Welding Metallurgy
Prof. Pradeep K. Jha
Department of Mechanical and Industrial Engineering
Indian Institute of Technology Roorkee

Lecture No. 54
Weldability of Cast Iron

Welcome to the lecture on weldability of cast iron. Apart from steel, if you talk about the ferrous components, then cast iron is one of the very important materials among the ferrous family, and we must be conversant with the weldability aspect of the cast iron. So, first of all, we will have some knowledge about the cast iron family. As we know that the cast iron is a family of ferrous alloys that normally contains more than 2% carbon and 1 to 3% silicon and also it has a small amount of sulfur and phosphorus.

So, basically, when you go from 2% carbon onwards it is the family of cast iron. And also silicon is also playing very important role in the case of cast iron. So, if you talk about the variety of cast irons. So, basically, you have four types of cast iron.

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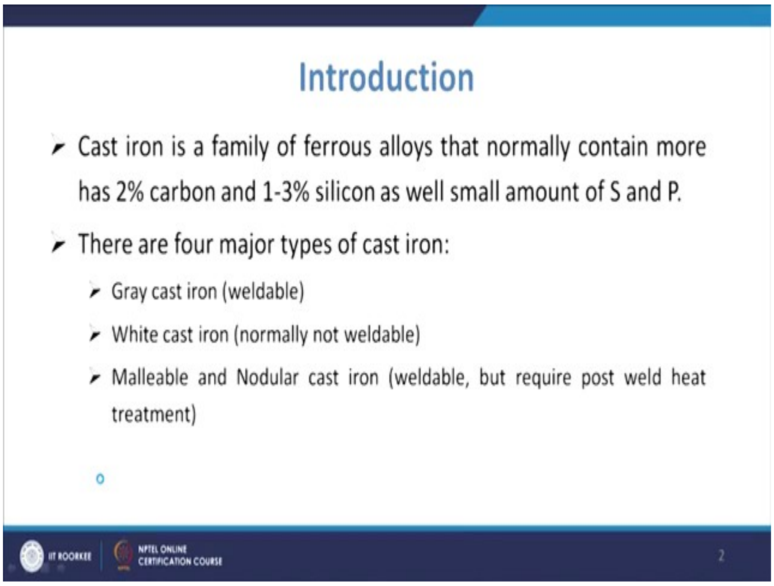

You have the gray cast iron which is weldable and we will talk about its traits later. Then, you have white cast iron which is considered having very poor weldability. Then you have the malleable cast iron and then you have the nodular cast iron. So, you have these four types of cast iron which are available as the types of cast iron. Malleable and nodular cast iron they are weldable, but they require post-weld heat treatment.

Now, if you talk about the gray cast iron, as you know, in the gray cast iron you have graphite flakes. Graphite is in the form of flakes. So, it will be showing the gray fracture surface, that is why it is known as the gray cast iron.

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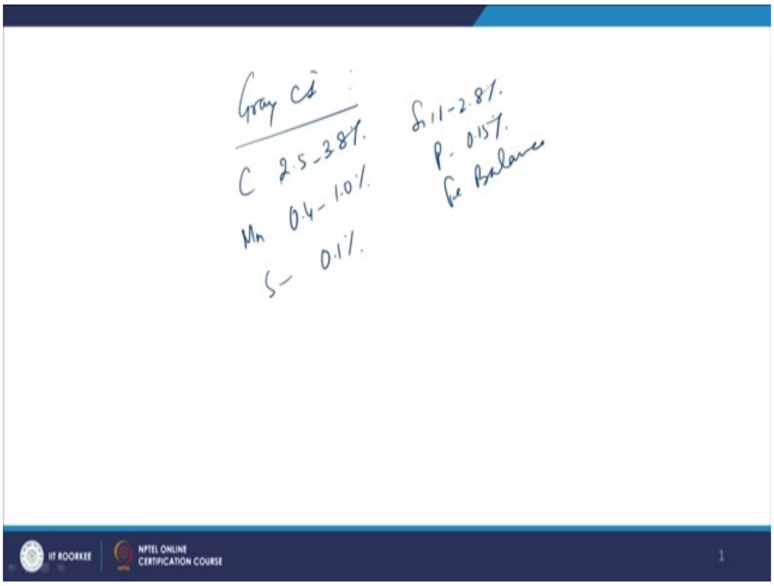

