Theory of Production Processes
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Lecture - 58
Weldability of Cast Iron

Welcome to the lecture on Weldability of Cast Iron. So, in this lecture we are going to discuss about the various aspects of welding about the cast iron components. So, cast iron components are as we know that they are very important you know material, which are used for the machine bed components or many you know automobile components and many other components are made by cast iron.

So, we certainly require welding of these cast iron components at times, maybe during the casting itself and you have the requirement of certain repairs in the cast iron components or many a times you need to join two pieces, which are made of cast iron.

So, we have to know that how what is the weldability of cast iron, how they behave to certain welding processes, what are the major challenges while we go for the cast iron components welding. So, this we will discuss in this lecture. So, as we know that it is a family of ferrous alloys, that normally contain more than 2 percent of carbon and 1 to 3 percent of silicon as well as a small amount of sulphur and phosphorus.

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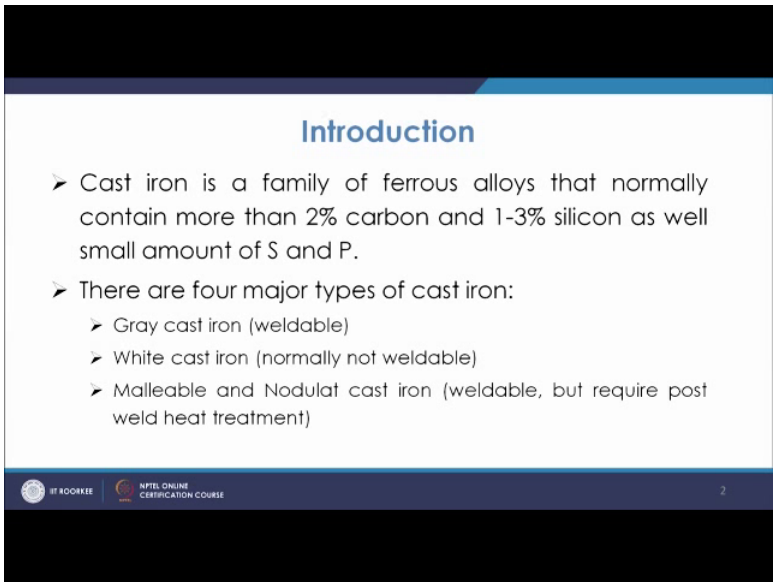

So, that is the you know the definition of cast iron. So, in the cast iron up to 2 percent you have the steel and then after 2 percent. So, you have normally up to 1.5 percent only we go for high carbon steels and all.

But then after 2 percent we go for the variety of this carbon and iron alloy that is cast iron. Now, in this it is characterized by the presence of some special alloying elements, and the most you know important of them is silicon. So, as we know that the silicon is an essential ingredient of cast iron components, I mean at macro structure level the silicon is present and we know that silicon you know effects many qualities, and as far as the melting is concerned because of the presence of silicon the eutectic point shifts towards left.

So, that is basically narrated by the presence of silicon and then for in that regard we have the define and definition of a term also known as carbon equivalent. So, that is c plus silicon percentage by 3. So, one third of silicon will behave like carbon percent. So, yeah. So, that is why we say that whenever we have 3 percent carbon and 4 percent silicon, you will have eutectic at 3 percent carbon if there is 4 percent of silicon because a 3 percent plus 4 by 3 so, about 1 by 4.3. So, that will be in normal case without silicon you have the eutectic point so, that way silicon is important.

Sulphur and phosphorus is also very important ingredient for this you know important element for this cast iron, especially in the gray cast iron. Once you go to the ductile iron varieties of cast iron, in that case certainly we feel that the sulphur should be less because of the presence of you know because of the deleterious effect towards notarization, because if sulphur is present then the magnesium will first. So, magnesium will be lost in that. So, for magnesium to do that notarization process the sulphur has to minimum. So, these are the problems and similar problems will be occurring when we wilt so, that we will discuss how that is going to affect.

Now as we know that we have 3-4 major types of cast iron we will discuss, all the one or two more exist, but 4 majorly we have types of cast iron the gray cast iron. So, gray cast iron is quite weldable, but you have also to have certain precautions, but otherwise normally what we do is, normally we do the welding mostly for the repair of castings or maybe many a times to join the two pieces of cost components so, the gray cast iron is there.

