HDG - GALVANISERS ASSOCIATION OF AUSTRALIA 1993 EDITION

occurs during galvanizing, producing thicker coatings, though at the expense of a rougher surface and poorer appearance.

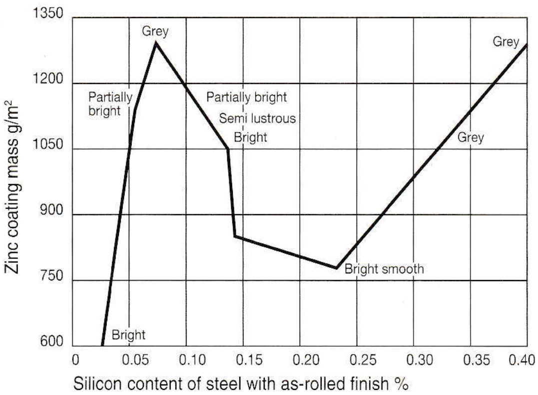
Application of this method of achieving thicker coatings is generally limited by practical and economic considerations. Where increased service life or reduced maintenance is required the use of duplex galvanizing-plus-paint systems is a preferable alternative, as discussed on page 65.

Composition of steel

Both silicon and phosphorous contents can have major effects on the structure, appearance and properties of galvanized coatings. In extreme cases, coatings can be excessively thick, brittle and easily damaged.

Silicon. As shown in the graph below, certain levels of silicon content will result in excessively thick galvanized coatings. These very thick coatings result from the increased reactivity of the steel with molten zinc, and rapid growth of zinc-iron alloy layers on the steel surface. The graph shows that excessive growth in coating thickness takes place on steels with silicon contents in the range 0.04 to 0.14%. Growth rates are less for steels containing between 0.15 and 0.22% silicon, and increase with increasing silicon levels above 0.22%.

Effect of silicon content of steels on galvanized coating mass and appearance



Phosphorous. The presence of phosphorous above a threshold level of approximately 0.05% produces a marked increase in reactivity of steel with molten zinc, and rapid coating growth. When present in combination with silicon, phosphorous can have a disproportionate effect, producing excessively thick galvanized coatings.

Suitability of silicon/phosphorous steels for galvanizing. As a guide to the suitability of silicon and phosphorous containing steels for galvanizing, the following criteria should be applied:

$\% \text{ Si} < 0.04\%$
and
$\% \text{ Si} + (2.5 \times \% \text{ P}) < 0.09\%$

Galvanized coatings on silicon steels are usually dull grey or patchy grey in colour with a rough finish, and may be brittle. Coating service life is proportional to the increased thickness and is unaffected by appearance, provided the coating is sound and continuous. In general, the thickness, adherence and appearance of galvanized coatings on silicon and phosphorous steels are outside the control the galvanizer. (See also 'Dull grey coatings', page 42.)

Double dipping or galvanizing a second time will not increase the thickness of a galvanized coating for reasons discussed under "Coating thickness" page 13, and may adversely affect coating appearance.

The terms 'double dipping' and 'double-end dipping' are sometimes confused. Double-end dipping is a method of galvanizing articles too long for the available bath by immersing one end of the work at a time, as described on page 33.

Mechanical properties of galvanized steels

The galvanizing process has no effect on the mechanical properties of the structural steels commonly galvanized.

Strength and ductility

The mechanical properties of 19 structural steels from major industrial areas of the world were investigated before and after galvanizing in a major 4-year research project by the BNF Metals Technology Centre, UK, under the sponsorship of International Lead Zinc Research Organisation. Included were steels to Australian Standard 1511 grade A specification, and British Standard 4360 series steels.

The published BNF report 'Galvanizing of structural steels and their weldments' ILZRO, 1975, concludes that '... the galvanizing process has no effect on the tensile, bend or impact properties of any of the structural steels investigated when these are galvanized in the "as manufactured" condition. Nor do even the highest strength versions exhibit hydrogen embrittlement following a typical pretreatment in inhibited HCl or H_2SO_4.

'Changes in mechanical properties attributable to the galvanizing process were detected only when the steel had been cold worked prior to galvanizing, but then only certain properties were affected. Thus the tensile strength, proof strength and tensile elongation of cold rolled steel were unaffected, except that the tensile elongation of 40% cold rolled steel tended to be increased by galvanizing. 1-t bends in many of the steels were embrittled by galvanizing, but galvanized 2-t and 3-t bends in all steels could be completely straightened without cracking.'

Embrittlement

For steel to be in an embrittled condition after galvanizing is rare. The occurrence of embrittlement depends on a combination of factors. Under certain conditions, some steels can lose their ductile properties and become embrittled. Several types of embrittlement may occur but of these only strain-age embrittlement is aggravated by galvanizing and similar processes. The following information is given as guidance in critical applications.

Susceptibility to strain-age embrittlement. Strain-age embrittlement is caused by cold working of certain steels, mainly low carbon, followed by ageing at temperatures less than 600°C, or by warm working steels below 600°C.

All structural steels may become embrittled to some extent. The extent of embrittlement depends on the amount of strain, time at ageing temperature, and steel composition, particularly nitrogen content. Elements that are known to tie up nitrogen in the form of nitrides are useful in limiting the effects of strain ageing. These elements include aluminium, vanadium, titanium, niobium, and boron.

Cold working such as punching of holes, shearing and bending before galvanizing may lead to embrittlement of susceptible steels. Steels in thicknesses less than 3 mm are unlikely to be significantly affected.

Hydrogen embrittlement. Hydrogen can be absorbed into steel during acid pickling but is expelled rapidly at galvanizing temperatures and is not a problem with components free from internal stresses. Certain steels which have been cold worked and/or stressed during pickling can be affected by hydrogen embrittlement to the extent that cracking may occur before galvanizing.