How Heat Treatment Can Contribute to Fastener Failures & Methods of Prevention

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The following is a case study revealing heat treating as the root cause of fastener failure.

Ten out of sixty *SAE 1045* fasteners were found to be cracked after heat treating in a continuous mesh belt furnace line (**see Figure 1**). The heat treatment called for austenitizing at 1600°F (870°C) for 30 minutes, oil quenching and tempering at 700°F (370°C) for two hours.

Discussions with the commercial heat treater indicated that a power failure due to a lightening strike on a substation had occurred while the parts in question were in the furnace. Loss of furnace atmosphere and temperature resulted.

The parts were unloaded, hardness tested, found to be low in hardness and then re-run in an attempt to salvage them. Subsequent hardness testing indicated the parts were within specification, and they were returned to the customer. On subsequent assembly, cracks were discovered.

Analysis

Both a cracked fastener and a known good part from a previous production lot were analyzed. Visually, the difference between the two parts was the presence of heavy scale on the "bad" component, especially in the thread areas while the "good" part was clean.

The fracture surface of the bad fastener appeared uniformly black—the same color as the exposed surfaces on the bad part. SEM/EDX analysis was performed on both the fracture surface and the exposed OD surface for comparison. Both of the analyzed bad fastener surfaces revealed continuous coverage with the oxide film with identical elemental composition.

Both the OD surface of the good fastener and the baseline material were analyzed by SEM/EDX for comparison with the bad part. The analysis revealed less oxidation on the good fastener OD surface. The material was identified as *SAE 1045* steel based of analysis the sectioned part wall.

A cross sectional examination was performed on both the good and bad fasteners as well. Both of the samples revealed a tempered martensite microstructure. A continuous film that is approximately 100 microns thick was observed on the exposed surfaces and fracture cross sections of bad fastener. In contrast, the surface film on the good fastener was approximately 2 microns thick.

Hardness was measured on the fastener cross sections using microhardness methods (Vickers, 500 gf) and converted into Rockwell C. Enough microhardness indentations were placed in the middle of the component or part wall to be statistically meaningful.

After metallurgical and failure analysis, the following conclusions were reached:

- The good fasteners were properly heat-treated exhibiting a surface and core microstructure of tempered martensite. A thin oxide layer was observed on the part surface indicative of tempering at elevated temperature in air.
- The bad fasteners were cracked during the heat treatment process, either the result of thermal or quenching stresses. The same composition and thickness of oxide layer was observed on the fracture surface as well as the outside diameter of the part.
- Hardness values (converted from microhardness measurements) on the bad fasteners found they were out of specification (high) indicating an inconsistency in response after the re-hardening operation. These measurements are considered more accurate than attempting to hardness test the surface using conventional Rockwell "C" measurements with scale present.

Corrective Actions

In this instance, corrective action consisted of instructions to the commercial heat treater not to re-work the parts, but to quarantine them until a thorough metallurgical analysis could be performed on them.

Further it was suggested that parts should be tested using dye penetrant or similar methods for the presence of cracks after heat treatment.

Additionally, routine (per batch) quality checks should be performed utilizing an independent source.

Finally, in-house heat treating should be considered if the problem is found to persist or if the quality control measures suggested above cannot be implemented.

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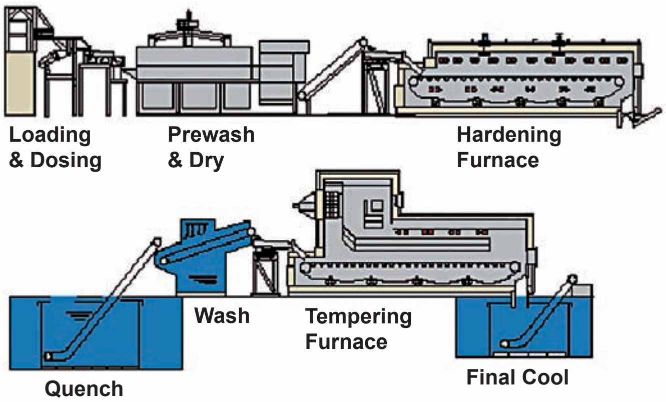
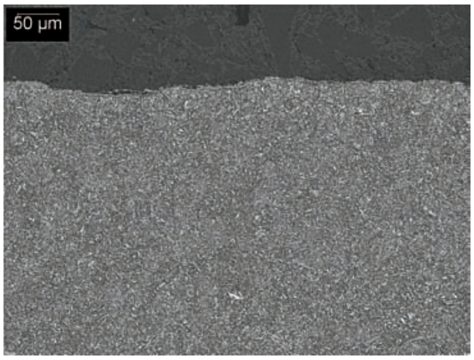


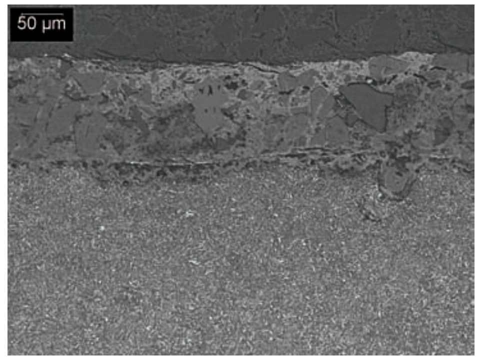
Fig. 1 — Typical mesh belt furnace system with oil quench capability.

