flame cutting, grinding to bright metal and dye penetrant or magnetic particle examination prior to welding(Ref. ASD 9th ed., J1.8 & M2.2; LRFD 2nd ed., J1.6 & M2.2). Similar provisions have been incorporated in the AWS Structural welding Code—D1.1. Preheating is intended to reduce the thickness of the brittle martensite layer, and the grinding is intended to remove the brittle layer and roughness of the flame cut surface and to facilitate magnetic or dye penetrant examination. The sections exhibiting problems after galvanizing are not necessarily group 4 or 5 shapes, but the same mechanisms which are responsible for cracking in jumbo shapes may also be initiating micro-cracks in the copes of smaller beams. If such beams are then subject to liquid metal embrittlement and the thermal cycles of the galvanizing process, the pre-existing invisible micro-cracks may be driven to visible size. Grinding of flame cut copes and magnetic particle or dye penetrant examination prior to galvanizing may be warranted as one possible precaution.

Ongoing research which started in the galvanizer industry and is now sponsored by the International Lead/Zinc Research Organization (ILZRO) at Metals Technology Laboratories of the Canada Centre for Minerals and Energy Technology (MTL/CANMET) is examining some factors that could contribute to the formation of this cope cracking. This research indicates that room temperature yield strength has an effect on the propensity to crack and combines with high residual stresses and liquid zinc reactions on steel to make the micro-cracks unstable until they propagate out of the tensile residual stress region. The effect of liquid zinc on steel and the reaction called 'liquid metal embrittlement' are being reviewed. Photomicrographs of cracked surfaces show zinc on the fractured surface indicating the crack occurs before the piece is removed from the kettle. Whether the zinc enters micro-cracks before they propagate or after while the piece is still submerged has yet to be determined. In studying the effects of the galvanizing temperature it was found that cracks did not form when samples were cycled through process temperatures without actually being immersed in liquid zinc. Trace elements from the steel have been found in concentrated levels at the grain boundaries near fractured surfaces. Elements such as copper, tin and nickel have been identified. To date there is no conclusion available linking these elements to cracking. The surfaces of the cracked section indicate a brittle behavior which

is consistent with the theory of a martensitic layer and residual stresses.

Some fabricators have elected to grind the area of the flame cut section near the re-entrant corner and report a significant reduction in the incidence of cracking but not a total elimination.

ILZRO will continue to fund work to determine the relationship between microstructure, stress and other factors such as steel chemistry. Remedial measures will also be explored. AISC will recommend to ILZRO that they explore the effectiveness of using a combination of pre-heat, grinding and magnetic particle or dye penetrant inspection to avoid cracks. We will report results of this exploration when it becomes available.

Near Term Practices

Unaided visual inspection of flame cut surfaces may not be effective in detecting micro-cracks. Until ongoing research determines more appropriate criteria, it would be prudent for flame cut surfaces of copes of structural members destined to be galvanized to be ground to bright metal and the surface examined by the dye penetrant or magnetic particle methods. After galvanizing, the area of the copes should again be visually inspected to assure that cracks are not left in the final structure.

Another method that may be effective in minimizing the potential for cracking problems is to pre-drill (not punch) the beam to form the radius portion of the cope as shown in ASD Commentary fig. C-J1.2 pg. 5-162 or LRFD Commentary Fig. C-J1.2, pg. 6-218.

The American Galvanizers Association has reported an alternative to avoid cracking that involves placing a bead of weld along the edge of the re-entrant corner on both side of the web. The weld is extended one inch in either direction from the corner of the cope. It is pointed out that a low silicon filler metal considered compatible for galvanizing is used. No cracks have been found in copes treated this way. While this may be effective, it appears to be an expensive solution.

The galvanizing can be repaired using methods described in ASTM A780, Standard Practice for repair of damaged Hot-Dip Galvanized coatings.

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