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Analysis of the mechanical behavior of a delayed coker drum with a circumferentially cracked skirt

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Abstract

The skirts of four coke drums of a delayed coker plant in an oil refinery became severely cracked as result of the service and a poor design. The cracks were located in the circumference just below the welded joint of the skirt with the pressure vessel of the coke drums. Since the cracks grew up to one hundred percent of the circumference, the drums were free to move both laterally and vertically. The present paper describes the results of the measurement of these displacements, as well as other non destructive test, done in order to analyze by finite element the mechanical behavior of the skirt and the drum-skirt system. The results showed that the greatest risk of failure was the plastic collapse of the skirt due to an uneven distribution of the vertical loads resulting from the lateral and vertical displacements of the drum. The analysis is used then to propose a unique reinforcement of the skirt that allows to fully rehabilitate the coker drums without re-welding the fractured skirts.

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Keywords: Cracked skirt; coke drum; mechanical behavior.

1. Introduction

A delayed coker unit in an oil refinery is composed of four drums of 1766 m^3 of volume each. The operating temperature is 449 ºC and the design pressure is 1.05 kg/cm^2 at the top and 3.9 kg/cm^2 at the bottom. The shell is made of SA387-Gr11 CL.2 steel with a 2.8 mm clad of 410S stainless steel. The main dimensions of the drums are: 8534 mm internal diameter, 27127 mm shell height and 6160 mm cone height and the nominal thickness is 25.4 mm. The

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skirt is a cylinder made of SA387-11 CL.2 steel, 25.4 mm thickness. The vessel is designed under the ASME Secc. VIII Division I, 2000.

After eleven years of service, during a routine inspection, the thermal insulation was removed in the area of the skirt junction in all four drums in order to make thickness measurements, after that a cracking along the circumferential skirt junction was detected; the cracks ran aside of the welded joint in the skirt side. An example of the cracked area and the cracking is shown in Figure 1. At the time of inspection, in the four drums, the entire circumference was cracked and the fractured edge of the skirt showed different levels of misalignment between the fractured edges, as shown in Figure 2. There was also observed that there was an opening and closure movement of the mating crack surfaces In addition to the skirt junction cracking; bulging of the skirt, anchorage bolt pull out and corrosion under insulation were observed.

Fig. 1. Left: Coker drum with the thermal insulation removed in the skirt junction. Right: Cracking of the skirt junction running along the weld line in the skirt side.

Fig. 2. Misalignment of the fractured edges of the skirt junction.

By visual observation of the drums in service, it was deducted that the misalignment was caused by the lateral displacement of the drums. It is worth to mention that the movement was fairly cyclic at a frequency of 1 Hz in the heating up stage of the drum operation. A literature survey pointed out that cracking of the skirt junction is a very common form of damage of the coker drums [Boswell (1997), Jani (2012), Schimidt (2012), API RP 571 (2013)], and it was known that these cracks are caused by the cyclic stresses induced by the differential thermal expansions of the pressure vessel and the skirt during the operational stages of the coker drum (load-heat up-quench-discharge), a mechanism referred as thermal fatigue [Boswell (1997), Jani (2012), Schimidt (2012), API RP 571 (2013)].

The Figure 3 shows a sketch of the skirt junction indicating the location of the cracking. The misalignment of the fractured edges of the skirt was measured directly on each drum, taking readings every 30 grads in the circumference (one technical hour). A positive value was assumed if the shell edge was displaced outwards and negative when the