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Analysis of failed ethylene cracking tubes

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Abstract

The failure of ethylene cracking tubes at an elevation of about 5 m in radiant chambers after one-year service has been analysed. Bulges and circumferential cracks, oriented towards the walls/burners, are the result. The investigation included tensile tests, optical microscopy, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), and X-ray diffraction (XRD) analysis. Analysis revealed that ruptures found in the tubes were caused by overheating of the tubes because of inappropriate burning of bottom burners. Significant growth of precipitates of carbide was observed in the failed zones which results in the drastic reduction of material ductility. The bulged zones also showed a globular form of grains. Tube bowing, due to the restricted growth during the hot expansion, promotes cracks. To avoid such overheating, precautions should be taken while improving the burning condition of the bottom burners and decreasing the peak tube metal temperature. It is necessary to check the tube temperature periodically in critical positions and one should ensure that the temperature is less than the design temperature.

Keywords: Bulging failure; Cracks; Overheating; Tube failures; Chemical-plan failures

1. Introduction

Ethylene cracking tubes or reformer tubes and other tubes, which are made from cast creep resistant austenitic steel HP grade (26 Cr, 35 Ni, 0.4 C) are usually designed for a normal life of 100,000 h (11.4 years), their actual service life, however, varies from 30,000 to 180,000 h, depending on the service conditions and of course on the quality of materials [1]. Due to prolonged exposure to high temperature, the microstructure of the material is subjected to degradation. Although sufficient care is taken in the selected

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materials, design and operations, failures can hardly be avoided because of various reasons, such as overheating [2], stress corrosion cracking [3], creep and fatigue [4–7].

In our paper, a detailed investigation of failure in ethylene cracking tubes was presented.

2. Background

The ethylene cracking tubes are vertically installed. The feed gas, such as naphtha and steam, enters at the top end at a pressure of 0.1 MPa and flows down individual tubes. The ethylene cracking reaction takes place in the tubes and is endothermic. For this, heat is provided by burners, distributed at two sides of the furnace symmetrically. There are 36 bottom burners and 48 wall burners. The bottom burners provide about 85% of total heat intensity. The heat is transferred to the cracking tubes through radiation and the metal temperature is maintained between 700 and 900 °C by design requirement. The material specification and design parameters are given in Table 1. The composition of tubes is in agreement with the requirements of the specifications for HP40 metal.

After about one year in service, four ethylene cracking furnaces were damaged. The damage style, ruptures of a number of tubes, is almost the same. All the cracks are circumferential and at an elevation of about 5 m in the radiant chambers. Bulges also occurred at this elevation. The cracks and bulges are oriented towards the walls/burners.

In general, failure of furnace tubes can occur in a variety of modes. In this case, however, the probably reasons may be one or more of the following: (1) overheating in this zone; (2) material strength cannot meet the requirement; (3) limitation of the tube elongation. To identify the failure reason, tensile and tests, metallography and fractography analysis should be carried out by light microscope and scanning electron microscopy (SEM).

3. Experimental and results

3.1. Visual examination

Fig. 1 shows the actual bulge and rupture of as received sample. The local bulge has penetrated as shown in Fig. 1(a). Cross-sectional view of the bulge tube is shown in Fig. 1(b). Tube diameter is now increased and

Table 1
Material specification of ethylene cracking tubes of sample and design parameters

Tube material	HP40	
Composition (wt%)	C	3.8
	Si	0.65
	Mn	0.31
	P	0.07
	S	0.04
	Cr	23.4
	Ni	41.9
	Nb	1.36
	W	0.80
	Fe	Balance
Design temperature	700–900 °C	
Tube size	Outer diameter	63 mm
	Thickness	6.4 mm
	Length	12 m