If you talk about the gray cast iron, the typical percentage carbon is about 2.5 to 3.8%, silicon will be 1 to 2.8%, then you have manganese as 0.4 to 1%, phosphorus is 0.15%, sulfur is 0.1%, and iron is balance. What you see is that you have the carbon and silicon are in considerable amount. Anyway (carbon + silicon)/3 is also defined as the carbon equivalent, even phosphorus also is taken into account in that way.

So, basically, you have the gray cast iron which has this composition as carbon is about 2.5 to 3.8%, you have silicon as 1.1 to 2.8%, manganese 0.4 to 1%, phosphorus 0.15%, sulphur as 0.1%, and then rest is iron. So, basically, the role of these elements are there, carbon and silicon primarily, you will have the graphitisation which is promoted by the presence of these and then phosphorus is for the fluidity and all that.

Accordingly, we define these materials, they have carbon in flaky graphite, and so you will have the free carbon in the graphite form that is in flaky form. Then, they are easy to machine, they have other good damping properties and all that.

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- **Gray cast iron**
  - ✓ Difficult to weld economically
  - ✓ Major application areas are
    - ❖ Repair of castings in foundry
    - ❖ Repair of casings damaged in service
    - ❖ Join together separately cast sections
- **Malleable cast iron**
  - Welding destroys advantages of annealing treatment
- **Nodular cast iron**
  - Chances of magnesium loss, Minimize heat input to avoid graphite degradation

Now, coming to its welding characteristics, it is probably among the most difficult among the metal which can be welded economically. That is because, what is happening is, especially in the gray cast iron you require the formation of graphite that is to be done at a very slow cooling rate and that is again a challenge in the case of gray cast iron. You have also very much use of the welding of this parts because you have a high number of parts whose service is required.

So, many a times you require their application in the area of foundry where you do repair, you have to do casings damage and you have to join together many cast sections. So, this way their use will be there. So, that way they are very important element among the variety of cast irons. If you talk about the malleable cast iron, in the malleable cast iron your carbon again in the free form, so it will be in temper form. Here, you will have quasi spheroidal type of carbon that is tempered carbon.

It is made from white cast iron. Since white cast iron can be used, so we use this malleable cast iron by giving proper heat treatment to this material. And when you are doing welding of the malleable iron, then it will be destroying that heat treatment. The heat treatment which is given to white cast iron for making the malleable cast iron, so when we are doing welding of such steels, basically that will be negating the effect of what heat treatment which we have given to these kinds of materials.

So, in these type of materials you have lesser value of the silicon because in this case the carbon we are getting from white cast iron. In white cast iron itself you have less silicon because silicon is the graphitiser. So, silicon will be in the range of 0.6 to 1.3%, you have carbon also on the lower side maybe about 2.3%, then you have manganese also less, 0.2 to 0.6%, phosphorus is 0.15%, and sulphur is 0.1% as usual.

That way, you have these malleable iron castings. Then, another type of cast iron which is important is the nodular cast iron. Nodular cast iron, as you see, in the case of gray cast iron you have the flaky graphite, whereas in this case you have the graphite which is there in the form of spheroids. So, you will have nodular appearance of the graphite. That way it is known as nodular graphite.

Most of the welding which is done is normally on the gray cast iron and very less is done on the malleable and the nodular iron. Now, we will talk about the welding characteristics of the gray cast iron.

