Welding Metallurgy
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Lecture No. – 55
Weldability of Non Ferrous Metals and Alloys

Welcome to the lecture on weldability of non-ferrous metals and alloys. So, we have already discussed about the weldability issues in different materials, mostly they are ferrous based. We talked about steel, we talked about cast iron, we talked about alloy steels. We also have the idea about the weldability of non-ferrous metals because they are very much one of the important materials because in many sectors we use to see because of their inherent advantages.

They are made of non-ferrous materials, and once you have the materials, then certainly you need to know the weldability behavior of these materials. So, prominently, we will talk about the weldability issues in materials like aluminium, copper, magnesium, these materials which are mostly used because of many advantages and we will have some idea about these welding aspects. First of all, we will have the weldability aspects of aluminium and its alloys as far as the properties are concerned.

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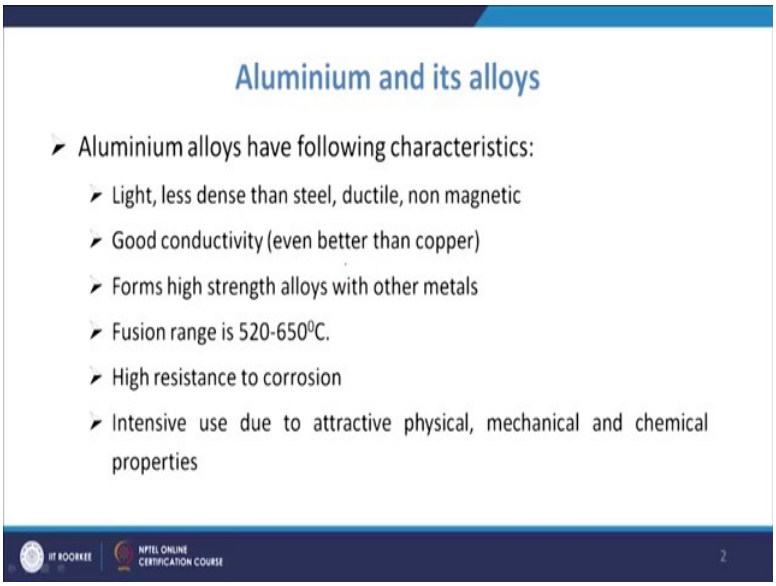

We know that aluminium is a silvery white material and it is a light metal which has very less density, even about one-third of the density of steel. It has very good ductility and also it is non-magnetic. Then, it has very good conductivity. Even its conductivity is better than that

of the copper. That is again another advantage, but then that may be challenging also when we talk about welding aspects.

So, we will talk about it, how these properties whether they are becoming a challenge or they are the qualities which we relish. Then, one of the very important thing also with aluminium is that it is forming very high strength alloys with other metals. That gives this material a very high advantage because when it is alloyed with some other materials.

Then the strength is quite high, and with lesser density it can be seen that you are getting very good properties of the component which is made from these alloys. So, that is one thing that in most of the cases, unless you require high ductility value or may be very high conductivity, in most of the cases we try to use aluminum alloys as it has this tendency that it is able to form very high strength alloys with other metals.

Even another added advantage is that you are able to have a variety of alloys which can be used for the different applications. Then, if you talk about other properties, if you see that it has very high resistance to corrosion, as compared to many other metals it has a very high value of resistance to corrosion. This is because of the protection by the thin oxide film that is formed on the surface itself. So, because of that, it has a very high resistance to corrosion.

Then, the fusion range is basically between 520 to 650 °C and melting point is close to 670 °C, or 660 to 670 °C. So, that is your melting point. Because of all these properties you have intensive use of these materials like aluminium. That is they will be becoming alloy with many elements like copper, chromium, then you make it with nickel, even iron, zinc, manganese, silica, and with them they are making a variety of materials.

