Case Studies in Engineering Failure Analysis 7 (2016) 56–64

Contents lists available at ScienceDirect

Case Studies in Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/csefa

Case study

Damage analysis of choke bean used in an oil–gas well

H.M. Tawancy *, Luai M. Alhems

Center for Engineering Research, Research Institute, King Fahd University of Petroleum and Minerals, KFUPM Box 1639, Dhahran 31261, Saudi Arabia

ARTICLE INFO

Article history:
Received 7 July 2016
Received in revised form 27 July 2016
Accepted 4 August 2016
Available online 11 August 2016

Keywords:
Oil and gas
Steel
Corrosion
Wear
Electron microscopy

ABSTRACT

A choke bean used in an oil–gas field has catastrophically failed during operation. It is shown that that the damage has been caused by leakage of the corrosive and abrasive drilling fluid. The choke bean adapter made of carbon steel has been corroded and embrittled by hydrogen ingress leading to its fracture in the presence of stresses created by the pressure of accumulated fluid at the bottom section. On the other hand, the choke corner body made of stainless steel has been damaged by abrasive wear of its outer surface.

1. Introduction

Process equipment used in the oil–gas industry relies heavily on various grades of carbon steels and stainless steels as structural materials for several components such as pipes, valves and chokes [1]. An assembly containing such components in addition to spools and fittings is commonly referred to as "Christmas tree" whose primary function is to control the fluid flow into or out of the well by means of chokes, gauges and lines usually referred to as choke manifold. The choke is an orifice installed in the assembly in order to restrict the fluid flow and control the production rate and also create downstream or back pressure [2]. During drilling, a fluid known as the drilling fluid (liquid-based mud) or drilling mud containing additives such as barium sulfate is circulated through the system to remove rock cuttings and bring them to the surface. Another important function of the choke is to control the backflow of the drilling fluid.

Chokes used in oil–gas wells are classified into two major types depending upon the operation mode, which can either be adjustable or positive. Adjustable chokes are flexible in that they allow the fluid flow and pressure to be adjusted in accordance with production requirements. In contrast, positive chokes do not provide that flexibility; however, they are more resistant to damage by abrasion or erosion. Adjustable chokes are usually used in large wells while positive chokes are commonly used in small wells. The calibrated opening of the adjustable choke is usually varied in 0.4 mm (1/64 in.) increments known as beans. Since highly abrasive materials pass through the choke at high speed over several years of service, hardened steel or a grade of stainless steel lined with tungsten carbide is used in the application and a grade of carbon steel is used to manufacture the bean adapter.

During operation, the chokes among other components of the Christmas tree can become susceptible to degradation by various types of wear [3–9], corrosion [1,5,10] and environmental-assisted cracking [11–13]. Although the terms Christmas

* Corresponding author. Fax: +966 13 8603996.
E-mail address: tawancy@kfupm.edu.sa (H.M. Tawancy).

http://dx.doi.org/10.1016/j.csefa.2016.08.001

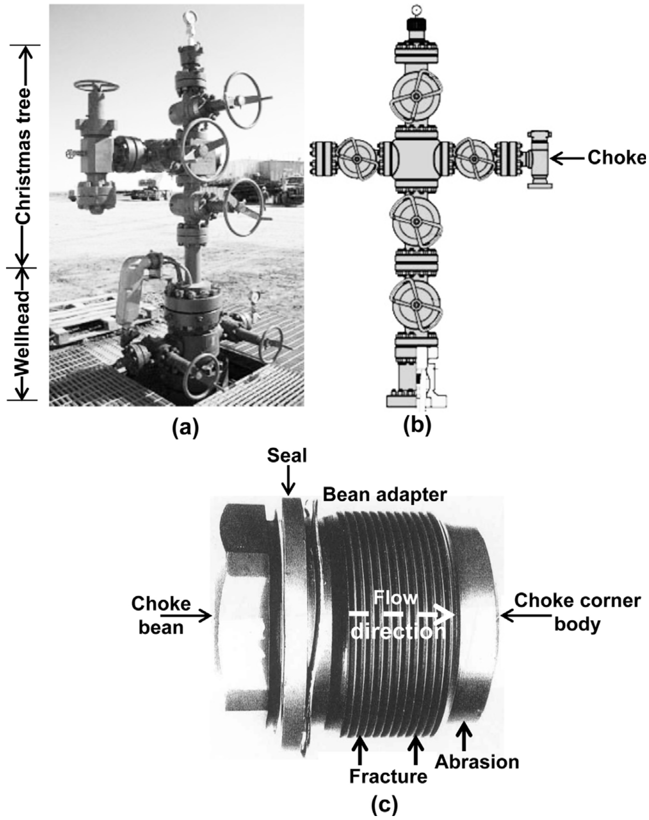

Fig. 1. An illustration of the layout of Christmas tree and wellhead showing the coke used to control the production rate and backflow of the drilling fluid. (a) A photograph showing the Christmas tree and wellhead used in oil–gas wells [2]. (b) A schematic illustration of the Christmas tree showing the location of the choke [2]. (c) A photograph of unused choke in the present study showing its components and the locations of the damage sustained during operation.

tree and wellhead are sometimes used interchangeably, the terms refer to separate equipment as illustrated in the photograph of Fig. 1a [2]. A schematic illustrating the Christmas tree showing the location of the choke is shown in Fig. 1b [2].

In the present case, an adjustable choke bean has been used in service at intermittent periods in an oil–gas well. During the last operation, the choke bean has catastrophically failed within the first hour of operation. The components of a choke bean never used in service are shown in the photograph of Fig. 1c. On-site inspection has shown two types of damage at the bottom of the choke as illustrated in Fig. 1c: (i) the choke bean adapter has fractured along the longitudinal direction, which is parallel to the flow direction and (ii) the outer surface of the choke corner body has sustained severe abrasive wear near the bean adapter. According specifications, AISI 1045 carbon steel and 316L stainless steels have been used to manufacture the choke bean adapter and the choke corner body respectively. The internal surface of the choke corner body has been protected by a surface layer of tungsten carbide. A water-based mud has been used as the drilling fluid. The base is an aqueous solution of Ca and Zn bromides and the solids consist of: (i) clays, (ii) organic colloids, (iii) barium sulfate to increase the fluid density and (iv) substances from the formation (region of the oil–gas reservoir) which are incorporated into the mud during drilling [14]. Items received to determine the most probable cause of failure included the failed choke components, a sample of the drilling fluid and as well as a solid mud sample.

2. Experimental procedure

Representative metallographic specimens were removed from the damaged and unused bean adapters for metallurgical evaluation using scanning electron microscopy (SEM) combined with microchemical analysis by energy dispersive spectroscopy (EDS). The chemical compositions of the choke bean adapter and choke corner body were determined by inductively coupled plasma-atomic emission spectroscopy (ICP-AES) with the exception of C content, which has been measured by combustion calorimetry. To reveal the grain structures, selected specimens were etched in 10% oxalic acid. Surface hardness measurement was used to evaluate the mechanical strength. Since the surfaces exposed by failure of the choke bean adapter were oxidized, selected specimens were descaled in hydrochloric acid to reveal the underlying morphological features. X-ray fluorescence was used to determine the average composition of the drilling fluid. The solid mud sample was analyzed by SEM and EDS.