Now, in the gray cast iron basically it is a basically represented by a carbon plus large amount of silicon towards higher side and then you have sulphur and phosphorus.

Now, in this case the carbon is in the form of graphite flakes and as you know that gray cast iron is normally considered to be poor, you know behaving in the tensile you know mode.

So, in this case basically the formation of there are formation of cracks, you know because the fracture in a brittle mode mostly; and then because of these large value of stress concentration especially at the you know flaked tips and you have its not impact value is quite smaller. The thing is that in normal case when we weld, that in that case the chances of increase of the value of stresses is quite high, in that case that may lead to the you know distortion or even cracks.

So, you have to have precautions in that talking about the white cast iron. So, white cast iron is normally not weldable properly, because white cast iron is extremely hard and brittle. So, white cast iron and also white cast iron is a not much used for engineering applications except for the situation when we need for giving a very very high compressive strength just like use of rawls in the steel plants or in the sugar mills or so.

So, that white cast iron has a very poor weldability and we do not normally think of welding is white cast iron. Coming to malleable and nodular cast iron so, as we know that the malleable cast iron it is a very useful variety of cast iron, and we have the idea that malleable cast iron is derived from white cast iron.

So, what happens that a in the case of malleable cast iron, the when we do the malleablezing treatment or that is annealing treatment, in that case the carbon which is there in the combined form that is cementite form, that decomposes because of that large you know time it takes by holding it at a temperature close to 8 to 900 degree centigrade depending upon how you are you know you know when and what is the heating rate, then you have holding and then for the cooling.

Now, depending upon cooling, cooling also will be determined will be basically deciding what kind of head matrix will be there paralytic or variety. But anyway the malleable iron, the basically the property which we get is because of the change in the morphology of the ferrite, I mean a graphite nodules. So, graphite otherwise carbon is in the form of F

e 3 C and when it is in F e 3 C that is in white cast iron that is the extremely brittle, but then once we go for the annealing treatment then in that case the carbon comes out and that is in the form of temper form or free form and that is in the form of small globules or nodules.

So, that is basically the malleable iron. The problem with malleable iron is that and when we do talk about welding of the malleable iron component is that, when we do the welding and as we know that when you do the welding in normal case, a if you do not take proper measures, then the heating I mean heating rate is anyway fast what cooling rate becomes very fast because the weld pool being smaller in quantity and it is on the other two sides you have the metallic metal that is same material having good conductivity.

So, certainly the cooling rate becomes quite high. And in that case the this because of the high cooling rate, again the structure becomes quite cast iron. So, what we do is, normally the challenge in the case of malleable iron is that this property of malleability is lost because of the improper cooling rate it is subjected to after the welding is over.

So, this is a challenge in the case of malleable iron and that is why, you require the post weld heat treatment, you have to keep in mind that if you either you cool it slowly or you have to further anneal the component. So, that again in the weld zone also you will have the similar structures as just like a malleable component has.

So, this is the you know precaution which you have to maintain in the case of malleable cast iron. Similarly is the case for nodular cast iron. Nodular cast iron the challenge becomes the loss of magnesium. So, we know that the nodular cast iron is you know is fabricated or is made by the treatment with magnesium. Now, what we happens that when you are doing the welding, in that case in the pool the magnesium may be lost. And if the magnesium is lost, then the component which is further solidifying that there may not be enough of nodulariazation.

So, basically the graphite turning to the graphite nodules, that will be hampered and that will affect the property of the nodular cast iron. So, basically you will have to see that that to does not get lost. So, that precaution has to be taken. So, that is how a we have to see what are the other challenges.