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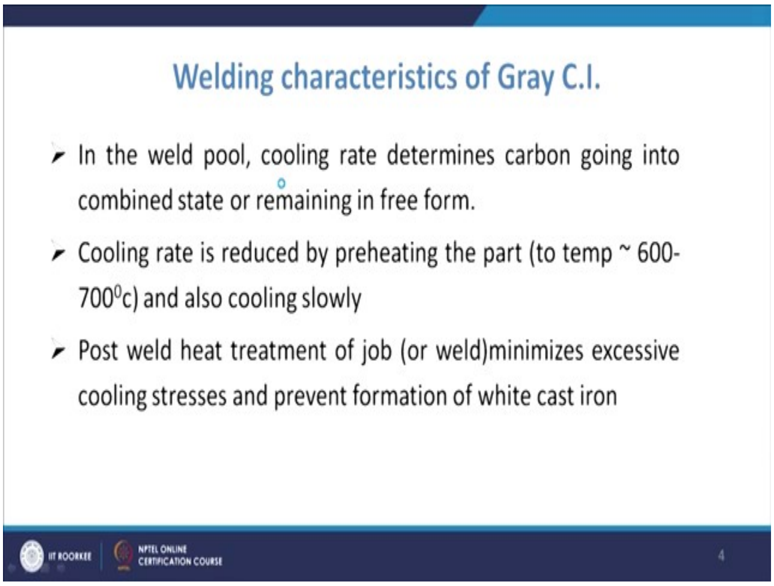

If you see in the weld pool, the cooling rate determines carbon going into the combined state or remaining in free form. So, certainly, as we know that when you are increasing the cooling rate, then most likely you are going to have the carbon going into the combined forms, it will make Fe_3C and the whole purpose of making the gray cast iron is lost. That is what is happening normally in the case of welding.

In the case of welding, in normal case, the cooling rate is higher. So, it is very difficult to have the formation of graphite under higher cooling rate conditions. So, you will have to reduce the cooling rate and that normally is done by preheating the part to a temperature of may be about 600 to 700 °C. And then also you have to have the cooling slowly. So, that is the process which is followed while doing the welding of the gray cast iron.

And also we do post weld heat treatment of the job that will minimize the excessive cooling stresses and prevent the formation of white cast iron. That is what is normally desired because in this case, if you are not giving proper heat treatment, there is likelihood of the formation of carbon in the combined form, that is your Fe_3C. That is what we normally do when we are talking about the welding of the cast iron.

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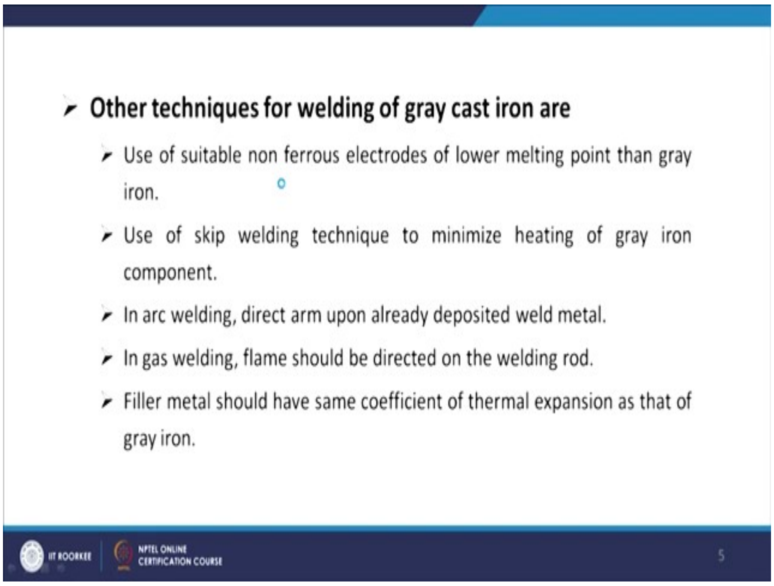

Other techniques for welding of gray cast iron, so that is what we normally do, is that we use suitable non-ferrous electrodes of lower melting point than the gray cast iron. So, that is one way which we do for minimizing the excessive cooling rate. By this process we can do that. We do the use of skip welding technique to minimize heating of gray iron components, as we have understood that we go for skip welding as well as we go for back-step.

