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Failure analysis of wire rope of ladle crane in steel making shop

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ABSTRACT

A 6 × 36 construction wire rope conforming to IS 7904: 1995-X grade of high carbon steel failed after nine months of service. Visual observation revealed broken strands with dry damaged core and inter-strand nicking along its length. The dry core indicated insufficient lubrication. The fractured end of wire rope exhibited crown/chisel shaped marks and fractography using SEM showed striations confirming initiation by fatigue. The appropriate bending fatigue upon consideration of factor of safety, sheave diameter, rope diameter, co-efficient of sheave shape, working load and metallic area was estimated to be six months. Microstructural examination exhibited drawn pearlite in the matrix. Improper lubrication led to fretting wear between the internal wires resulting in failure of individual strands while rest of them were unable to carry the tensile load in service. Additionally, bending fatigue was predominant when it passed through the sheave during which inter-strand nicking occurred. Changing of the schedule of the wire rope from 9 to 6 months was recommended. Proper inspection by NDT and application of heat resistant lubricant like super micronized solid lubricant -molybdenum should be implemented to avoid such failures in future.

1. Introduction

Wire ropes are used industrial applications like mines, lifts. Individual wires wound into strands, which are then wound into the final rope. During operation, the ropes are undergone to axial cyclic and bending loads, resulting microscopic motion of individual wires against the neighboring ones and caused fretting wear. The interaction of fretting wear and cyclic load causes crack initiation and propagation resulting fracture. The fretting fatigue also increases the failure of the rope [1–3]. Ropes require inspection, maintenance, and periodic replacement. In addition to the financial losses, failure of wire ropes may cause catastrophic events like falling of tackle, crane pulley, heavy components which are the threats to safety. Torpedo crane carrying hot metal for steel making area, the wire rope failed from a height of approximately 1 m while lifting the torpedo weighing approximately 6 tonnes. The failure of torpedo crane wire rope created a safety concern in the steel plant and huge production loss due to 10 h of breakdown. The wire rope failed after 9 months of service. The arrangement of Torpedo crane is shown in Fig. 1. The tackle lifts the slab with the tong which was attached to the pulley. The main hoist of Torpedo crane has four wire ropes, 2 nos. in West side & 2 nos. in East side connected with ladle lifting beam assembly. Failure location of wire rope was found near to ladle beam sheave assembly shown in Fig. 1. This paper presents an analysis of the failed wire rope and an assessment of the degradation mechanisms, principally fretting and fatigue, during service and calculation of bending fatigue life of wire rope which will help to prevent such kind of failure by changing the wire rope at scheduled interval.

2. Experimental procedure

Failure analysis was conducted by employing optical micrography, stereo micrography, chemical composition analysis by Inductive Coupled Plasma Atomic Emission Spectroscopy (ICPAES), hardness testing and SEM/EDS analysis. The failed components were collected from the plant for investigation. Fractography was carried out by Field Emission Gun Scanning Electron Microscopy (FEG-SEM) of the failed fractured samples. The samples were cleaned for visual examination before metallographic sample preparation. Samples for microstructural evaluation were made from the fractured end of the failed wires. These samples were mounted and polished by conventional metallographic techniques to obtain a scratch free surface. The polished samples were etched in 3% Nital solution (3 mL HNO_3 in 97 mL ethyl alcohol), and both unetched and etched samples were examined under an optical microscope (Leica DMRX). The micro-hardness of different phases was determined by micro hardness tester (Leco-LM247AT).