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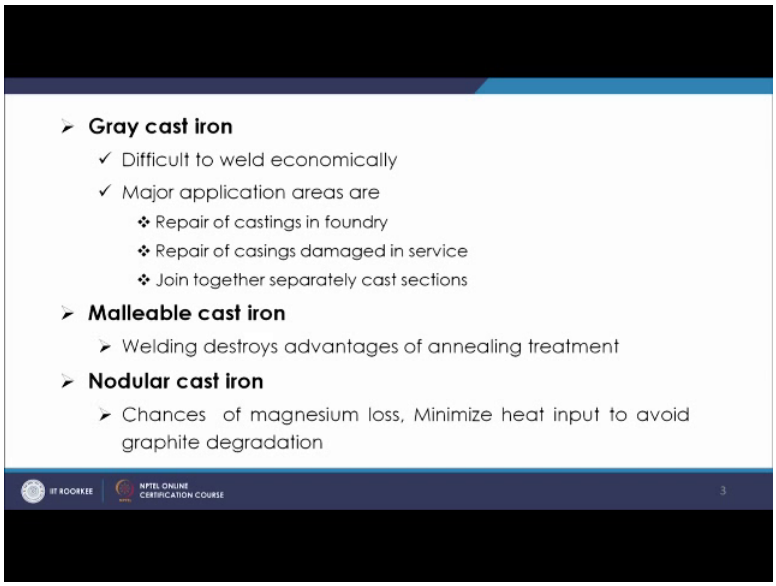

Now, as we know that the grey cast iron is difficult to weld economically, you will have to have the proper a pre and post weld heat treatment processes for by which you can do the welding. Then its areas are like repair of casting in the foundry, then repair of casting which is damaged in the service the service that time we go for this welding of gray cast iron. Then also you are joining together separately the cast sections. Malleable cast iron is when we do the welding that is destroying the advantage of annealing treatment.

So, basically we have to give further the annealing treatment of a particular section or the whole component itself, then you have nodular cast iron and here you will have the chances of magnesium loss. So, you have to minimize the heat input to help to avoid the graphite degradation.

So, graphite a turning into human nodules if you are not taking care of properly then the chances of the conversion of the conversion to the graphite nodules will be less and that is what the challenge is. Welding characteristics of the gray cast iron; So, what happens that in the weld pool the cooling rate determines carbon going into the combined state or remain in the free form.

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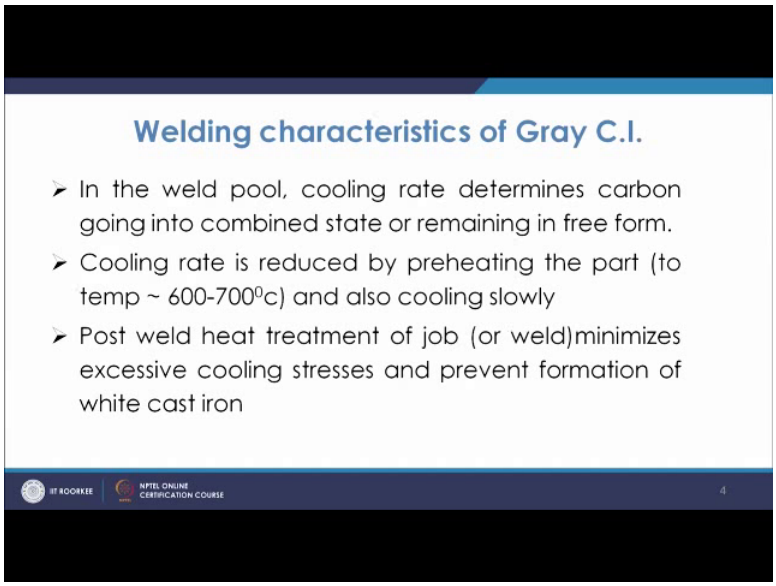

So, as you know that when the cooling rate will be larger, then you will have the chances of formation of the you know white cast iron or the carbon going into the combined form. And if it is the cooling rate is slow, in that case carbon will a convert into a graphite the graphite form and in normal case you will have the graphite flakes.

Now, depending upon the silicon percentage also, this conversion of carbon either into combined form or into the graphite flakes form is decided. And basically many a times even if you have wood the amount of silicon, but if the section thickness is small and the cooling rate is large, in that case also you have the chances of becoming you know white cast iron or the carbon going in the combined form.

So, basically the cooling rate will have to be reduced if you find or if you are thinking of having they gray cast iron type of structure or in the carbon going into the graphite form otherwise will be in the F e 3 C forms combined form.

So, that can be you know achieved by reducing the so, cooling rate you can reduce by preheating the part and also cooling slowly. So, one of the method of decreasing the cooling rate is, that you preheat the component up to certain degree. So, once you are preheating the component and you do the welding. So, when you are doing the welding certainly the metal is getting fused in that zone. So, it is about the melting temperature of the materials from there it will start getting solidifying.

