Engineering Science and Technology, an International Journal 19 (2016) 566–573

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Contents lists available at ScienceDirect

Engineering Science and Technology, an International Journal

journal homepage: http://www.elsevier.com/locate/jestch

Full Length Article

Updating temperature monitoring on reciprocating compressor connecting rods to improve reliability

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A R T I C L E I N F O

Article history:
Received 28 May 2015
Received in revised form
24 August 2015
Accepted 15 September 2015
Available online 28 October 2015

Keywords:
Reciprocating compressors
Temperature monitoring
Reliability
Cost analysis

A B S T R A C T

In recent years, formerly depleted domestic oil fields have become producers once again through tertiary oil recovery. In tertiary oil recovery, water and Carbon Dioxide (CO_2) are alternatively injected into reservoirs through injection wells. This raises the field pressure and forces oil to producing wells where it is then pumped to a storage tank referred to as a battery. This paper is focused on an operating division in the Permian Basin (USA). The CO_2 is acquired from underground domes in Colorado and then transferred through pipelines to oil fields in West Texas and New Mexico.

The compressors are used to move CO_2 and boost the gas to the required field pressure, usually around 2,200 psig. Reciprocating compressors are flexible and able to handle wide capacity and condition swings, offer an efficient method of compressing almost any gas composition in a wide range of pressures and have numerous applications and wide power ratings. This makes them a vital component in various industrial facilities. Condition monitoring of critical rotating machinery is widely accepted by operators of centrifugal compressors. However, condition monitoring of reciprocating machinery such as compressors and internal combustion engines has not received the same degree of acceptance. This paper examines the reliability impact as a result of upgrading the temperature monitoring devices on the connecting rods of electric driven reciprocating compressors. A cost analysis is also presented to demonstrate that the upgrade in hardware and software will eventually yield a saving in the operating cost.

1. Introduction

In recent years, formerly depleted domestic oil fields have become producers once again through tertiary oil recovery. In tertiary oil recovery, water and Carbon Dioxide (CO_2) are alternatively injected into reservoirs through injection wells. This raises the field pressure and forces oil to producing wells where it is then pumped to a storage tank referred to as a battery. The CO_2 tertiary recovery business was built using reserves found and depleted decades ago during the oil boom that ended in the early 1980s [1]. Companies have injected 10.8 trillion cubic feet of CO_2 since the 1970s to raise the yield from oil fields by some 650,000 extra barrels per day, more than 10 percent of daily US total production [2]. This paper is focused on an operating division in the Permian Basin (USA). Currently, 67 of the nation's 127 CO_2 tertiary oil recovery projects are located in the Permian Basin [3]. The CO_2 is acquired from underground domes in Colorado and then transferred through pipelines to oil fields in West Texas and New Mexico (see Fig. 1). The new and specialized use for CO_2 in the upstream oil and gas industry has created a need for compressor stations in the field to handle the gas [4].

Reciprocating compressors are the dominant style of compressor utilized due to their capacity control which allows them to adapt to changes in flow and pressure easily. The compressors are used to move CO_2 and boost the gas to the required field pressure, usually around 2200 psig. Reciprocating compressors are flexible and able to handle wide capacity and condition swings, offer an efficient method of compressing almost any gas composition in a wide range of pressures and have numerous applications and wide power ratings. This makes them a vital component in various industrial facilities. Condition monitoring of critical rotating machinery is widely accepted by operators of centrifugal compressors. However, condition monitoring of reciprocating machinery; such as compressors and internal combustion engines, has not received the same degree of acceptance. This paper examines the reliability impact as a result of upgrading the temperature monitoring devices on the connecting rods of electric driven reciprocating compressors.

In reciprocating compressors, pistons are moved in a reciprocating action to compress gas. They can be arranged in a single or double acting design. In the double acting configuration,

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Peer review under responsibility of Karabuk University.

