

Failure Analysis of a Metal Fastener



Northbrook, IL
847.528.3467
www.imetllc.com



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Background

Used in building interior to hold up wall system

Failed about 1 week after installation



mike@imetllc.com
847.528.3467

Analysis steps

1. Visual and stereo zoom microscope exam
2. Scanning electron microscopy and energy dispersive x-ray spectroscopy
3. Metallography and microhardness testing



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Scanning electron microscopy

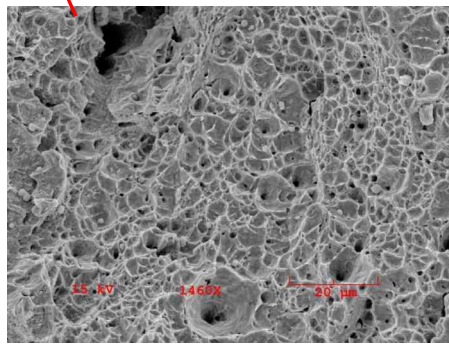
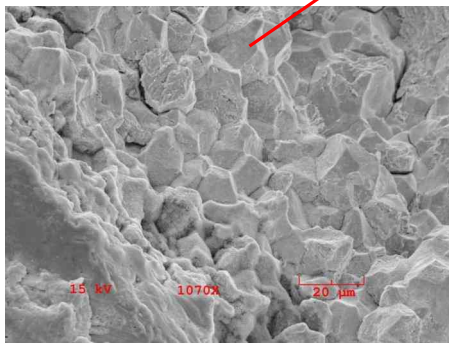
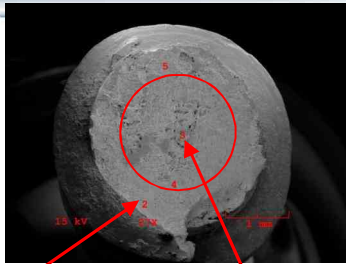
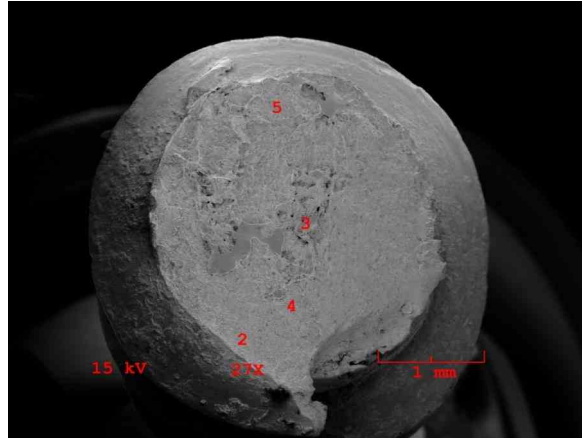
Use electron beam to examine fracture surface

Observe features on fracture surface to determine fracture mode

- ~ Information will help to determine failure mechanism

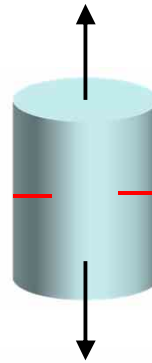


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2. As cracks grew, tensile stress on intact material increased
3. Fracture occurred when stress exceeded tensile strength of intact material

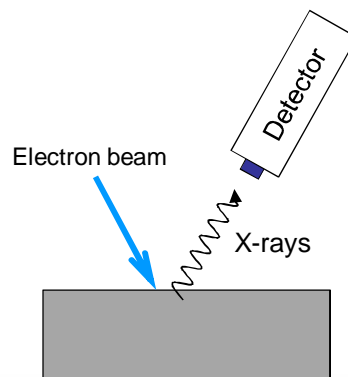
1. Cracks initiated at outer surface and grew along grain boundaries