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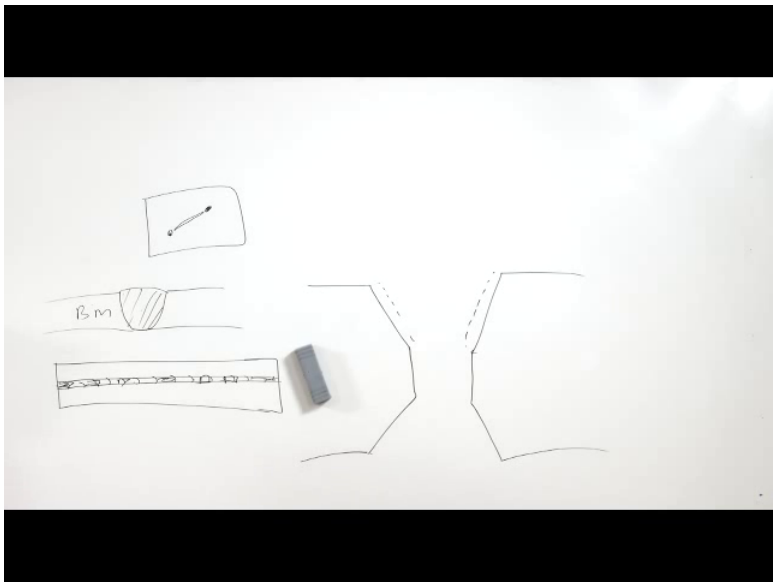

Now, from there if you have the so, if you suppose you have this as base metal and this is your weld metal. Now, in this case so, this being a close to the solidus temperature or in the liquidus temperature. So, now, here if this is higher, in that case the thermal gradient will be smaller. The difference of the temperature between this point and this point will be smaller, if you are preheating this component.

So, that is why one cooling rate a can be made smaller by doing some preheat of these components on both the sides. And normally a temperature of about 600 to 700 degree centigrade has been found to be satisfactory; you know when you are basically cooling the material. So, that way you have the chances of a retaining that graphitic form. Then you also go for the post weld heat treatment of the cast iron and post weld heat treatment of job will minimize the excessive cooling a stresses and prevent formation of white cast iron.

Now, you know post weld treatment is something like annealing of treatment. So, normally the stresses which are generated or residual stresses are there they will be smaller, if the stresses are larger then they will aid in the propagation of the crack and further the final fracture of the component so, basically what you. So, that is why we go for the post weld heat treatment and that way you try to reduce the excessive a cooling you know stresses and prevent formation of the white cast iron; other techniques for the welding of gray cast iron.

So, other techniques which are considered to be suitable when we try to well degree cast iron are, like use of suitable even non ferrous electrodes of lower melting point than gray iron. So, this way if the temperature the maximum temperature achieved peak temperature achieved is less, in that case the chances of you know rapid heat transfer or cooling rate high cooling rate or the formation of stresses that will be at smaller level.

So, that is one of the a method; then use of a skip welding to minimize heating of gray iron component.

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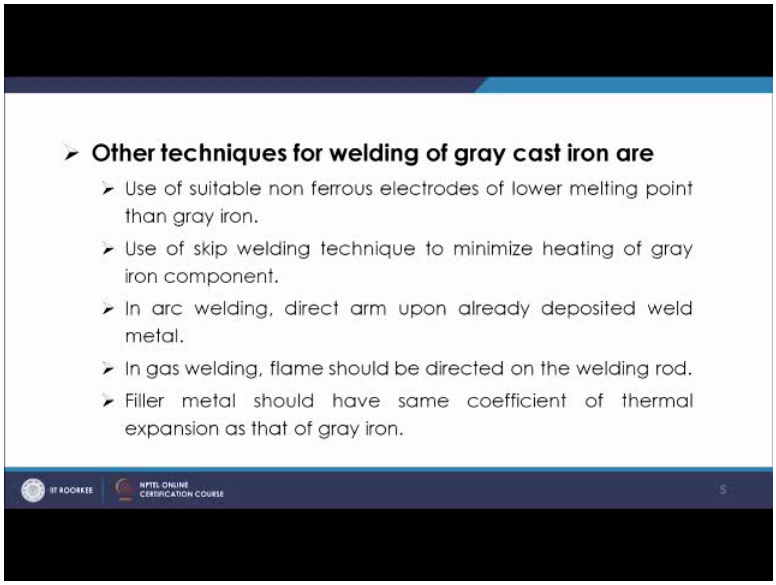