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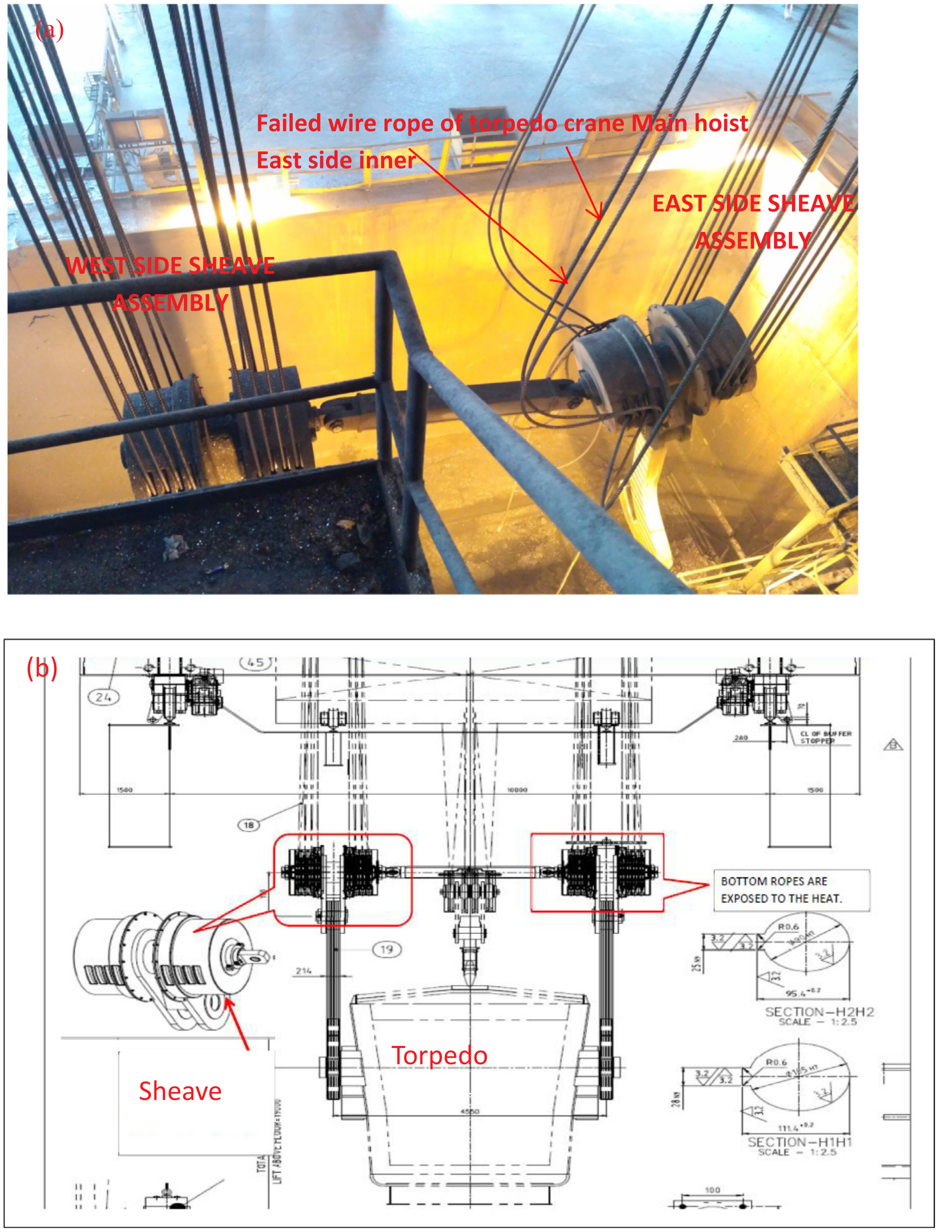

Fig. 1. (a) The arrangement of the wire rope of Torpedo ladle and failed wire rope of torpedo crane (b) drawing showing assembly of crane wire rope.

3. Results

3.1. Visual examination

The 6 × 36 classification of wire ropes includes standard 6 strands with a steel core. During visual observation the failed wire rope was found with damaged core as shown in Fig. 2(b) and (c). The steel core was found totally dry, devoid of lubrication. Along the length of the wire rope interstrand nicking was observed. Schematic representation of failed wire rope is shown in Fig. 2(f). At the internal breaks, abrasion and wear are evident and indicated abrasion with sheave of pulley of the wire rope. Mostly 60% wires failed in fatigue mode and rest finally failed in ductile mode (thinning observed at breakage end indicating tensile overload) as shown in Fig. 2(e).

3.2. Stereoscopic observation

The samples were observed from different strands of failed wire rope under stereo microscope. The resulting stereo images were presented in Fig. 3. The stereo image of the breakage end showed cup and cone type of failure which indicated failure under tensile load. Abrasion and fretting wear were observed in Fig. 3(a) which were away from the broken end (internal breaks region). The square shaped (valley breaks) and crown breaks as observed in Fig. 3(a) and (b) were the indications of fatigue [4,5]. Crown fatigue breaks occurs due to wear against sheave as shown in Fig. 3(a). Under normal operating conditions, appreciable surface wear were observed, followed by crown fatigue breakage. Under stereo-microscope, fatigue breaks were observed which were generated due to abrasion. A valley break is defined when a wire breaks between two adjoining strands. If a valley break is observed, it is a strong indication of fatigue of internal rope wires as well.

3.3. Fractography

The location of fractographic examination is shown in Fig. 4(a). The damaged area at the internal broken end showed two regions forming a step. They were named as zone A and Zone B. Zone A showed striations which indicated fatigue as shown in Fig. 4(b) and zone B showed