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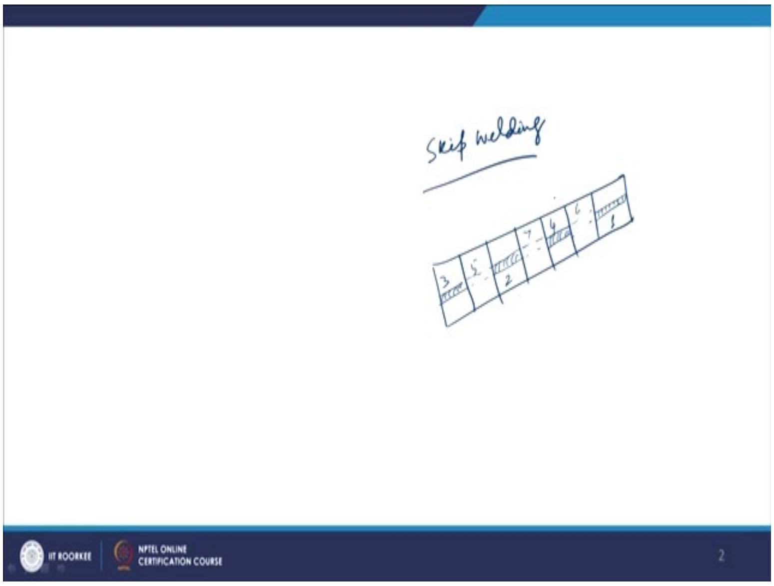

Normally when we talk about the skip welding what do we do is that, if suppose you have a plate and if you are making the weld beads, so you will have different sections. Suppose these are the seven sections, so, what we do normally is that you go for skipping, one part of the seam and then another part will be welded which would be away from that particular part. Suppose you are doing the welding, so you will be welding this part initially, and then you are leaving, you are not doing here, but rather you will be doing this.

So, this is your skip welding parts. Suppose, this is 1, then this will be 2, then you go to the third part. So, that way you will be doing this as the third part. Then, you can go for the fourth part like that. So, you are not doing continuously. That way the fourth, then you start 5, and then you for 6, and then you go for 7. That way, we use this skip welding technique and we also do preheating, may be 600 to 700 °C.

That is preheating is done in these cases. And we can also have good quality insulating, so that may be covered with good quality insulation so that you have good quality welded joints in these cases. Then, in arc welding, you direct the arc upon the already deposited weld metal that is normally what we try to have. So, we use to have the direction of the arc directly upon the already deposited weld metal.

So, that is a type of post weld heat treatment in one sense. Then, the filler metal which you are employing, that also plays a very important role and they should have the same coefficient of thermal expansion as that of the gray cast iron. So, whatever filler metal you are choosing they must have the same type of thermal expansion as that of gray cast iron. So, in that case, the undesirable effect will be minimum.

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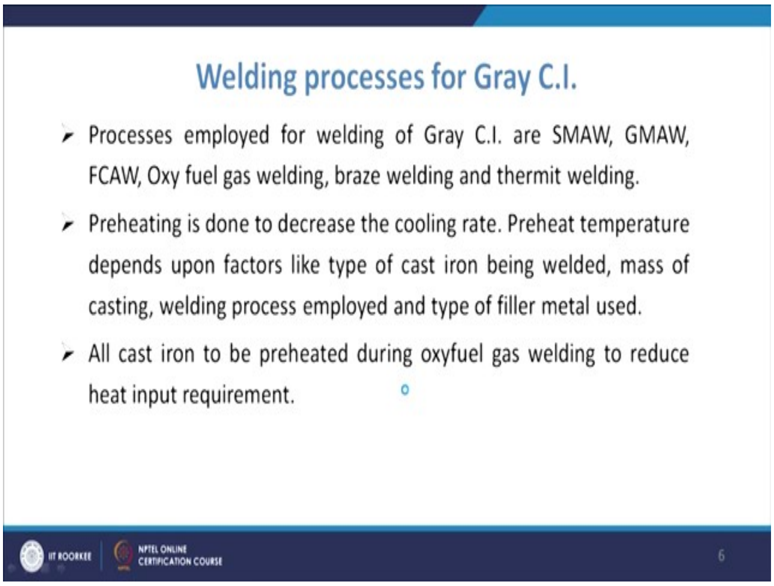