So, what we do is many a times we go for skip welding technique what is skip welding technique? Now, in the case of skip welding technique, you know weld is deposited in the part of the seam and a we do not do it in the continuous manner. So, what is there that, skip welding means if you are you have a weld bead like this. So, in the case of normal case you weld from this side to this side. So, this is this is type of seam.

So, when we go for continuous welding or seam welding, in that case in normal case you go from welding and this side to that side , but then in the case of this gray iron gray iron welding the skip welding is very popular in the sense that if you have the larger large seam. First of all you have the different zones, which is identified because of the presence of the tack wheels. So, tacking is another you know practice in the case of long welds because otherwise there will be chances of the you know deformation of these. So,

we have discussed about distortions in that case either the two shifts may go like this or it may be going like separating apart.

So, that type of situation may come so far that, we do the tack welding the; suppose we are doing a tacking at different points, now the thing is that step welding means we do not do the directly the welding from this to this, rather we will do fast welding here, we can do the next here, 3rd will be here, then 4th will be here, 5th will be here, 6th will be here or 7th will be here like that if you have certain zones.

So, that is known as the skip welding technique, this is basically the to minimize the heating of this gray iron component. So, this skip welding is very one of the very important type of you know practice, which is implied in the case of a skip welding a then. So, this is how that skip then it is also seen it is a good practice to see that in the arc welding, you have to direct the arc upon already deposited weld metal. So, that is basically doing the same purpose as that of annealing.

So, already deposited weld metal you do go in that case, that it will that. So, one of the other way to see that the weld is having less you know amount of residual stresses is, that you do the arc welding the arcs should be directed upon the already deposited weld metal. So, this way once it goes the flame is or arc is directed on the already deposited weld metal it does like the annealing treatment so that very stresses or stress relieving is done.

Similarly, the flame should be directed on the welding rod is there in the case of gas welding and filler metal should have the same coefficient of thermal expansion as that of gray iron, because if the filler metal is having the same a expansion coefficient, in that case the chances of you know any type of distortion or we go or the residual stresses formation will be less. What are the process for the gray cast iron?

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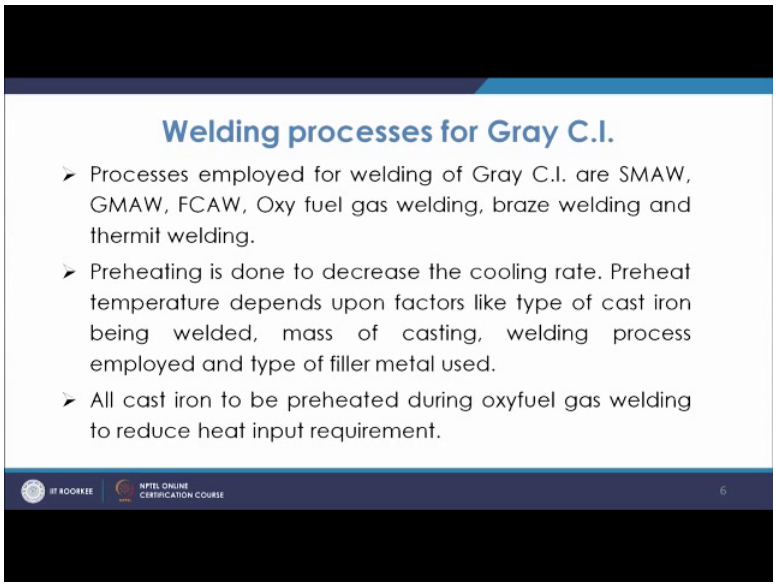

So, process which are implied are the weld the SMAW that is Shielded Metal Arc Welding, gas metal arc welding, flux core arc welding, oxy fuel gas welding, braze welding and thermit welding so, most of the processes are basically you know adopted for the welding of gray cast iron. Preheating is done to decrease the cooling rate, and if the preheat temperature will depend upon factors like type of cast iron being welded, mass of casting welding process implied and also the type of filler metal used.

