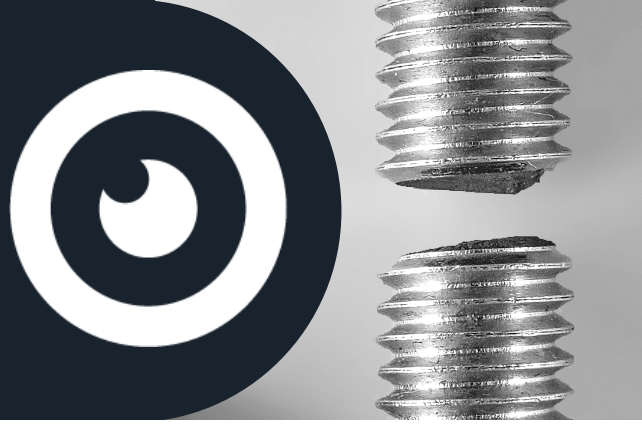
MATERIEX CASE 24-1

# HYDROGEN EMBRITTLEMENT IN STEEL FASTENER



## BACKGROUND

A fractured M8x40 hexagon socket set screw was received for failure investigation. According to the given information, the fracture was observed some time after the screw had been tightened. The screw material was specified to conform with zinc electroplated steel with the property class 45H (minimum hardness 450 HV).

## FINDINGS

- The hardness was measured to ∽505 HV which met the criteria for property class 45H.
- The macroscopic appearance of the fracture suggests that the fracture has been initiated in the thread root along the circumference (arrows in Figure 1) and rapidly propagated inwards/downwards towards the final fracture (white marked area in Figure 1).
- Investigation in SEM confirmed that the fracture had been initiated in the thread root. The fracture surface in this area had an intergranular brittle mode of fracture along the prior austenite grain boundaries (Figure 2). The grain facets exhibited so-called "crow's feet" (Figure 3) which is a microscopic feature typically associated with hydrogen embrittlement. The final fracture had a mixed ductile and brittle cleavage mode of fracture.

## CONCLUSIONS

Multiple factors strongly indicate that the fracture was caused by hydrogen embrittlement:

1. The character of the fracture surface: intergranular and with the presence of so-called "crow's feet".
2. Material properties: the screw is made of high strength steel with a hardness of ∽505 HV. High strength materials (>1000 MPa yield stress) are more susceptible to hydrogen embrittlement.
3. The timing of the fracture: the fracture did not occur immediately upon tightening but after some time.
4. The location of the fracture: the fracture was initiated in an area where high stresses are expected (e.g. thread roots).
5. Manufacturing process: the screw was zinc coated by electroplating which is known to be a process where hydrogen can enter and get trapped in the material.

## INVESTIGATION

- Visual examination
- Metallographic preparation and microstructural studies (LOM)
- Fractography (SEM)
- Chemical characterisation (EDX)
- Hardness measurements using micro-Vickers ($HV_1$)

LOM - Light optical microscopy
SEM - Scanning electron microscopy
EDX - Energy dispersive X-ray spectroscopy

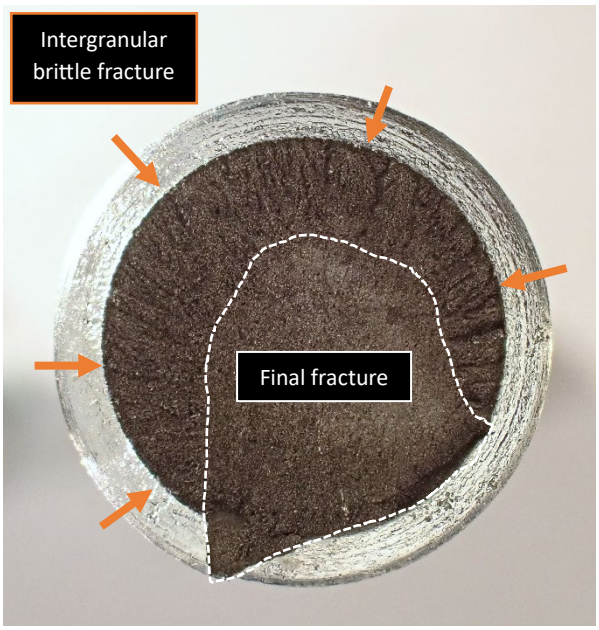



***Figure 1.*** *Fracture surface, arrows indicate crack initiation sites with an intergranular brittle mode of fracture. The white marked area shows the final fracture.*