Coming to welding processes for gray cast iron. The processes which are employed for the welding of gray cast iron are shielded metal arc welding, gas metal arc welding, flux-cored arc welding, oxyfuel gas welding, bridge welding, and thermit welding. So, all these processes are used and can be used for the welding of such cast iron. Then, you have preheating. So, preheating we are doing to decrease the cooling rate.

So, it will be depending upon the factors like type of cast iron being welded, mass of casting, then welding process employed and type of filler used. So, these points are to be taken into account. Then all cast iron to be preheated during oxyfuel gas welding to reduce the heat input requirement. In those cases, what you do is, first of all you do the preheating so that your heat input requirement will be smaller. So, that is what we follow in the case of cast iron welding.

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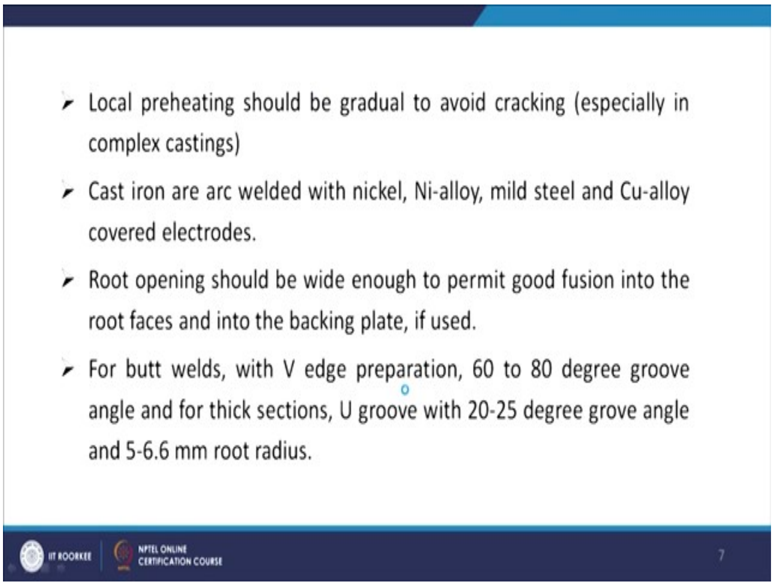

Then, we have already seen that local preheating has to be gradual so that your cracking is avoided especially in complex shape of castings. Cast iron are arc welded with nickel alloy, mild steel, and copper alloy covered electrodes. Root opening should be wide enough to permit good fusion into the root faces and also into the backing plate if used. For butt welds, with V edge preparation, 60 to 80° groove angle and for thick sections, U groove with 20 to 25 =° groove angle, and 5 to 6.6 mm of root radius.

So, these are basically the dimensions which should be followed normally for welding conditions when you do the welding of the cast iron components.

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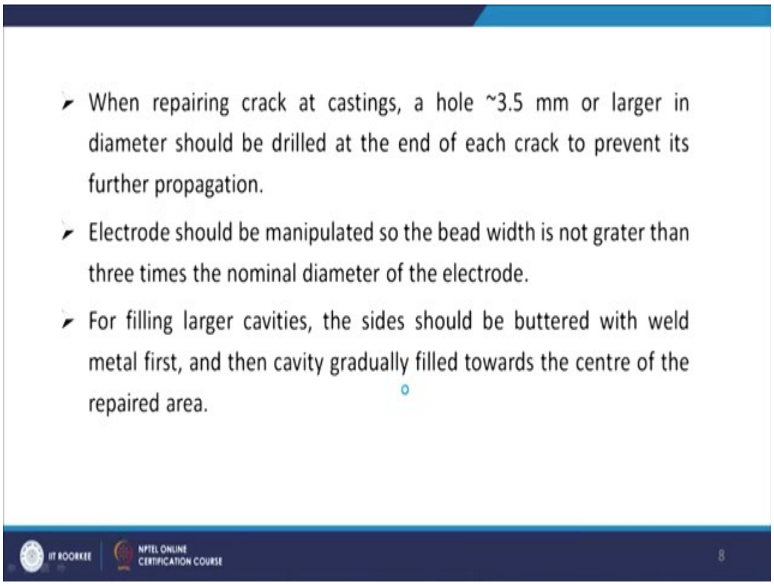

