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Failure analysis of the 13Cr valve cage of tubing pump used in an oilfield

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ABSTRACT

The 13Cr valve cage of a tubing pump fractured after 191 days service in an oilfield in China. The failure causes were analyzed by direct-reading spectrometer, Rockwell hardness tester, optical microscope, scanning electron microscopy, energy dispersive spectrometer, electrochemical method and finite element method in this paper. The results showed that the failure reason was typical corrosion fatigue fracture initiating at the root of the last thread next to the thread relief groove, where numerous corrosion pits and cracks were observed. In general, co-effect of two factors occurred to cause the valve cage to corrosion fatigue fracture. The downhole medium with high CO_2 and Cl^- concentrations was the environmental factor of the failure. Alternating stress caused by pumping cyclic motion was the main stress factor of the failure, while the high stress concentration on thread connection further induced cracking.

1. Introduction

In recent years, the continuous increase in energy demand has caused the decline of the availability of petroleum resource in the world. Artificial lift systems to produce oil are the most effective means to enhance production capacity of oil fields [1,2]. As a consequence, a lot of subsurface sucker rod pumps including tubing pumps and insert pumps are used in the world's oil fields. The American Petroleum Institute provides the requirements and guidelines for the design of subsurface sucker rod pumps in API Spec 11AX [3]. Tubing pumps are the oldest type of sucker rod pumps with a simple construction, including working barrel, plunger, travelling valve and standing valve, as shown in Fig. 1. Due to the relatively larger barrels to allow more fluids to pass than any other type of pumps, tubing pumps are highly efficient and widely used in petroleum industry [4]. However, the high impact of the ball in travelling valve and the reciprocating motion of the rod string could cause pump components to fracture easily [5].

With the development of the deeper wells, the downhole temperature is increasing significantly, and the downhole medium usually contains substantial amounts of salt water, carbon dioxide, and hydrogen sulfide (sour wells) [6]. The aggressive environment may cause cracking to speed up, such as corrosion fatigue characterized by a unexpected and sudden failure [7,8]. The corrosion fatigue failure of tubing pumps is catastrophic for oilfield production, causing huge economic losses. It is very important to evaluate and study the affect of materials, environment, stresses, etc. on the corrosion fatigue behavior of tubing pumps.

Due to better corrosion resistance than conventional low alloy steels and lower cost than other stainless steels such as duplex stainless steel, 13Cr martensitic type stainless steel has been widely used in petroleum equipment [9]. However, most recently, the

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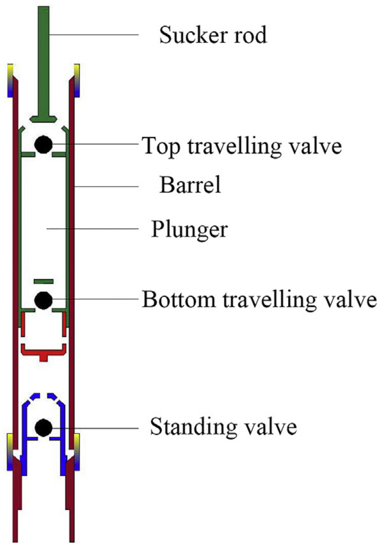

Fig. 1. Structural schematic diagram of a tubing pump with two travelling valves.

environmentally assisted cracking cases of 13Cr downhole equipment are increasing, although 13Cr stainless steel have been considered to be reliable up to 150 °C in CO_2 corrosion environment [10]. In the current work, the failure reason of the 13Cr valve cage of tubing pump was studied by chemical analysis, metallographic analysis, fracture morphology analysis, corrosion products analysis, electrochemical measurement and stresses simulating, which could provide some suggestions for the material applicability and manufacture of tubing pumps to avoid similar failures in an oilfield environment.

2. Background of the failure

The Φ38.10 mm tubing pump used in an oilfield was radically fractured on the top travelling valve at 3801 m depth downhole. The environment medium is oil-water mixture with some natural gas. The CO_2 content of natural gas is up to 23.21 mol%. The formation water with 128,500 mg/L chloride content is mainly calcium chloride type.

The top travelling vale cage is composed of a top open valve cage and a bottom closed valve cage which were joined by a threaded connector. The fracture surface is located near the last pin thread of the open valve cage, as shown in Fig. 2(a), and another part of the fracture pin thread remains in the box thread of adjacent closed valve cage. Fig. 2(b) shows the inner morphology of the closed valve cage by section. It can be seen the valve ball and valve seat in closed valve cage are undamaged without obvious general corrosion.

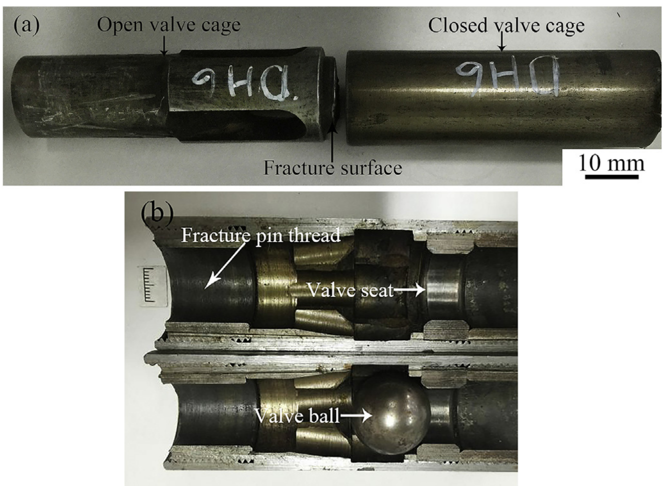

Fig. 2. The failed valve cages (a) and inner morphology of the closed valve cage by section (b).