Weldability of Metals
Prof. D K Dwivedi
Department of Mechanical and Industrial Engineering
Indian Institute of Technology-Roorkee

Lecture - 32
Weldability of Pre-Coated Steels - II

Hello, I welcome you all in this presentation related with the subject weldability of metals. In the previous presentation we had started the weldability of the pre-coated steels and we have seen that the steel sheets are coated with the aluminium or the zinc to enhance the protection against the oxidation and corrosion.

And in case of the aluminized steel building there are various issues like the poor weldability or the formation of the intermetallic compounds and we need proper precaution during the welding in order to produce the sound weld joints with the requisite mechanical properties. Now in this presentation we will be talking about the weldability of another pre-coated steel that is the galvanized steel. In case of the galvanized steel basically the zinc is coated.

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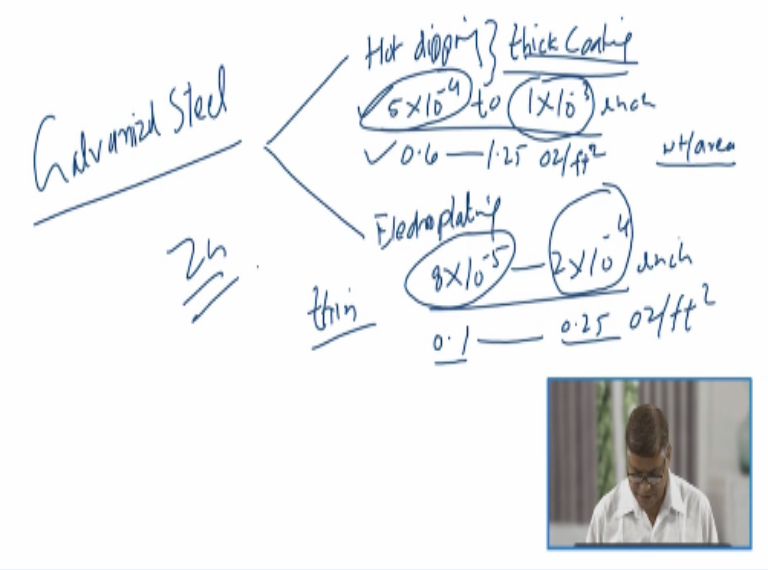

Galvanized steel: So basically there are 2 methods which are used for galvanizing. One is the hot dipping method. And another is electroplating in order to provide the coating of the zinc on to the surface of steel. Hot dipping method in general leads to the

development of very thick coating. And if the larger amount of the zinc is getting into the weld it will be more problematic from the weldability point of view.

If we see the kind of the thickness which is there with the hot-dipped galvanized steels it ranges from 5 * 10 to the power - 4 to 1 * 10 to the power - 3 inch. On the other hand the kind of the, the amount of the zinc like weight per unit area which is available in case of the galvanized steels produced by the hot dipping it ranges from 0.6 - 1.25 oz/sq feet. So these values of the thickness as well as the zinc per unit area in case of the hot-dipped coating is much more than that it available with the electroplated coatings.

So in case of the electroplating, thickness varies from very low level like 8 * 10 to the power – 5 to 2 * 10 to the power – 4 inch. So if we compare here the minimum thickness is 5 * 10 to the power of – 4 and here minimum thickness is 8 * 10 to the power – 5. And the maximum thickness is 1 * 10 to the power – 3 and here maximum thickness is 2 * 10 to the power – 4. So there is a lot of difference in terms of the thickness.

At the same time the kind of the weight of the zinc per unit area which is there in form of coating in case of electroplating it ranges from 0.1 - 0.25 oz/sq ft. So this is significantly lower like 4 – 5 times lower in terms of the weight per unit area of the zinc in case of the electroplating. So in general hot dipping leads to the thick coatings while electroplating leads to the development of thin coating of zinc in galvanized steels.