Then, next, when we are repairing the crack or the castings a hole about 3.5 mm or larger in diameter will be drilled at the end of each crack to prevent its further propagation. So, that is another way to avoid the propagation of these crack because in the case of the cast iron there is chance of crack propagation and because they are brittle materials so that way it becomes even more severe.

So, in those cases, there is a practice that you must have the diameter of about 3.5 mm or larger which should be drilled at the end of the crack and then you can prevent its further propagation. Electrode has to be manipulated so that the bead width is not greater than three times the nominal diameter of the electrodes. From design point of view it is important to know what should be the diameter of the electrode chosen depending upon the bead width.

For filling larger cavities, the site should be buttered with weld metal first and then cavity gradually filled towards the center of the required area. That is basically the buttering which is done. So, when you have larger cavities, in those cases, the sites are first of all buttered with the weld metal, and then you are filling the cavity gradually towards the center of the repaired area.

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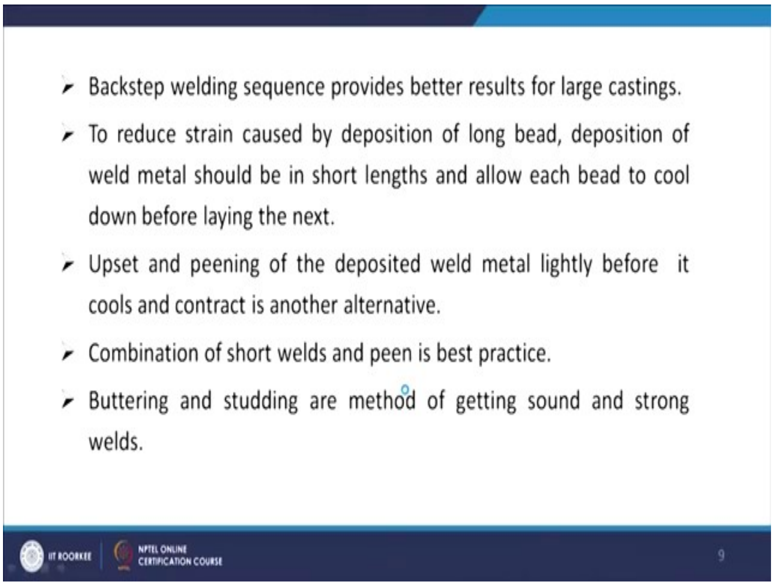

Coming to the type of welding, as we have discussed that back-step welding sequence will be providing you better results for large size castings, and to reduce the strain caused by the deposition of longer bead, deposition of weld metal should be in short lengths and allow each bead to cool down before laying the next. That is what the skip welding process tells because as we have seen earlier that when you are dividing this whole length into different sections.

Then you should aim to avoid welding in continuation in all the sections. So, basically, that way you can reduce that strain because of the deposition of the long bead. So, you are doing the weld metal in shorter lengths, and then you are allowing that bead to cool. That was skip welding, but here what we do is we do small length welding, and then we are stopping for some time, and then further. That way, you will have reduction in the strain.

Upset and peening of the deposited weld mental lightly before it cools and contracts is another alternative. As we have seen that we follow certain methods like upset or peening also because that peening process will be giving compressive stress and that basically will try to blunt the cracks which are microcracks which are likely to come up after the welding. That is another alternative which is being followed in this situation.

