Mechanical Properties of Hot Dip Galvanized Steels

The hot dip galvanizing process has no effect on the mechanical properties of structural steel.

8.1 STRENGTH AND DUCTILITY

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 hot dip 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 hot dip 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 was unaffected, except that the tensile elongation of 40% cold rolled steel tended to be increased by hot dip galvanizing. 1T bends in many of the steels were embrittled by galvanizing, but galvanized 2T and 3T bends in all steels could be completely straightened without cracking.

8.2 EMBRITTLEMENT

For steel to be in an embrittled condition after hot dip 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 hot dip galvanizing and similar processes. The following information is given as guidance in critical applications.

Critical Applications.
It is better to avoid cold work such as punching, shearing and bending of structural steels over 6mm thick when the item will be galvanized and subsequently subjected to critical tensile stress. If cold working cannot be avoided a practical embrittlement test in accordance with **ASTM A143** should be carried out.

Where the consequences of failure are severe and cold work cannot be avoided, stress relieve at a minimum temperature of 650°C before hot dip galvanizing.

Ideally, in critical applications structural steel should be hot worked above 650°C in accordance with the steelmaker's recommendations.

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

The Galvanizing Process
The galvanizing process involves immersion in a bath of molten zinc at about 450°C. The heat treatment effect of galvanizing can accelerate the onset of strain-age embrittlement in susceptible steels which have been cold worked. No other aspect of the galvanizing process is significant.

Recommendations to Minimise Embrittlement
Where possible, use a steel with low susceptibility to strain-age embrittlement. Where cold working is necessary limitations of punching, shearing and flame cutting, bending, edge distances and critical applications must be observed. *Refer to Chapter 9.*

8.3 FATIGUE STRENGTH

Research and practical experience shows that the fatigue strength of the steels most commonly galvanized is not significantly affected by galvanizing. The fatigue strength of certain steels, particularly silicon-killed steels may be reduced, but any reduction is small when compared with the reductions which can occur from pitting corrosion attack on ungalvanized steels and with the effects of welds.

For practical purposes, where design life is based on the fatigue strength of welds, the effects of galvanizing can be ignored.

Fatigue strength is reduced by the presence of notches and weld beads, regardless of the effects of processes involving a heating cycle such as galvanizing. Rapid cooling of hot work may induce microcracking, particularly in weld zones, producing a notch effect with consequent reductions in fatigue strength.

In critical applications, specifications for the galvanizing of welded steel fabrications should call for air cooling rather than water quenching after galvanizing to avoid the possibility of microcracking and reductions in fatigue strength.