

# Other Causes of Fastener Failures

by:

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There are failure mechanisms other than fatigue, hydrogen embrittlement, stress corrosion cracking and overload that must be dealt with by fastener makers.

Recently the failure analysis department at SMT&I in Huntington Beach created a brief survey of fastener failures analyzed by the group over a ten-year period and found that there were four predominant failure mechanisms accounting for 77% of the fastener failures analysis by SMT&I personnel. These predominant failure mechanisms were categorized as fatigue, hydrogen embrittlement, stress corrosion cracking and overload.

In general, most people working in the fastener industry have experienced or dealt with one or more of these major failure mechanisms and will sometimes elect not to perform a full failure analysis because they are "familiar" with these failure mechanisms or because the cost of the analysis exceeds the replacement costs of the fasteners.

However, there are numerous other failure mechanisms that are not as prevalent and may not appear as often in the fastener and precision formed parts manufacturing industry. This article presents three such failure mechanisms encountered by SMT&I failure analysis personnel.

## 1<sup>st</sup> Case History: Reverted Austenite

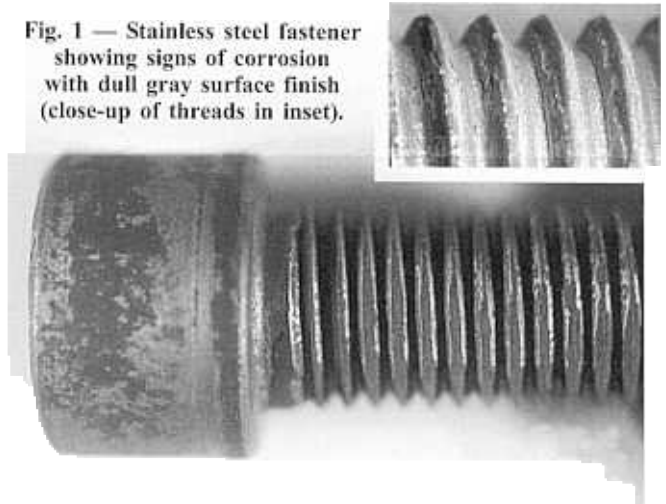
### *Category of Failure Mechanism in Survey: Heat Treat Related Failures (2%)*

A batch of stainless steel fasteners (Type 17-4 PH) was submitted to SMT&I for passivation, as is typical for this material. The fasteners were passivated in accordance with a specification such as *QQ-P-35*, which specifies the solution to be used (20% to 25% by volume of  $\text{HNO}_3$  and  $2.5\% \pm 0.5\%$  by weight of  $\text{Na}_2\text{Cr}_2\text{O}_7 \times 2\text{H}_2\text{O}$ ) as well as the time and the temperature of the passivation process (20 minutes at 120°F to 130°F or 49°C to 54°C) based on the material.

After passivation it was noticed that the samples appeared corroded or attacked, with a dull gray surface finish (as seen in Figure 1) that felt slightly gritty to the touch. The failure analysis group was asked to determine the cause of the problem. In this case, the fastener had not been in service, therefore the problem was limited to a manufacturing problem, a heat treating problem or a passivation process problem.

A longitudinal metallographic cross section through one of the "attacked" fasteners was mounted in Bakelite and then ground and polished to a metallurgical finish. An examination of the cross section in the as-polished condition did not reveal any obvious anomalies that would account for the response of the material to typical passivation procedures. However, in the etched condition, it was clear that the fastener had been attacked or eaten in areas that were metallurgically different than the bulk Type 17-4 PH stainless steel material. The etched microstructure exhibited a distinct non-uniform white

Fig. 1 — Stainless steel fastener showing signs of corrosion with dull gray surface finish (close-up of threads in inset).



layer (as seen in Figure 2) along the surface of the fastener that was found to be reverted austenite. The corrosion of this white layer was visible in several areas of the examined fastener.

Past analyses performed at SMT&I have found that reverted or retained austenite exhibits a much lower resistance to corrosive-type attack than the surrounding martensitic structure. The presence of such a non-uniform layer of reverted austenite is typically the result of nitrogen pick-up during heat treatment of the fastener and is commonly associated with a contaminated furnace atmosphere.