Combination of short welds and peen is basically the best practice, that is what we have seen. We should go for short weld and then do also peening. Buttering and studding they are methods of getting sound and strong welds. So, what we have seen is that we have studied buttering process where we are doing first the buttering layer and then we go for the final weld metal towards the center. And also we do the studding, so that is what we do normally.

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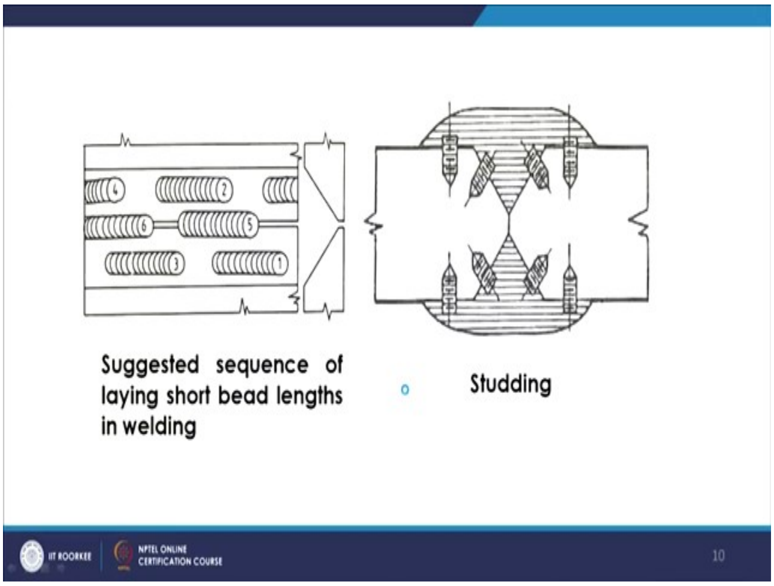

We are doing studding to give quite a good strength in those cases. So, here it is showing the short bead length which is being provided and this is studding way, this is a good way of welding of welding practice.

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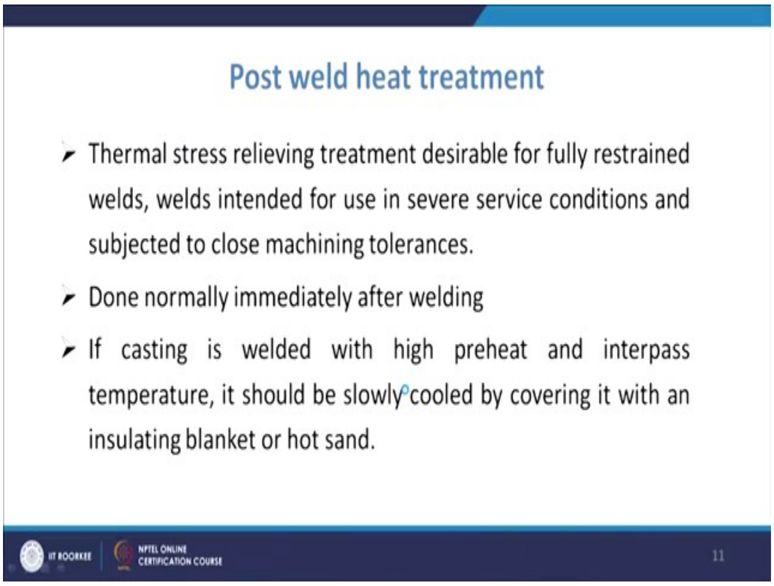

Then, we also go for the post weld heat treatment and thermal stress relieving heat treatment is desirable especially for the fully restrained welds. And then these components are supposed to be used where there is close machining tolerance. In those cases, you have to have stress relieving treatment as a necessity. This is done normally immediately after the welding and if the casting is welded with high preheat and interpass temperature, it should be slowly cooled by covering it with an insulating blanket or hot sand as we have discussed.

So, if you are insulating that, in that case, the thermal gradient developed will be smaller and in that case the chances of defect will be smaller.

