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Failure Analysis of a Screw due to Fatigue

Keywords: Cap Screw, Fracture, Fatigue

Material: Steel

Introduction

A 5/8—11 by 1—1/2 inch Grade 8 hex head steel cap screw used on a pump assembly had fractured during disassembly of the pump. Visual examination and metallographic analyses was performed on the submitted sections to look for root cause of the failure.

Visual Examination

Figure 1 is a photograph showing the two mating fracture surfaces. Failure had taken place by complete separation of the head from the shank. A major portion of the fracture was located at the fillet between the head and the shank. There are two distinct zones on the fracture. The first, light area, is a brittle conchoidal fracture texture and the other a fibrous, silky fracture texture typical of overload of a strong, tough material. The light conchoidal zone showed evidence of fracture surface rubbing. There were also several areas at its periphery which appeared to be fracture origins. Fracture therefore was initiated at several sites and propagated across approximately one half of the shanks cross-section when final fracture (dark area) occurred. The light area is typical of progressive(fatigue) fracture.

Fig 1 Fractured cap screw as received condition showing a fatigue fracture structure

Mechanical Test

Hardness tests conducted on the screw shank revealed a hardness of Rockwell C39. This is in keeping with the observed microstructure. This level of hardness reflects a strength well above that required for a grade 8 bolt.

Microscopic Examination

Two small samples were cut from the shank of the screw and mounted so show a transverse and longitudinal cross-section. After suitable preparation, the samples were metallographically examined. The microstructure of the screw material was found to be tempered martensite which indicates that the screw was in the heat treated (quenched and tempered) condition. Figure 2 is s photomicrograph (500X) showing the microstructure. The end of the shank containing the fracture was cut away and used for scanning electron microscopic (SEM) study. This examination revealed that the light zone way indeed a fatigue area. Figure 3 is an SEM fractograph (800X) showing the fracture surface at one of the origins on the light area. Note the striation typical of fatigue. Contrast this to the fracture

found in the dark area of the fracture shown in the SEM Figure 4 (800X). Here we have a dimple texture typical of tensile overload of a tough ductile material.

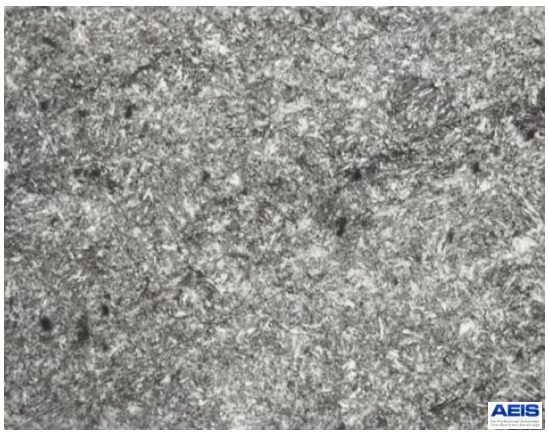

Fig 2 Microstructure of fracture screw showing a tempered martensite structure X500

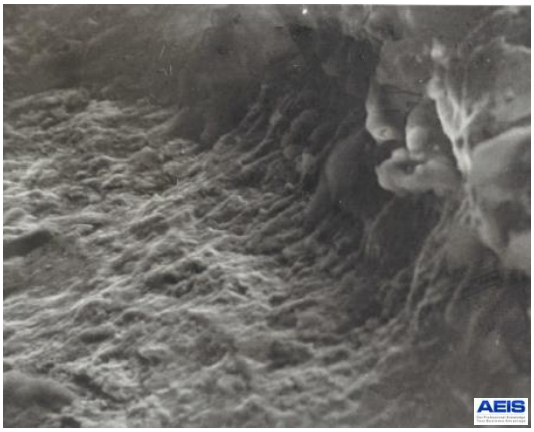

Fig 3 SEM at one of the fracture origin on the light area X800

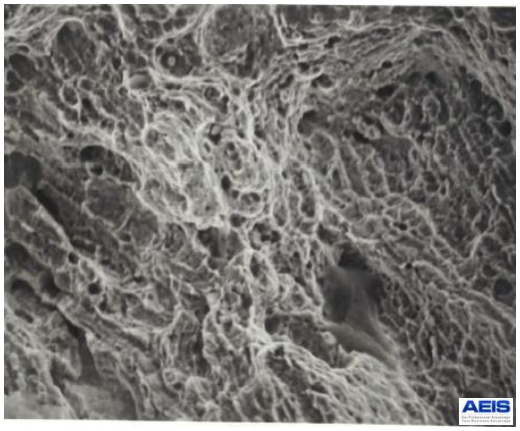

Fig 4 SEM of fracture surface at dark area

Conclusion

It is therefore concluded that the mechanism of failure on the subject cap screw was fatigue which was taking place over a period of time while the pump was in operation. The fatigue failure had progressed to the point where over half of the shank cross-section had been compromised. Sufficient force was exerted to fracture the remaining cross-section upon application of a wrench to remove the cap screw.