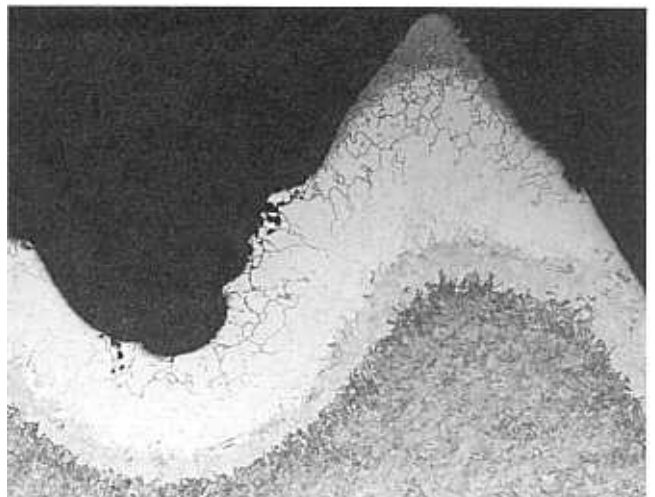


Fig. 2 — Reverted austenite layer layer on fastener (magnification 50X).

## 2<sup>nd</sup> Case History: Segregation of Inclusions/Forging Defect

*Category of Failure Mechanism(s) in Survey:  
Raw Material Defects (1%) and/or  
Manufacturing Defects (8%)*

Several aluminum toe bolts were submitted to SMT&I personnel to determine the cause of crack indications/bursts visible on the point end of the bolts (Figure 3) from two groups. One of the submitted groups of toe bolts did not exhibit any obvious indications of defects and was to be used as a control or comparison group of samples. Sectioning one of the "bad" bolts resulted in the core material falling out of the threaded portion as though the threads were a sleeve or a shell (as seen in Figure 4).

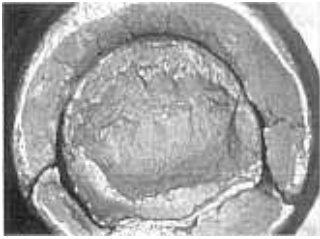


Fig. 3 — Cracks & burst visible on point end of bolts.



Fig. 4 — Bottom & side views of core material (l) that fell out of the threaded portion (r) of the bad bolt after sectioning.



Longitudinal and transverse cross sections through bad bolts were mounted in Bakelite and polished to a metallurgical finish. Examination of the samples in the as-polished and etched conditions revealed clear evidence of a path of segregated inclusions and/or bursts throughout the threaded section of the fasteners (as seen in Figure 5) as well as into the forged

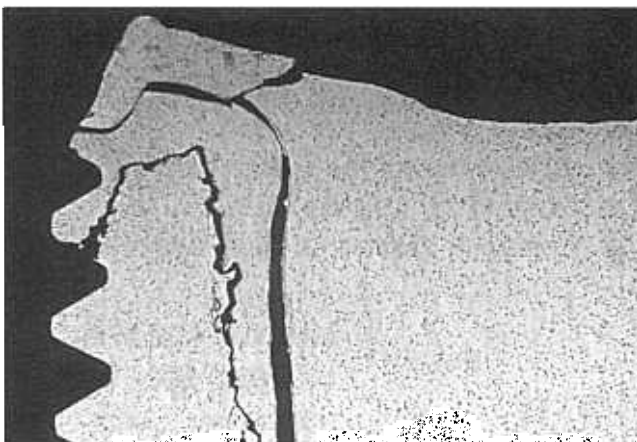


Fig. 5 — Path of segregated inclusions & bursts throughout threaded section of fastener (magnification 15X).

head. The inclusions and/or bursts were found to follow the contour of the head, suggesting that the bursts were created or accentuated during the forging process. In the transverse orientation, the segregation of inclusions was distinctly visible surrounding the path of the bursts in the toe bolt material.

The toe bolts were reportedly made of AA 2024 material in the T4 condition. But chemical analysis of the submitted bolts revealed the material to be AA 6061. Tensile tests performed on two of the samples containing no obvious indications of cracks revealed an average tensile strength of 47 ksi (324 MPa), which is consistent with AA 6061 in the T6 condition (45 ksi or 310 MPa). AA 2024 in the T4 condition would typically exhibit a tensile strength of approximately 68 ksi (469 MPa).