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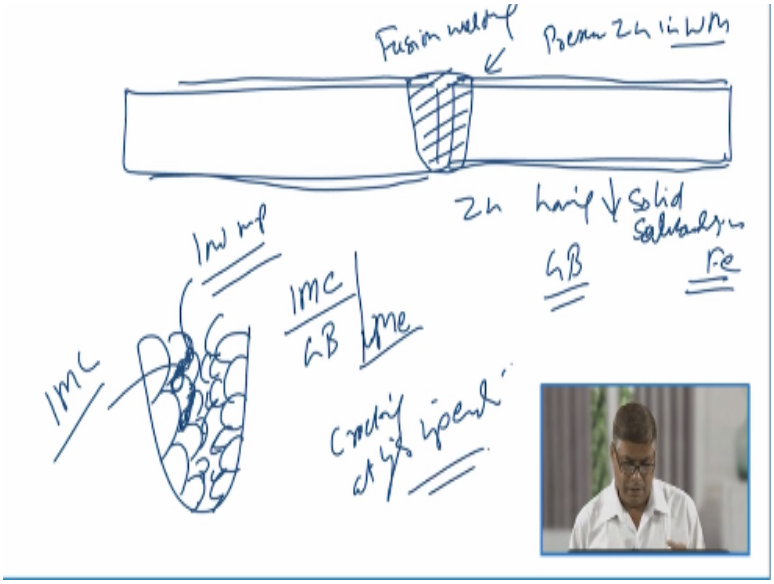

So the amount of the zinc which will be there with the steel sheet during the welding, that will bring in lot of difference in terms of the weldability like zinc coating is there both the sides of surfaces of the steel plate and when these are welded using the fusion welding processes; so in case of the fusion welding processes like we will be melting the both the faying surfaces of the both the components to be joined.

And this in turn leading to the presence of the zinc in the weld metal. So presence of the zinc in the weld metal is troublesome because the zinc having very low solid solubility in the iron and so even in the liquid state it tends to get segregate at the grain boundaries. So when the zinc goes into the weld metal it forms the intermetallic compounds as well as it gets segregated at the grain boundaries in the weld metal.

So, like this is the weld metal and here we have the grains which are being developed during the solidification. So the zinc will be present at the grain boundaries in the weld metal like this. Here it will be forming the IMC as well as it will be. So such compounds of the zinc will be having the lower melting point which will be leading to the increased cracking sensitivity, cracking at high temperature.

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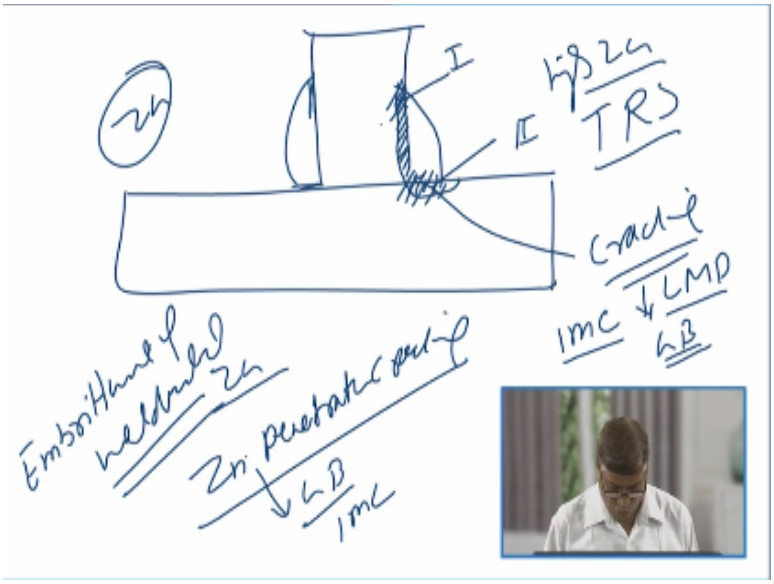

So especially when we develop the fillet joints like T- joints having the fillet welds. So what we will notice that the concentration of the zinc will be more near the root as well as in the zone 1 and zone 2 of the weld metal. And due to the high concentration of the zinc in these areas, combination with the tensile residual stresses we will get the increased cracking tendency in these zones.

And this cracking is attributed to the formation of the intermetallic compounds having the low melting point as well as the segregation of the IMCs at the grain boundary. So such kind of the cracking due to the presence of the zinc is termed as the zinc penetration cracking. Zinc penetration cracking is basically due to the localized presence of the zinc at the grain boundaries formation of the IMCs and in presence of the tensile residual stresses especially in case of the fillet welds leads to the increased cracking tendency.