And many a times when you talk about the strength of these alloys which is made by combining with other elements, they are approximately four times stronger than the same weight of mild steel or the iron-based lies. So, that is the advantage of such materials or alloys which is being developed by aluminum with the different alloying elements. You must have the idea about where they are used. Aluminum has use in many industries.

Because of its varying properties it has extensive use in different industries like you use in the transportation industries, you know, all these components are made by aluminum based

alloys. Then wherever you need conductors or heat exchanger parts, so, because of their high connectivity value you make these parts with aluminum alloys. Then, you also use in food industries, like in refrigeration equipments, you have storage containers, all these things are made by aluminium, even in the cryogenic applications we use aluminium parts.

So, that way, you have extensive use of these materials. So, we will talk about the welding characteristic of aluminum and its alloys.

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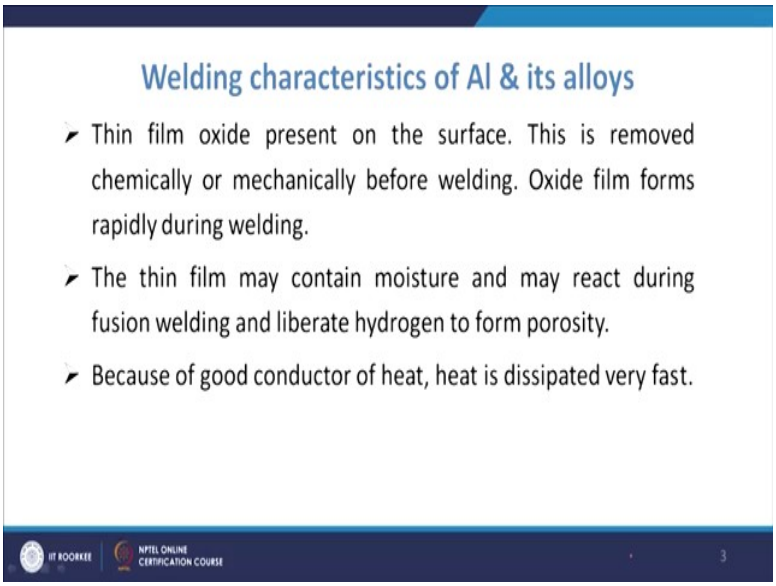

Now, what we earlier studied is that we discussed that there is a thin film of oxide that is present on the surface. So, this is removed chemically or mechanically before welding building because that basically is a protective layer for aluminum and that needs to be removed. So, you can remove it chemically or by mechanical means before the welding. And when you do the welding, then also you have rapid formation of these oxide films.

So, that is basically becoming a challenging job when you are doing the welding of aluminium. So, what is happening is that this thin film which is formed that may contain moisture and it may react during the fusion welding and liberate hydrogen to form porosities. So, basically that is the main challenge, the film which is formed may contain moisture and then once that comes in interaction with the heat then you will have the chance of the liberation of hydrogen and that will basically be forming the porosity.

So, that becomes a very, very, challenging job. So, you have to have eye upon this aspect because the type of welding process which you have to select it should be such that you have

to take care of that oxide layer. So, what you do is, normally you go for different means to remove that layer and for that we are taking the methods like brushing, then scrubbing, you know, these things we are doing before that welding.

We also take suitable flux during the welding or during the bridging operations. Suitable electrodes should be used. Normally we try to use DCRP, that is, electrode is connected to positive terminal, and it is found to be effective for MIG welding and AC is used for TIG welding. That is normally the practice which is being followed in the case of aluminum. So, what is happening is that if you take DCRP and use it in TIG welding, in that case, the tungsten electrode will be very much heated.

You know that when you connect to the positive terminal, then two-third of the heat is generated at the positive terminal. So, in that case, your two-third of heat is generated at the electrode and it gets overheated and there is no adequate melting of the metal. So, we use AC for the welding in case of TIG welding.

