Cope Cracking in Structural Steel After Galvanizing

There have been isolated reports of cracks in the flame cut radius of copes of galvanized steel

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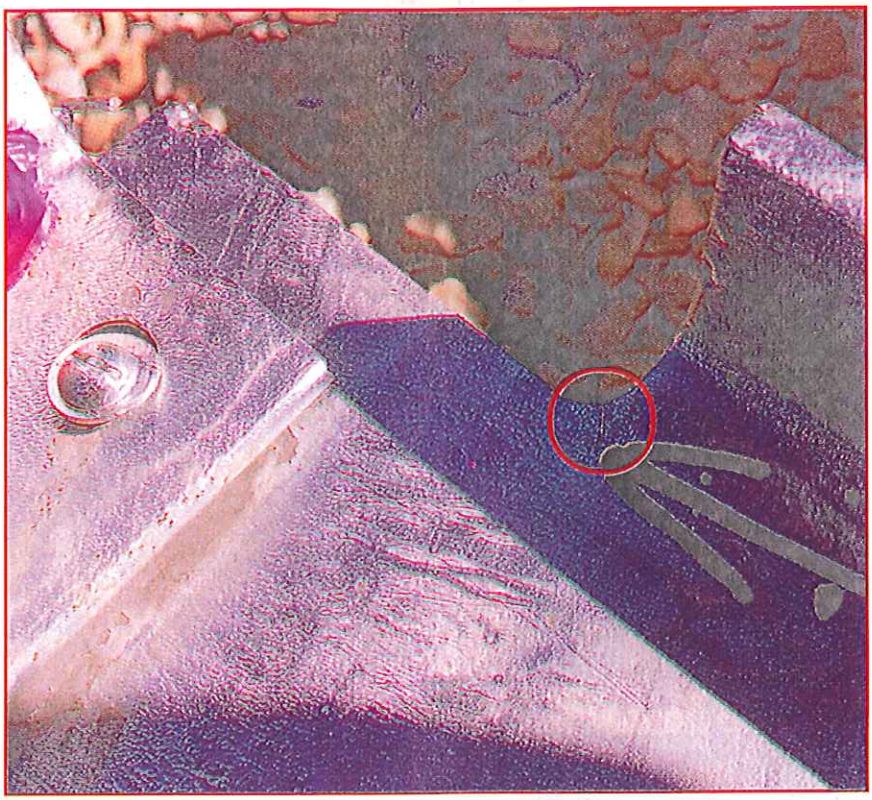
HOT-DIP GALVANIZING, THE PROCESS OF DIPPING STEEL PARTS IN MOLTEN ZINC has been successfully used for over 140 years as a corrosion inhibitor for steel structures. As the zinc coating weathers, it forms a very stable protective film on the surface of the material. This film provides many years of corrosion protection under all but the most severe environments. An attractive feature of galvanizing is the property of protecting small areas of exposed steel. Zinc acts as an anode in a galvanic couple between the zinc and the steel. The zinc is consumed before the steel rusts. During the galvanizing process, the zinc and iron form a metallurgical bond, a series of intermetallics. The intermetallics provide good abrasion resistance and a high adhesion strength of the coating to the substrate.



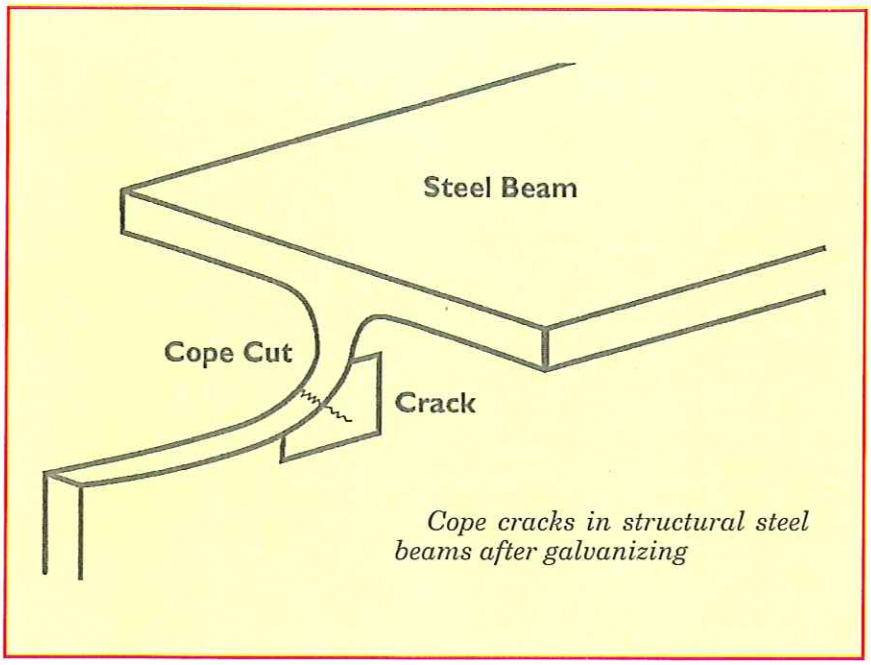
Pictured above is an example of cracking in an oxygen cut cope in a structural steel beam.