And this is what is typically termed as the zinc penetration cracking. So apart from the cracking IMC formation leads to the embrittlement of the weld metal. So this is one typical problem associated with the zinc when zinc is getting mixed with the molten metal and leading to the formation of the intermetallic compounds.

This kind of the cracking tendency is found more in the regions where the zinc concentration is more which is specially the root of the weld metal where zinc tends to get segregate or zinc is found in the greater quantity.

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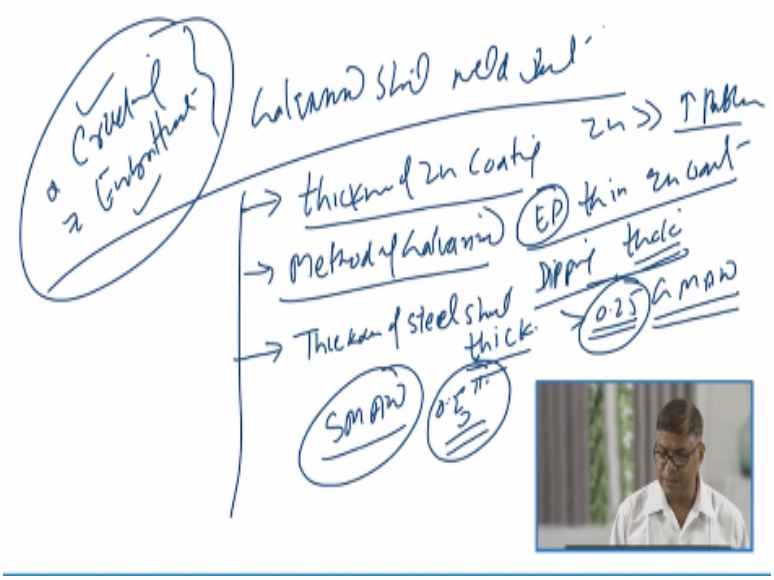

So the cracking and the embrittlement of the galvanized steel sheets weld joints these are the two typical problems. But these problems are not equally encountered means the severity of both these problems is not equal with all welding processes as it is affected by the large number of the factors. These factors include like the thickness of the zinc coating whether it is more or less.

In general greater is the zinc coating thickness, greater will be the problems associated with. Next is like method of galvanizing. We know that the electroplating results in the very thin zinc coating as compared to that of the hot dipping, the coatings applied by hot dipping where we get very thick coating.

So the galvanized steels produced by the electroplating leads to the lesser problem associated with the cracking and embrittlement due to the lower content of the zinc in the weld metal that will be contributed by the zinc coating as compared to the galvanized steel sheets produced by the hot dipping method. There are other aspects like the thickness of the sheet, thickness of the steel sheet which is being welded.

Normally, when the plates are welded, it will depend upon the process a lot. The problem is more when the thickness is greater than the 0.25 in case of the GMAW weld. So the kind of the zinc which is produced, which is made available in the weld metal and the kind of residual resistance which are produced in case of the GMAW welds, the thickness greater than 0.25 inch contributes to the cracking more significantly than the other welding processes.

Like the weld joints of the galvanized steels produced by SMAW process do not show much cracking even up to the 0.5 inch of the steel sheet thickness. So when the galvanized steels up to the 0.5 inch thickness welded by the shielded metal arc welding process do not show much of the cracking tendency while in case of the GMAW it shows significant cracking tendency.