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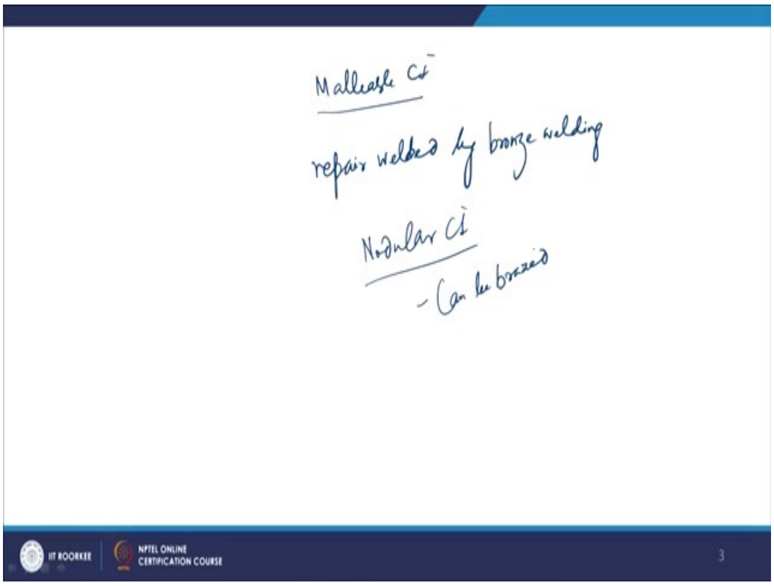

Now, if you talk about the welding aspect of the malleable iron, if you talk about the malleable cast iron, in this case what is this happening is that you are doing annealing heat treatment and then you are getting temper carbon structure by decomposition of the combined form that is Fe_3C. If you are welding and if the temperature is exceeding 760 °C and that is likely to be, so in that case, the metallurgical structure of heat affected zone part where it is going back.

So, because of the further large cooling rate that structure will be again becoming white cast iron. This is not desired, in fact, because you have given a large annealing treatment and you have made these malleable cast iron from white iron. So, basically, you should not heat these malleable iron above that temperature. Otherwise, you have to go for malleablizing treatment.

That is not very much justified economically because that takes a large amount of time. But if that is the case, in that case, you have to go for heating around 850 °C, hold there for an hour for each 25 mm thickness, and then you are cooling in the furnace still in the 600 to 727 °C, that is your lower critical temperature. There you are further allowing it to be hold for large time, may be for 5 to 6 hours and then further you are cooling.

That is what the annealing cycle is there for making malleable cast iron. That you have to follow. Most of these malleable cast iron they are repair welded. So, normally you have to do repair welded by bronze welding. So, this is normally used and you use the cast iron rods for worn parts. If you go for oxy-acetylene or arc welding, then they pose difficulties because the temperature will go above 760 and then you will have to go for malleabilizing treatments.

So, that is normally for the malleable cast iron. If you talk about nonpolar cast iron, nodular cast iron also is facing the same kind of difficulty as being faced by the malleable cast iron. In the case of nodular cast iron the nodularisation is being done by elements like magnesium, and when you are basically heating in that case if there is loss of magnesium, then this nodularisation is gone.

And when you are basically doing the welding, depending upon the cooling rate you will have the formation of white iron mostly, and may be gray iron if you are maintaining the cooling rate by preheating or so. But then, the nodularisation is basically gone because of the loss of Mg. So, what we do is, in the case of nodular cast iron, normally they can be brazed. So, we do the brazing of these components.

We normally avoid gas welding of these components because, again, the same thing which is happening in the case of the malleable iron, similar problems may be encountered in the case of even the nodular cast iron. Apart from that, you have also alloy cast iron which are similar to the gray cast iron they are also welded. The parent metal competition has to be there. So, if the filler composition is near to the parent metal composition mostly it is the preferred one.

So, this is mainly about you know, we discussed about the weldability aspects of the cast iron family. Thank you very much.