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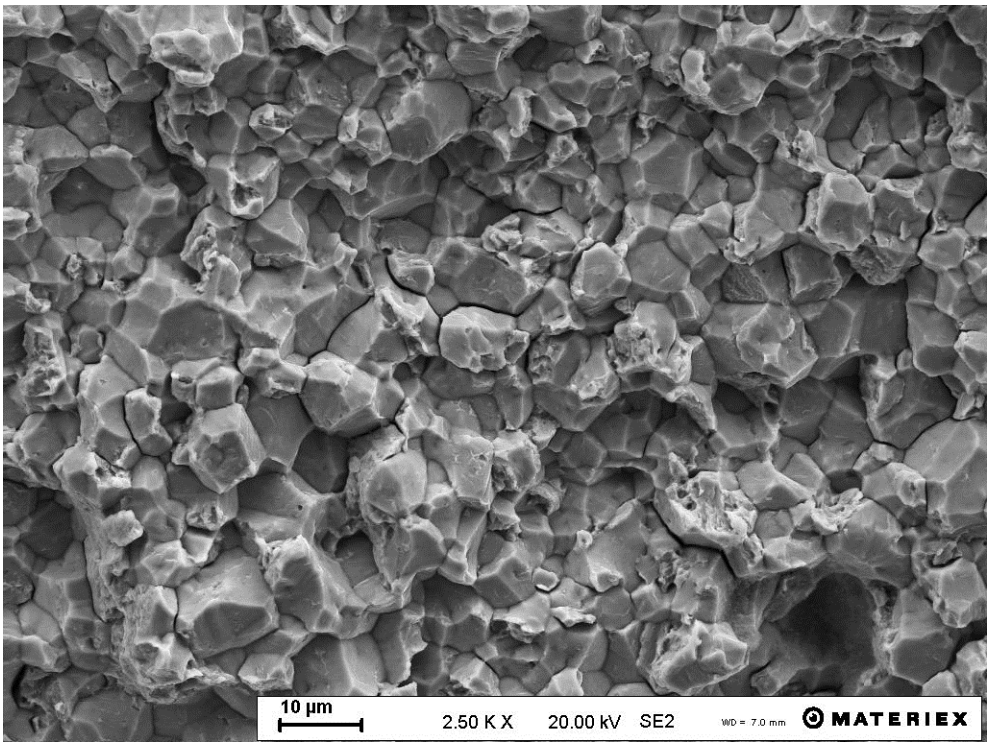


***Figure 2.*** *Intergranular brittle mode of fracture revealing austenite grain boundaries.*

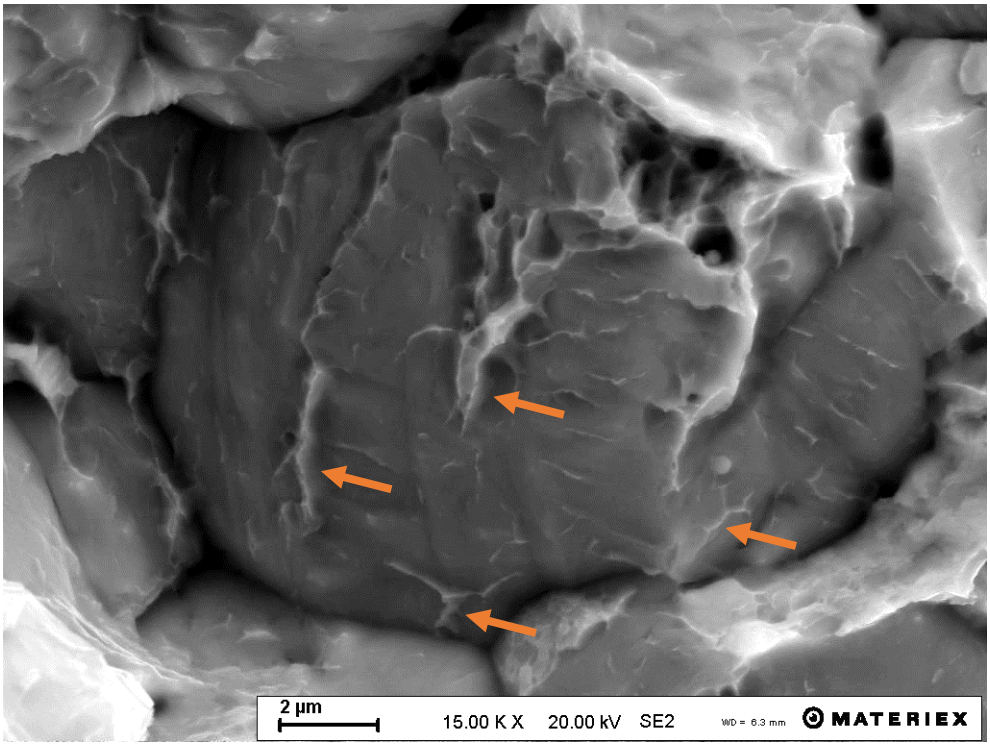


***Figure 3.*** *High magnification SEM- image showing the so-called crow's feet.*