2.2 Requirements for Steel for Galvanizing

Galvanizing Process

During the hot dip galvanizing process iron and steel components are heated to the temperature of the zinc bath, about 450 °C. While the steel is immersed in the liquid zinc layers of zinc-iron alloy are formed on the surface by a process of diffusion. When the steel components are withdrawn from the bath these alloy layers are often covered with a coating of pure zinc. This normally produces a shiny silvery coating, sometimes with a distinctive zinc floral or spangled pattern (fig. 1).
The formation of the zinc-iron alloy coating (also known as the hard zinc coating) depends principally on the chemical composition of the steel.
All common steels and cast irons can be hot dip galvanized, but steels with particular silicon contents may produce a very fast reaction between the iron and the zinc. During this process the coating is greater than normal. In extreme cases the entire coating may consist of zinc-iron alloy layers. In such cases the total thickness of the coating is also usually significantly greater than normal. Because of its greater thickness it gives longer protection from corrosion (fig. 2) but, on the other hand, a very thick zinc-iron alloy layer can be associated with a decrease in cohesion.

Effect of Silicon

It is now known that the silicon content of the steel plays a decisive role in the reaction between iron and zinc during hot dip galvanizing. Accelerated growth of the zinc-iron alloy layers may be observed when steel has a silicon content between approximately 0.04% and 0.12% (the Sandelin Effect) and with silicon contents above 0.25%. Fig. 3 shows the relationship.
In these cases a significantly thicker galvanized coating, which is cark grey in appearance, is formed. The cark grey appearance of the coating may cover the entire component or may be found only in certain areas (fig. 4). In some cases a grey reticular pattern may be apparent.

Phosphorus Content

It has also been established that when the silicon content is below the Sandelin region, the phosphorus content in the steel also plays a key role. This applies if the silicon content is less than 0.03%.
The empirical formula for defining low reactivity steels is:

$$Si + 2.5\%P < 0.09\%$$

This provides a rough guide for estimating the reactivity of steels with low silicon contents. If the percent of silicon shown by the steel analysis is added to the phosphorus content multiplied by 2.5, the total should not exceed 0.09%. If dark grey coatings are to be avoided.

Fig. 1

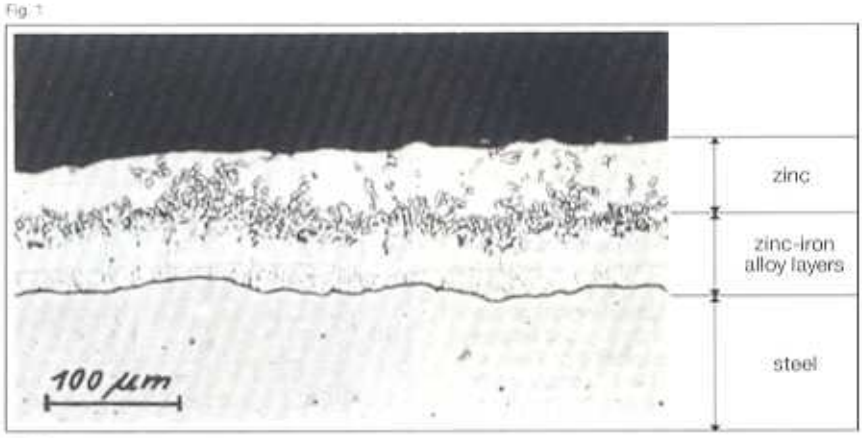

Fig. 2

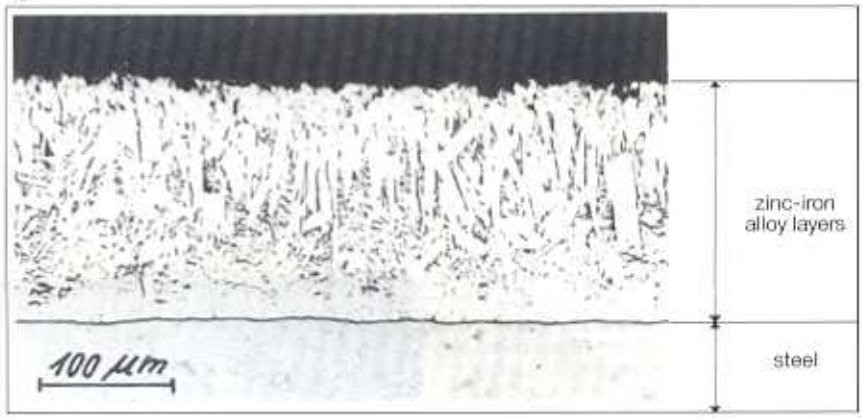

Figure 1: Section of hot dip galvanized steel with typical coatings.