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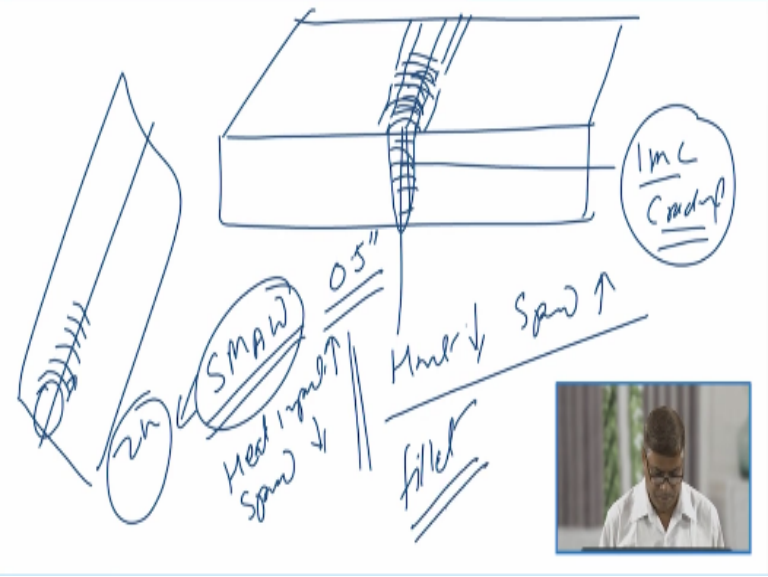

And to understand this we need to see the way by which two processes work like these are the sheets which are being applied. Since the SMAW process like this the plates being welded this is the line of the weld. So when the GMAW process is applied the heat input is less, the welding speed is more. So as a result of this whatever the zinc is present, most of the zinc will be going into the weld metal and promoting the IMC formation leading to the increased cracking tendency.

So increase in thickness will be increasing the severity of the cracking due to the increased residual stress formation as well as the kind of the zinc which is going into the weld metal. As compared to the case when we use the SMAW welding, in case of the SMAW welding, heat input is more and the welding speed is less.

So combination of the higher heat input and lower welding speed leads to the effective melting and evaporation of the zinc during the welding. So like, this is the plate, this is the line of the weld and this is the source of the heat that is arc. So since the arc is moving slowly, so by the heat of the arc, the zinc which is present ahead of the weld center line that will be melting and evaporating.

So the most of the portion of the zinc will be evaporated instead of getting into the weld pool. So the zinc concentration in the weld metal is reduced in case of the SMAW weld and that is why it is able to tolerate the cracking up to the greater thickness, let us say up to 0.5 inch. While less heat input and higher welding speed in case of the GMAW favors the greater concentration of the weld metal in the zinc and which in turn promotes the intermetallic formation and the cracking tendency.

So no cracking up to the 0.5 inch in case of the SMAW weld as compared to the case when the cracking is observed significantly when the thickness is greater than the 0.25 in case of the GMAW weld. And these cracking are more predominant in case of the fillet welds as compared to the butt weld joints.

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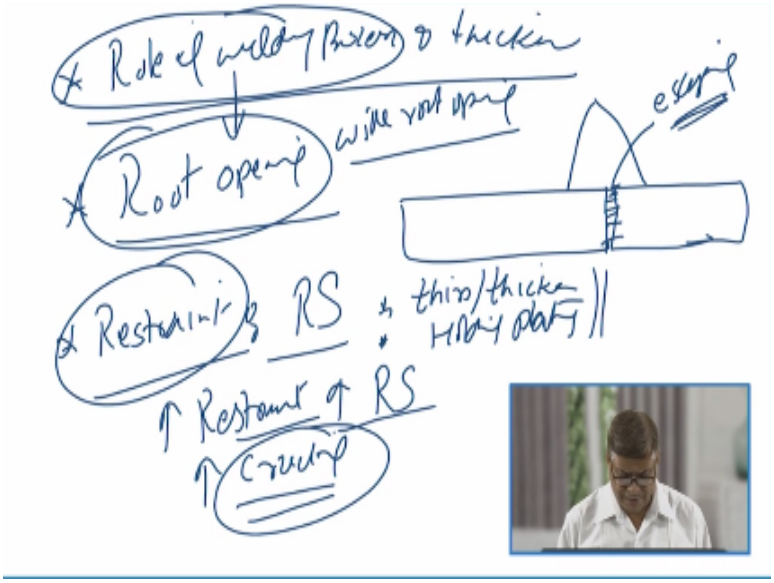

So the thickness of the sheet, this is how we can understand the role of the welding process and the thickness, both we have seen. Greater thickness is a problem but if we change the welding process favorably then it will help in reducing the problems associated with the greater concentration of the zinc in the weld metal. Now another important aspect that will be affecting the role of zinc in the weldability of the galvanized steel is the root opening.