Another advantage is that when you use AC, in that case in half of the cycle the cleaning of oxide is carried out and that is done in the positive half cycle, and in the negative half the electrode gets cooled down and the base metal gets heated up so that we will have chance of adequate fusion at the interface. Another thing is that since it is a very good conductor of heat, it will dissipating the heat at a very very fast rate.

That is one property which is worth looking at because being a very good conductor as soon as you employee or as soon as you subject the heat at that particular position, that heat is getting transferred very quickly because of very high conductivity value. So, you have to have a proper way to control this heat loss so quickly from the joint. Normally, for that what you do is you take the nozzle somewhat larger, slightly bigger.

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- Nozzle slightly longer
- Convent value slightly longer
- Preheat of flue stack

So, mostly in the case of gas welding, or if you are using other type of welding processes, especially in arc welding, you take the current value somewhat larger. This is as compared to the welding of steel. And also that when you are doing the welding of thick seats, in that case, you try to preheat, because if you are doing the pre-heating, in that case, the rate at which the heat will be transferred that will be smaller because of the lesser temperature difference. So, that is the advantages of having these points in those cases.

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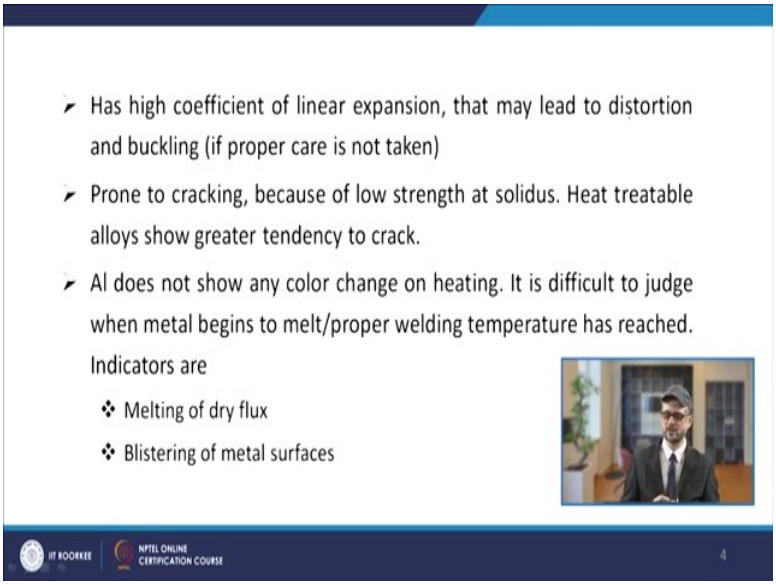

Then, the high coefficient of linear expansion that may lead to distortion and buckling. Again, it has a property that it has a very high coefficient of linear expansion. So, you will have the chance of distortion and buckling if you do not take proper care during that welding operation. So, you will have to have proper joint design, proper edge preparation, all that you have to have, and also preheating so that this cracking may be avoided.

Prone to cracking because of low strength of solidus, this is another problem, because when the temperature is high, so certainly its strength is quite low. So, it is very much prone to cracking when you have the temperature near the solidus. That is why when they are welding under restraint, then, the metal is likely to crack. So, that is a challenge in this case. Treat treatable alloys show greater tendency to crack.

So, in the case of aluminium, especially duralumin and all that alloys which are heat treatable, they show very much the tendency to crack. Then, if you are doing cold working, if have cold worked or pin worked weld metal, that is more attacked than the annealed metal especially under corrosive condition, when you have corrosive media. In that case, when you

have these pin metals are there, in those cases they are basically more likely to be having corrosion cracking under corrosive atmosphere.

So, that is there. Another challenge with aluminum is that it does not show any kind of change in the color. The challenge is that, in the case of aluminium, it does not show any color change on heating. So, many a times when you are doing the welding and there is change in color, in case of iron suppose, because of the change in the color you can have the feel what is the temperature, whereas in aluminium that is not the case.