Aside from the variation in material and tensile strength from the reported information or drawing information, the presence of such segregation of inclusions within the material would be problematic. It could not be determined, however, if the forging bursts were related to the variation in material properties/improper material. For instance, if a more severe force is used to forge AA 2024 T4 material than would be used for AA 6061 T6, then it is conceivable that the bursts may not have been present if the appropriate forging conditions were used for the material actually used to make the bolts. However, the segregation of inclusions is not related to the forging of the bolts. Rather, it is associated with the wire or bar stock used to make the fastener blanks. Therefore in this case, two types of failure mechanisms contributed to the failures of the toe bolts. These were raw material defects (inclusion segregation) and manufacturing defects (forging bursts).

## 3<sup>rd</sup> Case History: Poor Grain Flow

*Category of Failure Mechanism in Survey:  
Manufacturing Defects (8%)*

One failed hex bolt was submitted to SMT&I to determine the cause of the failure. The fracture was located on the underside of the head as shown in Figure 6. Examination of the mating fracture surfaces did not reveal any obvious evidence of a single point origin or pre-existing defect (quench crack, lap, etc.) that would account for the failure of the hex bolt.

A longitudinal cross section through the mating pieces of the fractured bolt was mounted in Bakelite and polished to a metallurgical finish. Examination in the as-polished condition revealed no obvious evidence of foreign material or other manufacturing anomalies such as laps or folds that would account for the failure. The sample was etched using a solution of 3% Nital and re-examined.

The etched sample revealed flow lines from the heading operation extending into the shank of the bolt, which is typically considered undesirable (see Figure 7 on the next page). Further examination of the etched cross section revealed the heavily deformed grain flow to be ori-



Fig. 6 — Fracture located on underside of head on failed hex bolt.

## Emphasis: Other Causes of Fastener Failures

ented almost completely perpendicular to the axis of the bolt. The fracture path was found to follow the orientation of the grain flow from heading, resulting in the relatively flat and smooth fracture surface within the head of the bolt.

Typically, the intersection of the longitudinal axis of the fastener and transverse axis of the heading flow lines is at a distance of at least  $D/4$  from the bearing surface (in the head). In this hex bolt case, the location of this intersection was less than  $D/4$  from the bearing surface of the failed fastener.

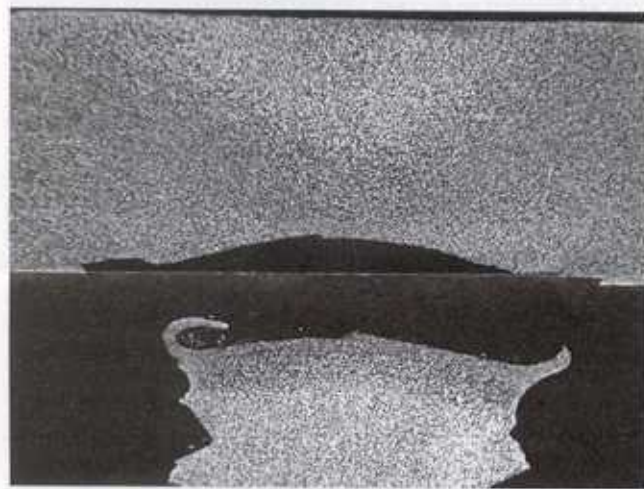


Fig. 7 — Flow lines from the heading operation extending into the hex bolt's shank.

Examination also revealed the presence of wing-like indications consistent with planes of significant strain/deformation within the head of the bolt (Figure 8). It is unknown to what extent these strain bands may have contributed to the failure of the submitted bolt.



Fig. 8 — Wing-like indications in the bolt head.

The failure in this case would most likely have been avoided had the heading grain flow pattern been isolated within the head of the fastener and not extended into the shank of the bolt, passing through the bearing surface of the bolt. This failure was classified as a manufacturing (a forging) problem.

For more on the services offered by SMT&I, contact the author at [carrie.menendez@stork.com](mailto:carrie.menendez@stork.com) or Circle 203. **FTI**

### Author & Company Profiles...

*Carrie Menendez has a Bachelor's degree in Metallurgical Engineering and has worked at Stork Materials Testing & Inspection, Huntington Beach, CA, USA, for six years. She is a registered professional engineer in her home province of Alberta, Canada.*

*Stork Materials Technology (SMT), maintains a network of full-service testing facilities across the USA including Stork Materials Testing & Inspection. These facilities are staffed and equipped to provide rapid and cost-effective failure analysis and reporting. In addition to failure analysis, SMT facilities offer testing services including chemical, mechanical, metallurgical, dimensional and nondestructive testing for a wide range of materials and industries.*