So, basically a that will be the parameters which will be decided that what should be the preheating temperature. All cast iron is to be preheated during oxy fuel gas welding, to reduce heat input requirements. Now, the thing is that in the case of oxy fuel gas welding, as we know that the temperature higher the maximum temperature is smaller as compared to the arc welding. So, it takes a larger time to basically do the welding. So, for that you have to direct the flame for larger amount of time and that increases the chances of deformation in the component.

So, basically when if you preheat the component to suppose 6 to 700 degree centigrade, then that heat requirement may heat input requirement becomes less. So, that is a master, I mean that normally the practice when we see a in the case of the cast iron components. Local preheating should be gradual to avoid cracking especially in complex castings.

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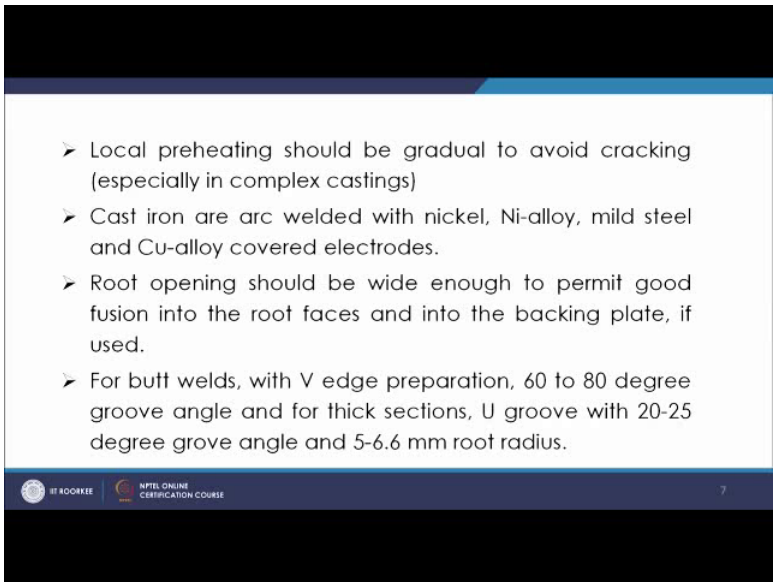

Now, when we do the preheating; So, it is locally, in that case the it should be gradual otherwise again the thermal gradient may develop and because of the value of residual stresses or stresses developed and that may lead to the car the cracking.

So, that preheating what we do is normally done in a gradual manner. Cast iron are arc welded with nickel, nickel alloy, mild steel and copper alloy covered electrodes. So, they are arc welded with all this type of electrodes. Root openings should be wide enough to permit a good fusion into the root faces and into the back plate backing plate if used. So, that you have a good strength being developed.

So, that is why your root opening has to be wide enough. It is seen that now in the case of, but Wales the for the vias preparation, a value of about 60 to 80 degree of the groove angle is there and for thick section in the u groove, you have something like 20 25 degree and then groove angle and then 5 to 6.6 mm of root radius.

So, that that is defined and that has been shown that it will give you a good you know strength of the joint. When repairing crack at castings a hole about 3.5 mm or larger in diameter, should be drilled at the end of each crack to prevent its further propagation. So, a means when we are doing the repairing of crack, then we have to ensure that this crack should not be you know propagate or this should not extend. Suppose you have a casting and you have a supposed crack and this is to be basically welded. In that case what it

tells that a hole of about 3.5 mm or larger in diameter, should we drill that end of his crack to prevent its further propagation.

So, basically you should have this hole drilled and so that this does not further propagate towards the ends. So, that a it does not propagate while welding and then you do the welding because the crack when you are doing the welding otherwise from one side and from the other side that may go and then get you know extended in certain direction.

So, for that we must see that this on the both the side we are having some type of hole so that it does not further you know proceed. Electrodes will be manipulated so, that so, the bead width is not greater than a 3 times the nominal diameter of the electrode. So, that a you know these are the standard data like you must have the bead width not greater than 3 times the nominal dia of the electrode.

