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Investigation of a failed axle of a reduction gearbox

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Abstract

After 11,300 h of operation, one of the axles of the reduction gearbox of the hoist mechanism of a dockside crane failed due to the propagation of a fatigue crack. The axle contained two gears, the largest of which was mounted swith a key, while the smallest gear was an integral part of the axle. On both ends of the axle a bearing was mounted: one cylindrical bearing and one spherical roller bearing (locating bearing).

The axle was made from 17CrNiMo6 steel, and the machined gear teeth were case carburised. The failure of the axle occurred in the middle between both bearings of the axle, on a non-contacting part of the gear machined on the axle.

During visual inspection striations were observed on the fracture surface and three separate crack initiation zones could be observed on three neighbouring gear teeth. The ratio of final fracture versus fatigue fracture was low, indicating a low nominal stress on the axle.

The three initiation sites were investigated with optical microscopy and SEM, and clear indications of a ductile overload fracture were found. In an etched longitudinal section of one of the gear teeth where initiation took place several cracks could be observed in the hardened case of the tooth.

The hardness at the initiation site was found to be 777 HV, while the hardness at the final fracture (diametric position relative to the initiation of the crack) was found to be lower, namely 722 HV.

It was concluded that at the initiation site during the case carburisation quenching cracks were formed, which then propagated through the whole section of the axle under relatively low operation load.

Keywords: Cranes; Gear tooth failures; Quench cracks; Carburisation

1. Application

The hoist mechanism of a dockside crane is driven by an electric motor through a reduction gearbox. The gearbox has a total reduction of 24.92 and is designed for a nominal driving torque of 3800 Nm (with an

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Fig. 1. View of the two parts of the failed axle.

engine speed of 850 rpm). After 11,300 h of operation of the hoist mechanism the axle connecting the first and the second stage of the gearbox was found to have failed.

The fractured parts of the axle are shown in Fig. 1. The gear visible on the left of Fig. 1 is an integral part of the axle and belongs to the second stage of the transmission. The teeth of this gear are case carburised. On the part shown on the right in Fig. 1 a gear of the second stage of the transmission was mounted, connected to the axle by means of a keyway (not shown in Fig. 1). Both the left and the right part of the failed axle contain a bearing seat (visible in the bottom of Fig. 1). On the left part a non-locating cylindrical roller bearing is normally mounted, while on the right part a (locating) spherical roller bearing is mounted. As shown in Fig. 1 the axle failed due to a crack in the middle between both bearings. This crack is situated on a non-contacting part of the gear machined on the axle.

2. Visual observations

Both crack faces are shown in Fig. 2 (left part of Fig. 1) and in Fig. 3 (right part of Fig. 1). On both crack faces striations indicating a fatigue crack are clearly visible. Also visible on both crack faces are some dark temper coloured zones, which are most probable due to the use of a blowtorch during dismounting.

When the crack face shown in Fig. 3 is investigated more closely, three different initiation sites can be discerned (marked A, A′ and A″ in Fig. 3). Final fracture of the axle is located at the site marked B in Fig. 3. The dark tempercoloured band extending between C and C′ in Fig. 3 is most probable damage produced by the use of a blowtorch during dismounting. A fourth possible initiation site is marked D in Fig. 3. The fatigue crack propagated through the axle starting from A, A′ and A″ towards B. The ratio of the surface occupied by the fatigue crack and the surface occupied by the final fracture indicates that the nominal working stress of the axle was low, as the final fracture surface occupies only a small part of the total crack surface [1]. The distribution of the striation lines over the fatigue crack surface and the location of the final fracture indicate that the axle was mainly loaded in rotating bending [1].