Figure 2: Section of hot dip galvanized steel with interspersed Zn+Fe alloy coating.

In the hot dip galvanizing process the combination of silicon and phosphorus in steel is only significant with low silicon contents. In steels with higher silicon contents (> 0.12%) normal phosphorus contents have negligible influence upon the galvanizing properties of the steel.

Ordering Instructions

The galvanizing parameters have no practical influence on the increase in zinc-iron alloy layers caused by the composition of the steel. For this reason the choice of a steel which is suitable for hot dip galvanizing may be especially important.
British Standard BS 729 : 1971 (1986) makes the following comment:
"In some cases, particulary with steels with a significant silicon content, the galvanized coating may have the dark grey appearance of the zinc-iron alloys showing at the surface. Providing that such a coating has adequate adhesion the dark grey finish is not detrimental to corrosion resistance."
Although the phrase "significant silicon content" is not qualified it is generally accepted that to avoid this reaction the silicon content must be between approximately 0.12% and 0.3% or below 0.04%.
It is recommended that when ordering steel for fabrications which will be galvanized, the fact that the steel is to be galvanized should also be given. This additional information can be extremely useful for the stockholder in selecting the correct type of steel.
If on occasion there is no information concerning the composition of the steel, or there is doubt about the suitability of a particular material, it is recommended that a small test piece of the material is galvanized. Reliable results from such a test can only be obtained, however, if galvanizing is carried out under conditions similar to those of the production run. Keeping to the same conditions is espec-

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ially important with regard to the immersion time of the test and the temperature of the zinc bath.

Embrittlement

Although it is rare for steel to be in an embrittled condition after galvanizing, such an occurrence may happen with an unusual combination of factors. Under certain conditions, some steels can lose their ductile properties and become embrittled. There are several different types of embrittlement which can occur and one, strain age hardening, can be aggravated by the hot dip galvanizing process.

The susceptibility of a steel to strain age hardening is principally caused by the nitrogen content of the steel which, in turn, is largely dependent on the steel making process. BS 4360 (weldable structural steels) permits the customer to specify the steel making process and minimize the amount of nitrogen in the steel.

The degree of strain introduced into a fabrication will depend on the cold forming operations carried out and on the thickness of the steel. Cold working operations carried out before galvanizing which may give rise to embrittlement of susceptible steels include the punching of holes, severe bending and shearing. No steel is likely to be severely affected when its thickness is less than 3 mm.

The following recommendations should be followed to avoid risk of embrittlement.

1. Use a steel which is not susceptible to strain age hardening whenever possible.
2. If a susceptible steel must be used, avoid severe cold work, e.g. punched holes or bending over a radius less than three times the thickness of the material. Punched holes are generally satisfactory in hall low nitrogen, low oxygen steels high U_2 steels up to a thickness of 18 mm. Holes in susceptible steels over 6 mm should be reamed after punching or be drilled. If severe working is unavoidable it is better, from a galvanizing point of view, if the fabrication is hot worked.
3. If severe cold work on a susceptible steel cannot be avoided, stress relieve at a minimum of 600 °C before galvanizing.

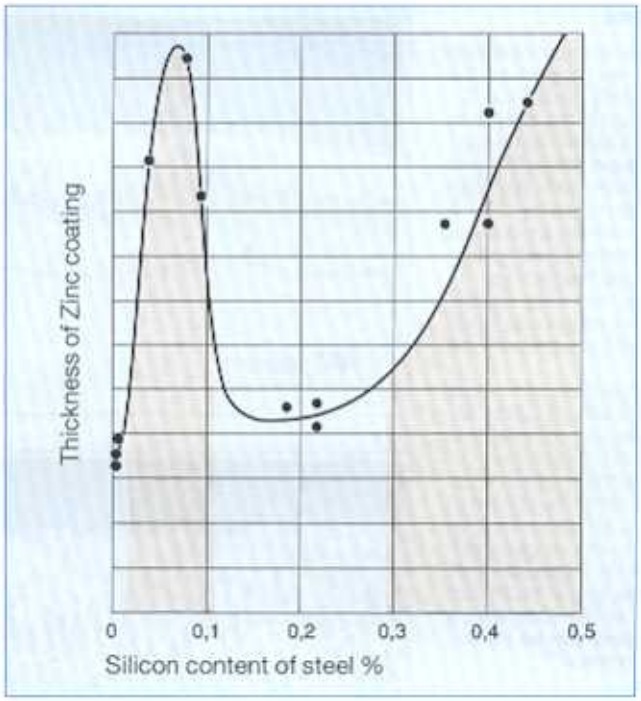

Figure 3: Effect of the silicon content in the steel on the zinc coating.

Figure 4: Grey reticular appearance of the zinc coating.

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