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Failure of two overhead crane shafts

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ABSTRACT

The failure analysis of two overhead crane shafts is presented: the failure of an overhead crane drive shaft and the failure of an overhead crane gearbox shaft, due to rotating-bending fatigue. The fracture of the overhead crane drive shaft originated in small radius fillet between two different diameters of the shaft. A new shaft was made with a larger-size fillet, resulting in reduced stress concentration in this region. The failure of the overhead crane gearbox shaft originated at the intersection of two stress raisers, at the change in shaft diameter and in the keyway corner. A new shaft was made with a larger-size fillet and a larger size radius of the keyways corner to minimize stress concentration in this section. In both cases the installed couplings were replaced by gear couplings in order to allow parallel and angular misalignment as well as to avoid additional load due to misalignment. The analysis shows that the fatigue life can be significantly increased with a simple change in the structural details.

1. Introduction

The fatigue fractures of shafts originate at points of stress concentration, such as changes in the shaft diameter and ends of the keyways. The sharp corner at the intersection between two different diameters of the shafts or in the bottom of the keyway can cause local stress to be few times greater than the average nominal stress. The failure analysis of an overhead crane trolley drive shaft is presented in the first part of this paper. The failure originated in the radius fillet between two different diameters of the shaft. The failure analysis of an overhead crane trolley gearbox shaft is presented in the second part of the paper. The failure of this shaft originated at the intersection of two stress raisers, the change in the shaft diameter and keyway.

2. Failure of overhead crane drive shaft

In “Steelworks Split” the high-speed electric overhead crane, Fig. 1, was suitable for transport of the billets from the melt shop to the rolling mill hall. The crane was rated at 10 tons with span 20.5 m and handled about 100 lifts and transports per day, each lift averaging 5 tons. The stepped drive shaft used for an overhead crane trolley wheel fractured after 24 months of service. The electric motor power rating was 3 kW with an output speed of 940 rpm. The maximum travel speed of the trolley was 32 m/min.

The shaft was connected with the gearbox by a roller chain coupling, supported by two roller bearings and connected with the wheel by a key, Fig. 2.

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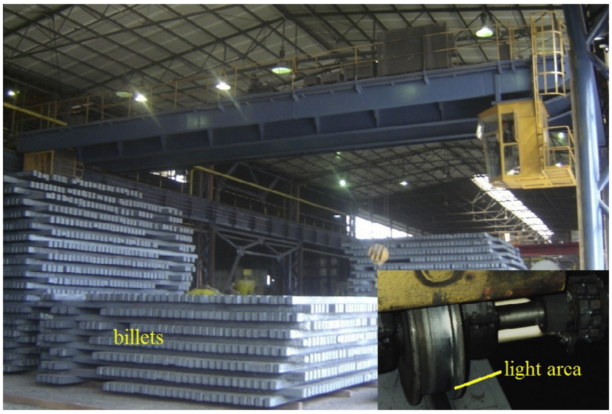

Fig. 1. Overhead crane for transport of billets.

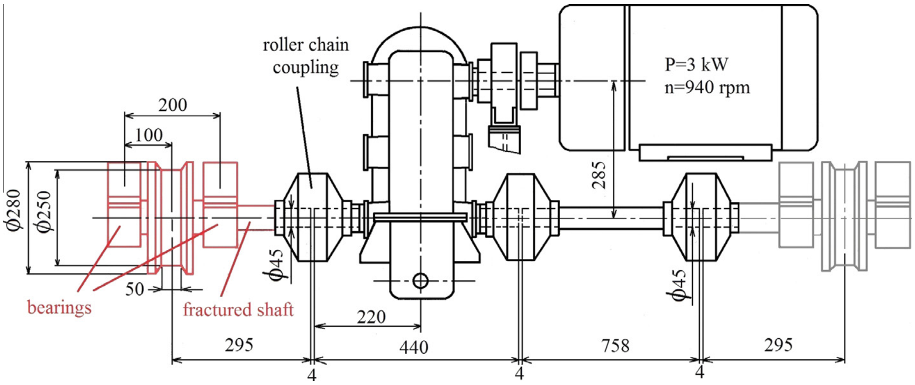

Fig. 2. Overhead crane trolley [2].

The shaft was made from quenched and tempered steel 25CrMo4 according to German standard DIN (Deutsches Institut für Normung) [1]. The chemical composition of material was verified by using quantometer. The hardness and the microstructure were confirmed to be tempered steel 25CrMo4. The fracture occurred on the fillet at the change between two different diameters of the shaft approximately 225 mm from the driven end and approximately 30 mm from one end of the keyway where the crane wheel was keyed to the axle, Fig. 3.

2.1. Fracture surface investigation

The contour of the fracture surface was convex with respect to the smaller-section side. There were three fracture regions, Fig. 4: a region of multiple crack origins around the outer perimeter (at A); a region of the crack propagation zone (at B); and a region of the final, fast fracture (at C).

The presence of multiple crack origins separated by ratchet marks around the outer perimeter was an indication of rotational-bending fatigue with severe stress concentration.

The relatively small size of the final fracture region was an indication of low nominal stress. In rotational-bending, during each revolution, every point of the shaft circumference was subjected to tensile–compressive stress and therefore the crack could be initiated at any point on the shaft periphery.

The individual cracks propagated toward a single crack front, region B, Fig. 4. The crack surfaces were pressed together during the compressive component of the stress cycle, and mutual rubbing occurred. The beach marks were not visible because they were obliterated by rubbing.

The conclusion from the surface investigation was that the shaft fractured as a result of rotational-bending fatigue. The primary cause of the fracture was the bending load during the rotation, although the total load was a combination of bending and torsional loads. The small radius of the fillet at the change in shaft diameter, detail B in Fig. 3, resulted in high stress concentration, which initiated the crack.