http://dx.doi.org/10.1016/j.jestch.2015.09.012

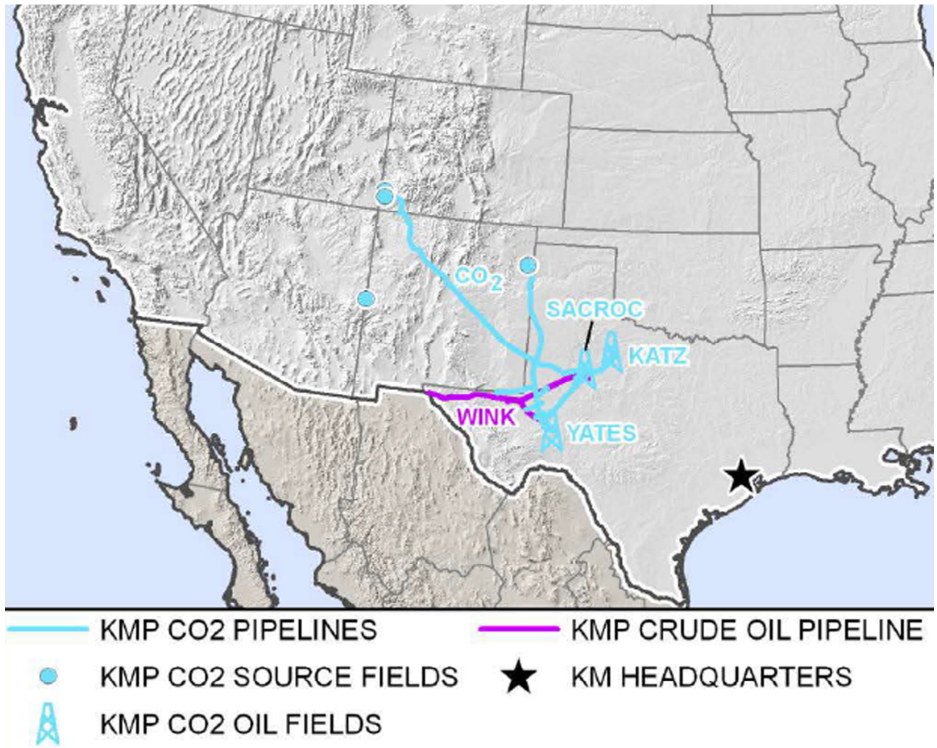

Fig. 1. KM HQ and KMP locations.

compression occurs on both sides of the piston during both the advancing and retracting stroke [5]. In a reciprocating compressor, the oil flows from the main bearing through a passage in the crankshaft to the crank pin bearing. It then flows from the crank pin bearing through a rifle-drilled hole in the connecting rod to the crosshead bearing. The crosshead bearing is the last point of lubrication. The load on the crosshead bearing depends on the gas pressure in the cylinder and the inertia force of the reciprocating parts [6].

The dynamic piston load in double acting cylinders changes direction from compression and tension. The change in direction creates clearance between the crosshead bearing and crosshead pin which is the point of lubrication. A lack of direction change starves the crosshead bearing for oil and heat is generated between the crosshead bearing and the crosshead pin. The heat has the potential to seize the pin and the bearing, causing a catastrophic failure. The lack of change is referred to as a lack of reversal [6]. The crosshead pin transfers the load from the connecting rod to the piston. The deformation that it undergoes during operation must be considered so it does not have surface contact with both simultaneously [7].

A guideline is that reversal must occur for at least fifteen degrees of rotation and have a magnitude greater than three percent of the loading in the opposite direction [8]. The rod load by API definition is not actually a rod load, but a pin load. It should also be noted that different OEMs evaluate rod loads differently [9]. All operating cases, such as low suction pressures and part-load steps, should be carefully studied to ensure rod reversal is sufficient for long term reliability [10]. A non-reversing load can occur when an application contains slow speed operation, single acting head end operation and low volumetric efficiencies [11]. In most reciprocating compressors, the maintenance costs for valves, packing and rings amount to approximately 65 percent of the overall maintenance budget [12]. However, what is often overlooked is the effect leaking valves and rings have on the dynamic forces of the compressor which can reduce the rod reversal and cause catastrophic failure of the crosshead bearing and pin [13].

Most common reasons for unscheduled shutdowns are: broken sealing elements of valves (about 36%), faulty pressure packing (about 18%) and piston rings (about 7%) [14,15]. Monitoring systems enable condition-based maintenance for detecting abnormal behaviors pointing to faults or to system failures. Several papers have been published about valve fault (i.e., leaking valve) detection in reciprocating compressors [14,15]. Condition monitoring can be based on measurements of various physical states: vibration, flow rate, power, position, temperature, and pressure. The data required for diagnostic evaluation depend mainly on the types of faults expected and observed. Pichler et al. [15] have presented vibration analysis and pV diagram analysis and Pichler et al. [14] have described pV diagram analysis for early detection of cracked or broken valves.

One of the methods to detect non-reversal is temperature monitoring of the connecting rod bearings and this article deals with the temperature monitoring. However, the movement between the connecting rod and compressor frame makes it challenging to make a temperature measurement on the crosshead pin bearing [16]. Eutectic probes are characterized as an offline solution that is unable to provide any quantitative information about the bearing temperature. They provide only an alarm or shutdown indication with no temperature data to support corrective action or indicate false alarm. Radar-wireless measurement of bearing temperatures uses a sensor in direct contact with the bearing shell to provide fast, accurate, real-time continuous temperature monitoring. It provides a constant indication of a potential issue and justification for an emergency shutdown [17].

The compressors currently utilize eutectic temperature sensors in the connecting rods. Often compressors have been saved by shutdowns due to eutectic or “turkey popper” temperature devices in connecting rod bearings [18]. The sensors use a fusible eutectic material that is designed to fail at a designated temperature, in this case 200 °F. The fuse rod threads into a thermowell in the connecting rod parallel to the bore of the sleeve bearing in the connecting rod. When the fuse rod fails under spring tension it trips a