Since 1991 there have been isolated reports of cracks found in galvanized structural steel wide-flange sections. Many of these reports are not well documented. Commonly, the problem is found and repaired before it is reported and investigated. Repairs destroy the evidence and indications that could be used to determine the physical cause for the cracks. There have been common threads through most of the reports. The cracks are commonly found in the flame cut radius of copes and extend radially away from the copes at 45 degrees. They are visible on both sides of the web indicating they extend through the material. The cracks have appeared in A36, A572 and probably in A588. Cracks have been found in some material from a given heat and not in other material from the same heat. There have been reports of cracking in material made by the blast furnace method as well as the currently prevalent electric arc furnace method. Fabricators and engineers who have witnessed the problem report cracks are more prevalent in sections around 21 inches deep but they have been found in material as small as 10 inches. Members without flame-cut copes show no signs of cracking. Reports to date indicate that cracks can be identified by

visual examination. Visual inspection of copes prior to galvanizing has not revealed any 'pre-galvanized' conditions leading to cracking. At least one fabricator alleges a difference in the incidence of cracking between galvanizing companies.

There are a number of areas to investigate in searching for probable causes for cracking and developing appropriate procedures to minimize cracking problems.

- The galvanizing temperatures are below the critical transition temperature for steel, but variations in cooling rate and the presence of molten zinc result in metallurgical reactions effecting steel properties and changes in residual stresses.
- The flame cutting causes high tensile residual stresses (at or near yield point) along the flame cut surface of the cope. The galvanizing temperature can create stresses at a lower level, but throughout the member as evidenced by warping in some sections.
- The reaction of steel to the presence of liquid metal can cause an effect called liquid metal embrittlement. Galvanizer's pickling baths and handling techniques can vary to some degree.
- ASTM A143-74 Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement (ASTM VOL 1.06) states that the duration of pickling can effect embrittlement. The standard further states that heating to 300 deg F. between pickling and galvanizing in most cases results in expulsion of the hydrogen absorbed during pickling. Variation in galvanizer practices such as bath temperature, quenching, bath additions and pickling time have not been found to have a measurable effect on probability of crack occurrence according to the American Galvanizers Association.
- The processes of steel making have changed significantly over the last twenty years with the possibility of varying amounts of trace elements and different mechanical properties across sections than those which were typical with past practice.
- The mechanical properties of the steel including the lower toughness in the area of the fillet between the flange and the web can also be effected by differences between cooling rates in the different thicknesses of material, segregation, and less grain refinement due to mechanical work by the mill rolls. Any of these factors could contribute to the problem.



Cope cracks in structural steel beams after galvanizing

Because of a number of instances of cracks that emanated from weld access openings of full penetration welded splices of jumbo sections subject to applied tension in the early 1980s, a special task committee of the AISC Committee on Specifications was appointed to study the problem and develop recommendations for specification provisions to minimize the potential for such occurrences. A review of the investigations which had been conducted on the reported incidents and study of related research clearly revealed that the area of the web-to-flange junction of heavy rolled shapes were often characterized by large grain structure of low toughness, and further, that the flame cutting operation resulted in a very thin layer of brittle untempered martensite on the flame cut surface. It was further noted that magnetic particle or dye penetrant inspection of the cut surfaces revealed the existence of microscopic cracks in the brittle surface material which could not be detected by unaided visual examination. These observations were confirmed by research by Kennon and Kohler, Australian Welding Research, 1979 and Alexander Wilson, AISI 1987 which showed that flame cutting a variety of structural steels including A36, A572 and A588, resulted in microcracks along the edges of cut surfaces. The AISC Specification task group therefore recommended that weld access openings for full penetration welded splices of ASTM group 4 and 5 shapes (jumbos) which were to be subject to applied tension should be subject to supplementary notch toughness testing requirements, preheating before