning in projection welding.

So, these are the varieties, then you have other varieties of also resistance welding these are which these are basically very much used in the automotive components. You ever try to go to any automotive industries then you can see that you have the different resistance welding setups and they are that is why the one of the very important welding processes which are to be you know studied.

Thank you very much.