Visual Analysis Illustrations

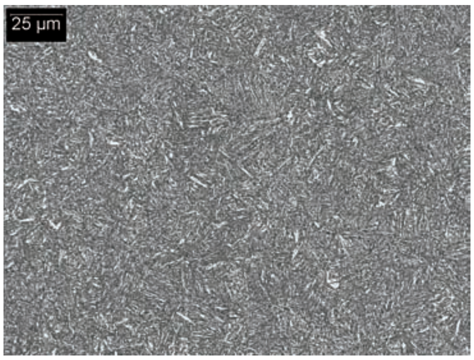
Surface microstructure of good sample revealing thin oxide film at the surface.



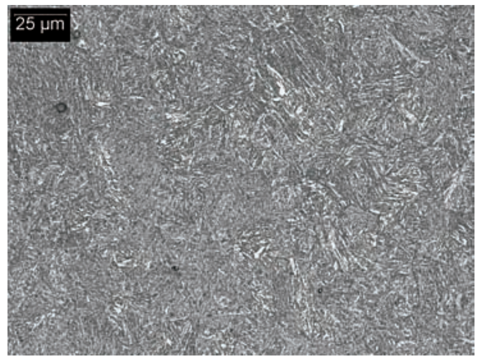
Surface microstructure of bad sample revealing thick oxide film at the surface.



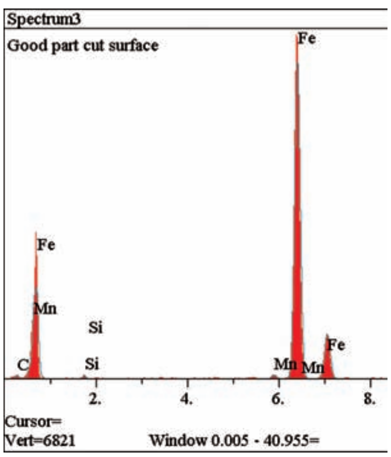
Core microstructure of good sample consisting of tempered martensite.



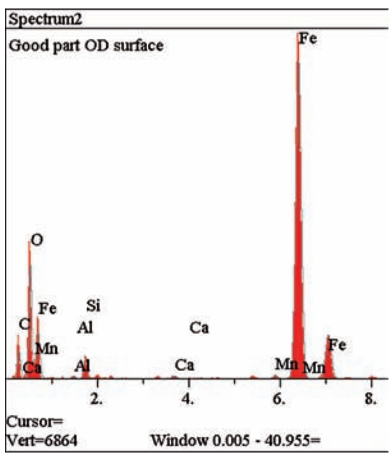
Core microstructure of bad sample consisting of tempered martensite.



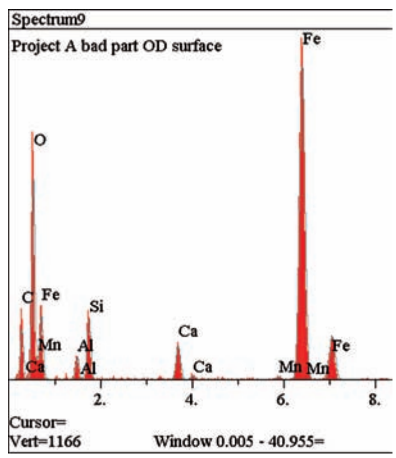
SEM/EDX Analysis Illustrations



Baseline EDX results.

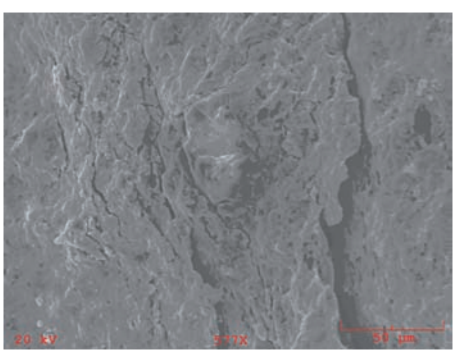


EDX results on OD surface of good sample.



EDX results on OD surface of bad sample.

SEM view of surface of good sample.



SEM view of surface of bad sample.