So, because of that, many a times it becomes difficult to judge when is the metal beginning to melt or when the proper welding temperature has reached. So, for that you have to have the two indicators to the welders and these are basically the melting of the dry flux and the blistering of the metal surface because these two are indicating that the proper welding temperature has reached, and then you can accordingly take the immediate measure what has to be done.

Then, otherwise, if you look at the different temperature, different processes which can be used for welding and its alloys, so these are like oxy gas welding, metallic arc welding, resistance welding, carbon arc welding, you have brazing, then you have solid state welding, MIG welding, TIG welding, atomic hydrogen welding, all these processes can be used in the case of welding. So, mainly, we had the privilege to know the aspects about its properties which we will tell you, what precautions you need to take while welding aluminum because of its properties.

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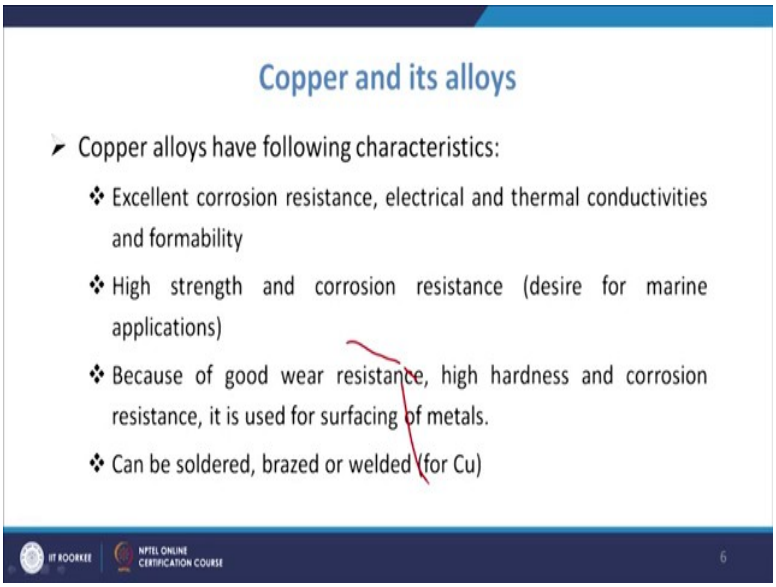

Now, we will talk about copper and its alloys and we will have the information about the weldability aspect of copper and its alloys. As we know, copper alloys have characteristic properties like they have excellent corrosion resistance, very good electrical and thermal conductivities, and also they have very high formability. Now, this high strength and corrosion resistance this property makes them suitable for marine applications.

That is another advantage of copper. Then, since it has very good wear resistance, high hardness, and corrosion resistance, it is also used for surfacing of metals. They can be soldered or brazed. These are the properties. Easily they can be polished, they can be plated easily because of very high conductivity. So, all these properties are there for the copper.

Now, if you talk about the welding aspects of copper, what you see is that copper has very very high thermal conductivity and that necessitates very high heat input into the parent metal because we have studied that for even aluminium also because there is a very large value of thermal conductivity it will basically increase the tendency of heat to flow very readily.

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Welding characteristics of Cu & its alloys

- High thermal conductivity necessitates high heat input into the parent metal (preheating of the parts may be necessary)
- Greater thermal expansion coefficients may induce residual stresses (advisable to go for slow welding speed or covering welding joint with insulating material)
- Tendency to absorb oxygen (to avoid oxidation problem, suitable flux or inert gas is necessary)

So, what you do is that, either you preheat or may be you have to give very high heat input to the parent metal to contract the defect, because if that will be dissipated fast, that may lead to undesirable results. So, we can have high heat input or you can also do preheating. Then, you have large value of thermal expansion coefficient. So, that again will induce the residual stresses.

Normally it is advisable to go for slow welding speed or covering the welding joint with insulating material. So, that is what the advice is in the case of copper that you go for slow welding speed or cover the joint with insulating material because the thermal expansion coefficient is high, so there will be more warpage because of the stresses which are generated. Then, further, it has the tendency to absorb the oxygen.