And for filling larger cavities the sides should be buttered with weld metal first and then cavity gradually filled towards the center of the repaired area. What it means is v that when we are making the weld and you have a very a large a weld metal zone which is to be filled.

In that case many a times first of all we do the buttering of the layer so, , this is known as buttering especially when you have the joints like double v joint. So, suppose you have the joint like this. So, now, in these cases this is a double v joint and in these cases u its very large. So, now in these cases the practice is that first of all you do some buttering.

So, this is known as. So, that is what the buttering is; a when we have the larger cavities the sides should be buttered with weld. So, first of all weld metal we are providing in the sides so, that this becomes narrower and then finally, you should filled the. So, that is what the buttering means.

So, first you go for making a layer on the sides, and then slowly. So, you can have further the buttering layers and then ultimately you filled the center of the repair radius that is how the practice is followed back step welding sequence provides better results for large castings.

Now, the thing is back step welding means we discussed about the skip welding. Now, back step welding means if the welding the direction is this, if this is the welding

direction is this, now back step welding means the welding is carried out in this sections. So, this is how the welding should be done.

Now, the thing is that this back step welding technique is preferred they are giving the good results for the. So, back step as well as the skip welding provided together. So, first welding sequence will be like this, then you will have this, then further you will have this, then you have this side this side and this side and this side like that we do the welding.

So, back step welding sequence and skip welding together they provide good you know welding practice and back step welding basically is giving quite satisfactory results in the case of these large castings. Now, to reduce the strain caused by deposition of long bead deposition of weld metals should be in the short length and allow each bead to cool down before laying the nest.

So, that is what also a you know first the first layer, and next layer when you give then you see that it should be allowed to cool down before that, you are we also do the upsetting and pinning of the deposited weld metal a lightly so, before it cools and contracts.

So, that is another alternative for getting a good weld combination of sort weld and pin that is also so, sort welding and then pinning. So, that is also a good practice while we do the cast iron welding. Buttering and studying; now buttering we have already known, then studying is another practice where a we can see this, this is the studying practice. So, this is the sequence of laying sort bead lengths.

So, with this is how we can have a sort bead lengths first, in opposite side then this is the second, then this is third, then fourth, fifth, sixth, like this and then this is the studying.

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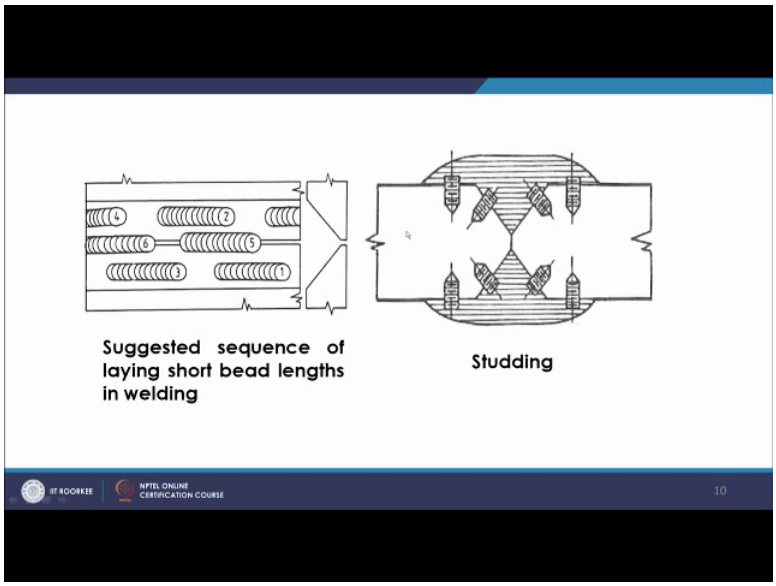

So, in the case of studying what we do is, you provide these studs you know that gives extra strength. So, that studies first put in and then around that the weld metal will be deposited and they will have the bound. So, this way you get this welding carried out and that this property is known as studying. So, these are the normal practices which are followed in the case of the welding of cast iron components.

You can study more about other issues like what are the different you know processes which are followed and then supposing we are doing the gas welding or we are doing the brazing or so, we will have the choices of fluxes, cleaning of fluxes then clean you know these are the standard you know precautions which are required. So, that can be studied and you can have more and more details about them.

Thank you very much.