This is important because here we know like if the gap is very less then whatever zinc is there that will not be getting, that after evaporation will not be getting time to escape. So escaping of the zinc vapors is restricted when the root opening is limited. So it is always preferred to have the wide root opening so that the zinc which is evaporating gets enough space for escaping so that associated problems like the pores due to the zinc vapors can be reduced.

Next is the restraint or the joint restraint. Joint restraint directly governs the kind of the residual stresses which will be developed during the welding which in turn will depend upon the number of fabrication conditions including the thickness of the sheet and the kind of the holding of the plates during the welding. So high restraint during the welding will be increasing the residual stress development.

And which in turn will be promoting the cracking tendency. So efforts are made to have the to hold the plates in such a way that the degree of restraint during the welding is reduced so that associated tensile residual stress magnitude can be reduced in order to reduce the cracking tendency of the galvanized steel weld joints.

So reducing the restraint, increasing the opening, selecting the welding processes favorably, reducing the thickness of the galvanized sheets all these will be favoring the weldability and reducing the problems associated with the welding.

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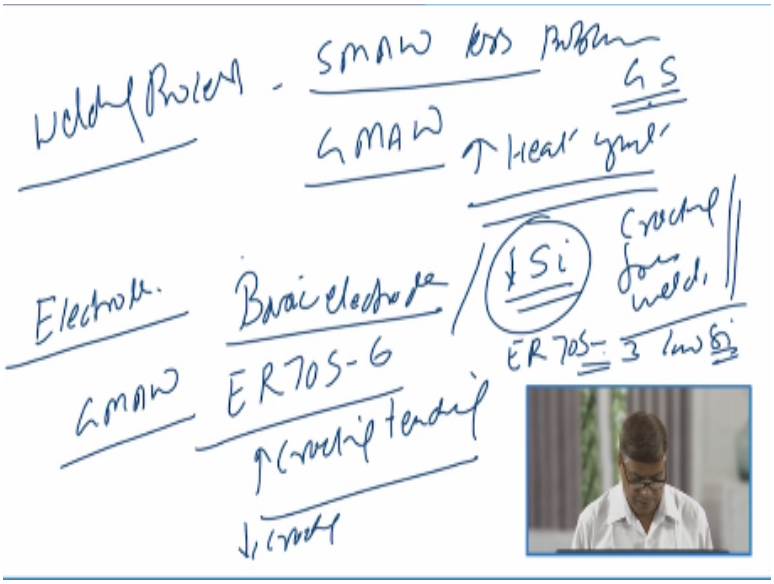

As far as the welding process is concerned as we have seen the SMAW process leads to the better weldability, less problems associated with the galvanized steel welding as compared to the GMAW process. So basically the higher heat input, higher increase in heat input favors the weldability of the galvanized steel. Next is like that the kind of the electrodes which are used.

So electrode classification basically we prefer to use the basic electrodes for effective shielding in case of the SMAW. And the electrode is having the lower silicon content. Silicon content in the electrode is lower for producing the crack free weld metal. So in order to reduce the cracking tendency, this has to be lower.

For example like if we use in case of the GMAW process, if we use one typical filler like ER70S – 6 type which is having the higher concentration of the silicon increases the cracking tendency significantly as compared to the case when ER70S – 3 type of the low silicon electrode is used this reduces the cracking tendency significantly. So use of the suitable type of the welding consumables having the lower silicon will facilitate in developing the weld joints which are free from the cracks.