So, what is happening is that, since it has very much the tendency of absorbing oxygen, so for avoiding that problem what we do is we normally take suitable flux or even inert gases. So, that is the way by which you can have control upon this phenomenon like the oxidation problem related to the welding of copper. Apart from that, if you look at other properties, like if you say for copper, in the case of copper, molten copper that is considered to be more fluid as compared to molten steel.

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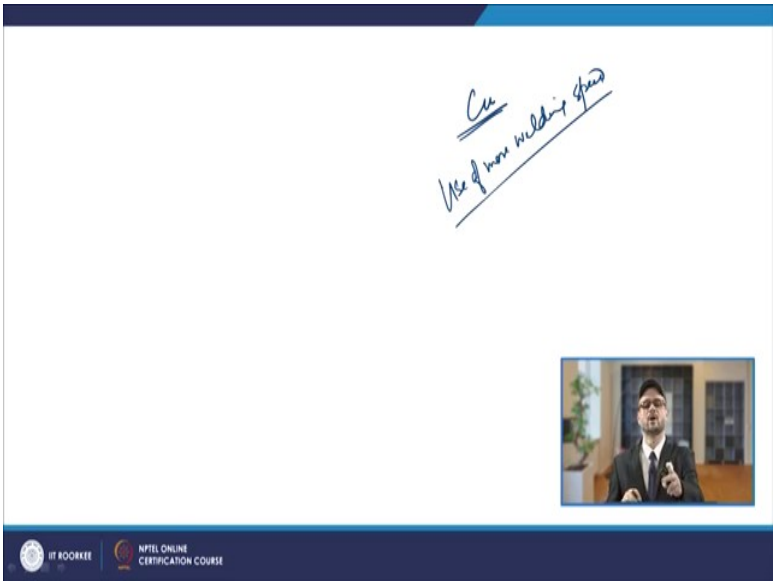

So you can have the use of more welding speed as compared to steel because in this case it has more tendency to be in the fluid state as compared to that of steel. So, this is that. Then, one more property is that it has very low relative strength at something close to above 482 °C, and so cracking may be developed in the copper because it has low strength at that temperature, I mean above that temperature or close to 500 degrees centigrade or above. So, the chances of cracking are there in those cases.

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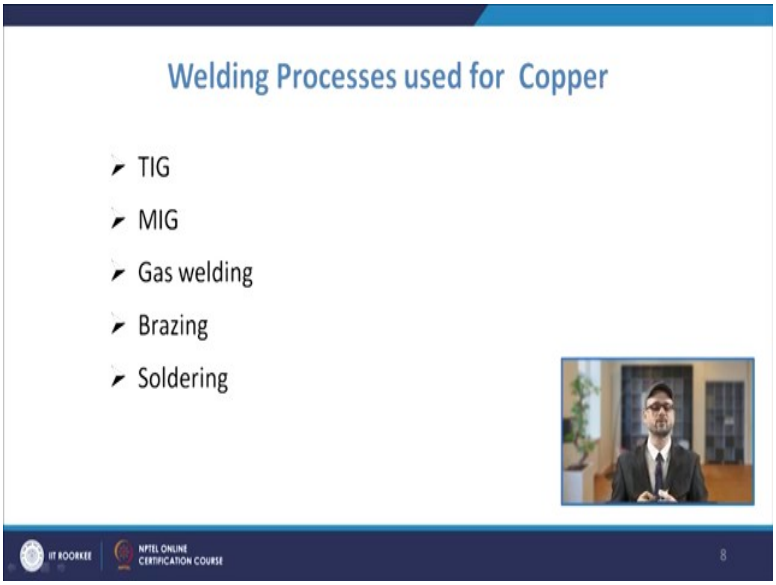

If you talk about the different welding processes which can be used for copper, they are TIG, MIG, gas welding, brazing and soldiering. They are the processes which are used for copper welding. So, next is the important alloy or the material which alloys are very much used are magnesium alloys.

