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Failure analysis of connecting bolts and location pins assembled on the plate of main-shaft used in a locomotive turbochanger

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Abstract

Three connecting bolts, three location pins and navel of turbo-disk fractured, which were assembled on the plate of the main-shaft used in a locomotive turbochanger. Detailed fractographic study and metallurgical analysis were focused on the trouble bolts. The fatigue fracture is the main failure mechanism of the bolts. Appearance of the surface decarburization layer in the thread tip and root regions of the three failed bolts make the hardness at the thread regions decrease intensely so that the fatigue cracks initiated form the root at the first engaged thread. Surface damage morphology with cutting, wear and plastic deformation features was found on the working flanks of the engaged threads. Other components fractured in succession after the trouble bolt fractured.

Keywords: Bolts; Fatigue fracture; Decarburization; Failure analysis

1. Background

Connecting bolts and location pins connected a turbo-disk with the plate of main-shaft, and the navel of turbo-disk fractured during servicing. The failed main-shaft system was used in a locomotive turbochanger, which had serviced for 1,00,000 km.

The specified materials and the mechanical properties of the failed components are listed in Table 1. The threads of the bolts were cold rolled after quenching and tempering processes.

2. Investigation methods

The chemical composition of the materials for the failed components was determined by spectroscopy chemical analysis. The micro-composition in various zones of the fracture surfaces was determined by energy

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Table 1
Materials and mechanical properties of the failed components

Failed component	Specified material	Mechanical properties
Bolt	35CrMo	HB260-300, $\sigma_b \geqslant 980$ MPa, $\sigma_{0.2} \geqslant 835$ MPa, $\delta_5 \geqslant 12\%$
Pin	35CrMo	HB260-300, $\sigma_b \geqslant 980$ MPa, $\sigma_{0.2} \geqslant 835$ MPa, $\delta_5 \geqslant 12\%$
Main-shaft	42CrMo	HB260-300, $\sigma_b \geqslant 882$ MPa, $\sigma_{0.2} \geqslant 686$ MPa, $\delta_5 \geqslant 12\%$
Turbo-disk	GH2132	HB255-321, $\sigma_b \geqslant 930$ MPa, $\sigma_{0.2} \geqslant 620$ MPa, $\delta_5 \geqslant 20\%$

dispersive X-ray spectrometer (EDX). The microstructure was observed by optical microscopy (OPM) on an Olympus GX51 optical microscope. The fracture surfaces were analyzed by visual and SEM observation on a Philips XL-30 scanning electron microscope to study the failure mechanism. Microhardness profiles were made on an MH-6 Vikers meter with a load of 500 g.

3. Results

3.1. Fractography

The main-shaft showing the fracture location is shown in Fig. 1. The fractured connecting bolts, location pins and navel of turbo-disk were assembled on the plate of the main-shaft end (Fig. 2). The fractured bolts and pins are, respectively, numbered as bolt 1, pin 2, pin 3, bolt 4, bolt 5 and pin 6 in Fig. 2.

3.1.1. Connecting bolts

The three bolts fractured at the first engaged thread. The fracture surface of bolt 1 is relatively smooth and the beach marks showing fatigue crack propagation [1] can be observed faintly (Fig. 3a). Differently from bolt 1, the fracture surfaces are relatively rough and obvious necking phenomenon took place on the fractures of bolts 4 and 5. Appearance of the fatigue striations on the fracture surfaces of the three fractured bolts (Figs. 3b, c, 4b and 5b) demonstrates that the fatigue fracture is the main failure mechanism of the three bolts. The fatigue crack propagation area of bolt 1 is larger and the final fracture area is smaller (Fig. 3a). No obvious plastic deformation can be observed in the final fracture region of bolt 1. But the fatigue crack propagation area of bolts 4 and 5 (Figs. 4a and 5a) is corresponding and smaller than that of bolt 1. The final fracture area is three fourths the full fracture, in which larger plastic deformation zone was found. The final fracture zones exhibit dimple morphology (Figs. 4c and 5c). According to the size of the fatigue crack propagation area and the coarseness of the fracture surface, it can be deduced that the low stress-high cycle fatigue fracture is the failure mode of bolt 1 and the great stress-low cycle fatigue fracture is the failure mode of bolts 4 and 5 [2].

From the orientation of the beach marks and the location of the final fracture region, it can be concluded that the fatigue cracks origins for the failed bolts initiated from the thread root (marked in Figs. 2, 3a, 4a and 5a). The breakage sequence of the three bolts was bolt 1, bolt 4 or bolt 5.

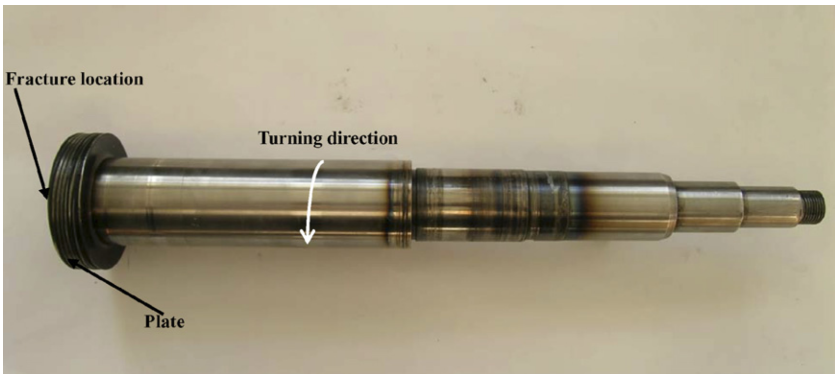

Fig. 1. Main-shaft showing fracture location.