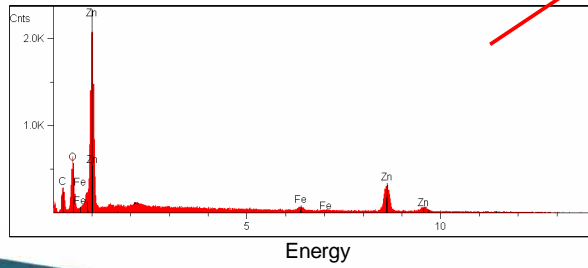
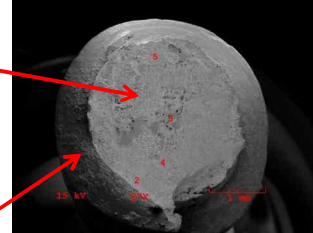
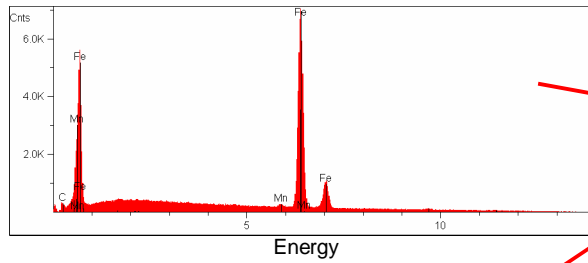
Energy Dispersive X-ray Spectroscopy (EDS)

X-rays emitted are characteristic of each element

- ” Identify elements present in the metal and their relative amounts



Detector collects, sorts, and counts x-rays



Electroplated zinc for galvanic corrosion protection



Metallography and microhardness testing

Examine microstructure with optical microscope



Cut up, mount, polish, and etch sample

Cut sample



Mounted sample



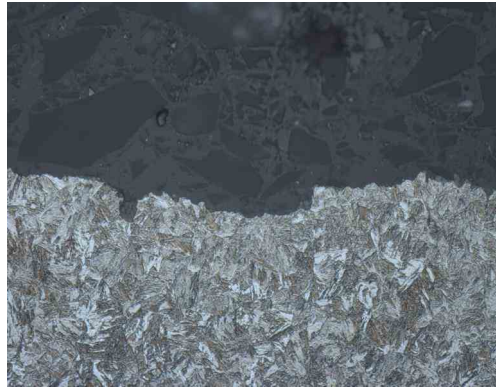
Polished sample



0.020 inch

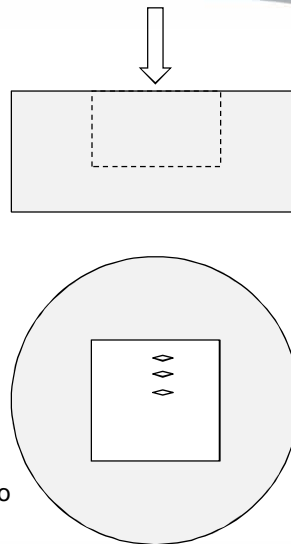


Tempered martensite



0.002 inch

Microhardness testing



Hardness calculated based on load used to press the indenter and size of indentation

Microhardness testing



Depth from tooth surface	KHN ₅₀₀ Conversion to HRC
0.006+	45
0.012+	45
0.020+	45
Core	44/45

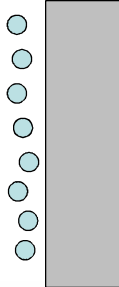
Through hardened, not case hardened



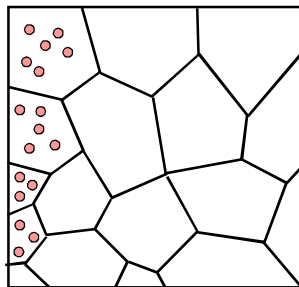
Conclusions

1. Intergranular cracking followed by ductile overload
2. Hydrogen embrittlement due to electroplating

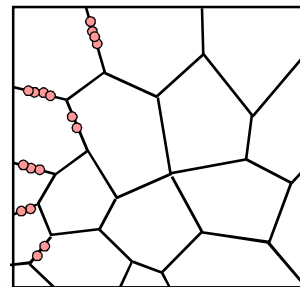
Hydrogen bubbles on metal surface
 $H_2 \rightarrow H + H$



Hydrogen diffuses into metal



Hydrogen diffuses to grain boundaries



Conclusions

3. Root cause: Insufficient or no hydrogen bake-out after plating with zinc

Bake-out required for hardened steel

- ~ Heat metal up to 400 °F for 2 to 24 hours
- ~ Hydrogen diffuses out of metal
- ~ Do within a few hours of electroplating



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Michael Pfeifer, Ph.D., P.E.

President of Industrial Metallurgists

Over 20 years experience

- ~ Failure analysis and root cause analysis
- ~ Engineering consulting
- ~ Training (on-demand metallurgy courses)



Author of Materials Enabled Designs: The
Materials Engineering Perspective to
Product Design and Manufacturing



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