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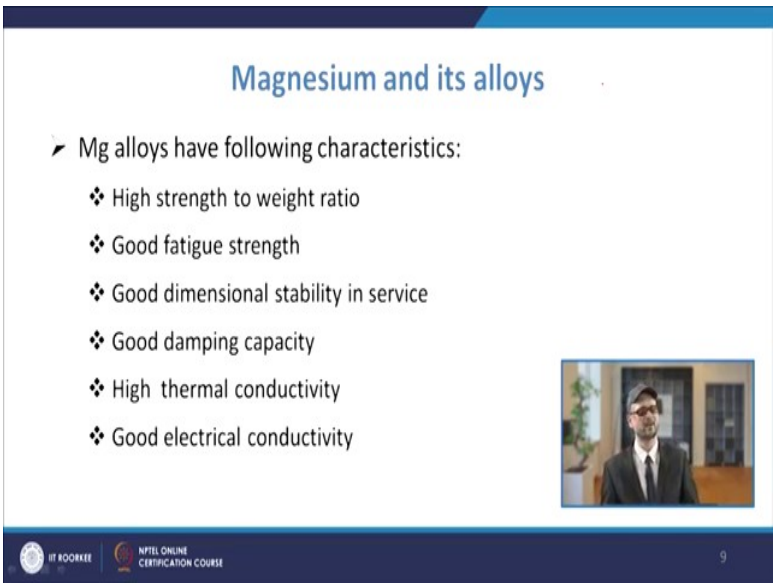

Now, magnesium alloys have the following characteristics like it has very high strength to weight ratio. It is also a silvery white material and it has very high strength to weight ratio. Its specific gravity is even smaller, it is even lighter than aluminium. It is only 1.74. So, you can have the idea how light it is. Aluminium lies about 1.5 times, like it has something close to 2.6 or so, and if you look at other materials it is even larger.

So, copper is about five times, iron is about four times or so. So, that way, what you see is that, it has very high strength to weight ratio, it has very good fatigue strength, it has also melting close to that of iron that is 650 °C , and it has very good fatigue strength. Because of their strength to weight ratio they are used in aviation industries or oil industries where you require saving in the weight.

Then, it has very good fatigue strength, so that is one very good quality of these materials. They have very good dimensional stability in service and also very good damping capacity, these materials. They have very high thermal conductivity and also they have good electrical conductivity too. So, these actually make them used in many applications like they are used for airframes, engine, then they are also used in marine applications.

Then, they are used in missiles, engine transmission pumps, then for the textile machines and printing equipment. Then, at many places we find the application of these alloys of magnesium that is used.

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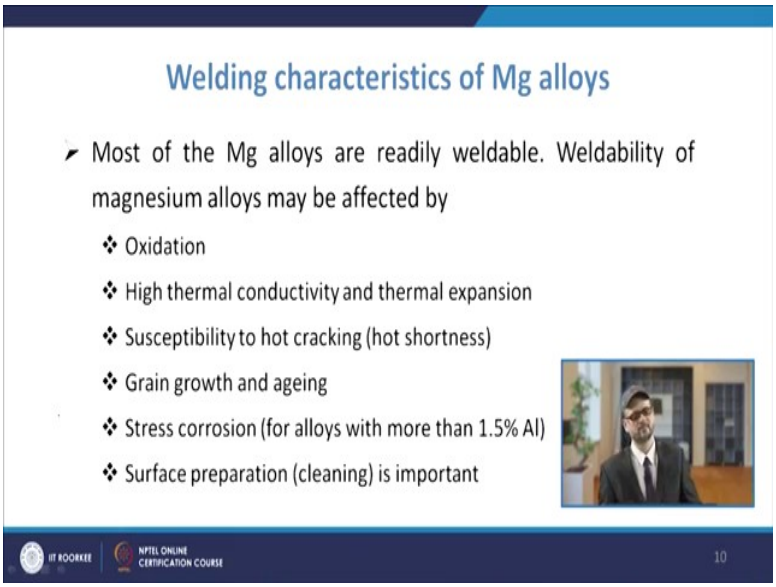