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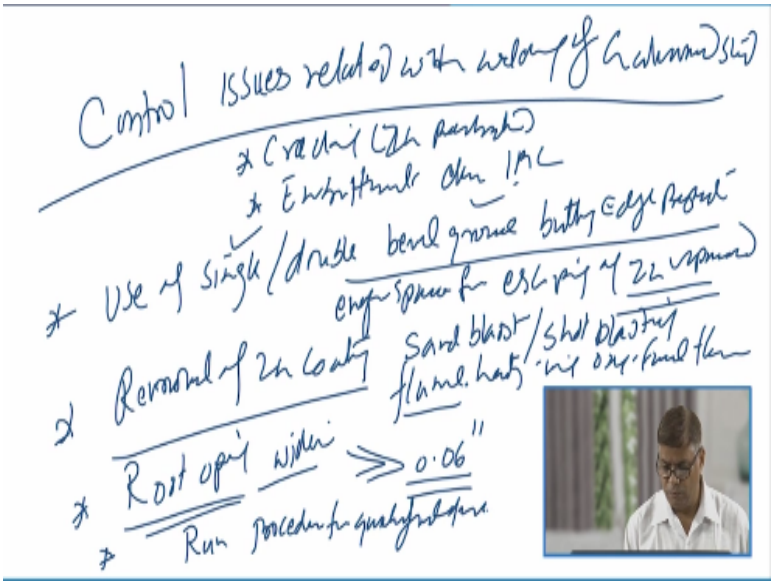

Now there are certain techniques which have been suggested in order to control the issues related with welding of the galvanized steels. What these issues are, so the issues are like the one is cracking. Basically, this is zinc penetration cracking and the second is the embrittlement of the weldment due to IMC formation. So in order to take care of these, some of the methods have been suggested.

One is like use of the single or double bevel groove butting edge preparation. Instead of the square one we will be preferring to use the single or the double bevel groove butting edges so that it provides the enough space for escaping of the zinc vapors which are being produced due to the evaporation of the zinc during the welding. The another method is like removal of the zinc coating itself.

And for this purpose we can use the sand blasting, short blasting or heating by flame, a flame heating using the suitable oxy-fuel flame so that the zinc can be evaporated from the surface and once the zinc is taken care of the problems can be reduced. Another is use of the suitable root opening. As has been suggested that it is always preferred to use the wider root opening so that the vapors which are being generated can get enough space to escape out.

So the proper root opening must be greater than the 0.06 inch. That is the kind of root opening minimum should be given. And then we must run procedures for qualification of welds.

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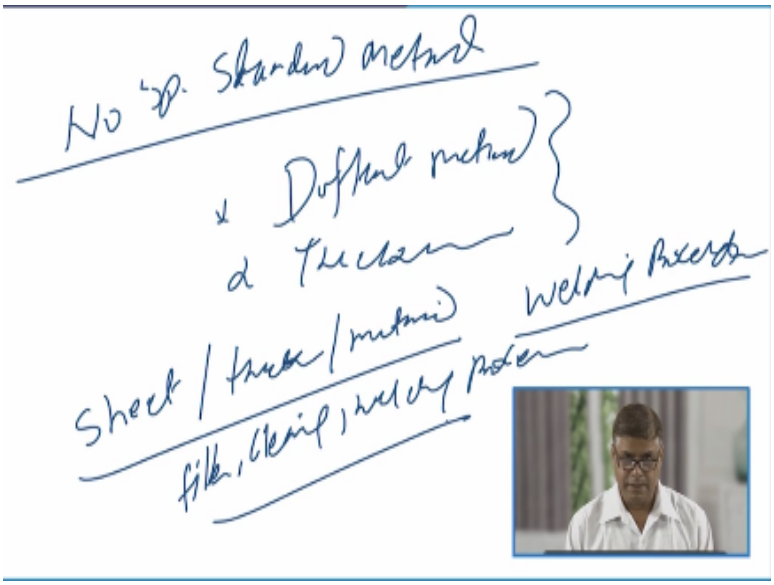

The reason for this is there is no specific standard method to take care of these issues. Since the different pre-coated steels are made by the different methods in the different thicknesses and that is why for each sheet for a given thickness, for a given method we must develop the welding procedure so that the crack free weld with the required combination of the properties can be realized.

So whether it is the filler, cleaning method, welding process whatever is to be used for developing the weld joint of the pre-coated steels those should be established carefully so that the crack free welds with the required combination of the properties can be realized.

Now I will summarize this presentation. In this presentation, basically I have talked about that there are two broad methods of developing the coatings of the zinc on the galvanized steels.

In general, the hot dipping results in the greater thickness of the zinc coating as compared to the electroplating and there is a range of the factors associated with the welding which significantly affects the weldability of the galvanized steels. Thank you for your attention.