If you try to discuss about the welding characteristic of magnesium alloys, most of the mechanism alloys they are readily weldable and they can be affected by the oxidation because the oxidation of magnesium and its alloys is very very rapid. When it is heated to the melting point in air, then it is readily trying to get oxidized. There may be burning, there may be fumes. So, it is considered to be very, very challenging.

So, you normally try to have inert atmosphere and use suitable fluxes basically in those cases. It has very high thermal conductivity and also very good thermal expansion and because of that you have the challenge in the welding of magnesium because there may be large residual stresses that may be formed that may lead to distortion of the component. So, there are precautions taken and we take like you go for fast welding speeds.

Then you have smaller welding beads that are taken, then holding the parts in the jig and use of lower melting point lower shrinkage welding rods. So, these are the materials we have studied, these are the points that if you use, they will be effective in controlling the distortion. Then, susceptible to hot cracking, that is another challenge with magnesium alloys.

Especially with magnesium, aluminium, and zinc alloys when you have about 1% of zinc, they are very much susceptible to hot cracking and many a times the welds in these hot short alloys. So they should be started from the end of the seams, started away from the end of the seams to have control on hot cracking. So, these are the welding aspects of the magnesium and its alloys. Apart from that, you have grain growth and aging also that is also observed in such materials. So, here, in this case, you have the chance of grain growth and aging.

You have the probability of stress corrosion. When you alloy it with more than 1.5% of aluminium in those cases you have the chance of also stress corrosion and then you have surface preparation or cleaning. Many a times, what you do is when you do the welding, at that time surface preparation or cleaning is basically adopted. So, that is considered to be a good welding practice in the case of magnesium.

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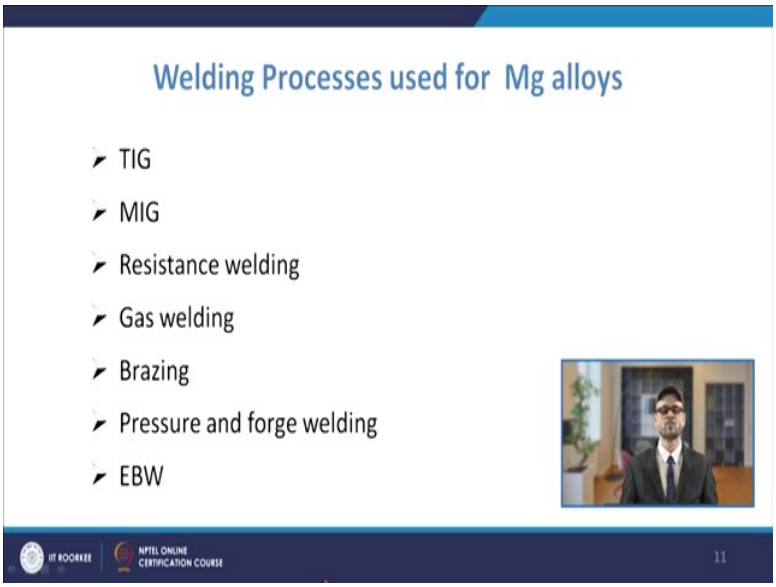

So, the process which are used for magnesium alloys are, like they use TIG, MIG, resistance welding, gas welding, brazing, pressure and forge welding, then electron beam welding. These are the normally used welding processes which we use in the case of magnesium alloys. So, we have got some information about the weldability aspect of aluminum, copper, and magnesium alloys. We can have the information by reading the books on other materials also. Thank you very much.