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Fracture analysis of the threaded joint of the level gauge in a reabsorption tower

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ABSTRACT

The fracture of the threaded joint of the level gauge in the reabsorption tower has been analyzed. Through the investigation of operational condition, macroscopic examination of the broken threaded joint, chemical composition analysis of the threaded joint material, metallographic examination of the threaded joint and specimens with cracks, mechanical property analysis, microscopic appearance analysis and energy spectrum analysis, the cracking mode can be attributed to Stress Corrosion Cracking (SCC) of austenitic stainless steel caused by the combined action of wet H_2S and Cl^- in medium. In this case, the material of the broken threaded joint was not 304 stainless steel, but a high Mn substituted Ni steel, beside, the threaded joint produced a lot of induced martensite during large deformation of cold working which greatly increase the sensitivity of SCC, so the material did not meet the requirements was the main factor in this fracture accident.

1. Introduction

Austenitic stainless steel is known for its excellent corrosion resistance, mechanical properties and formability [1], it is widely used in medicine, chemical, nuclear field, transportation and other fields [2–4]. Austenitic stainless steel can be broadly divided into two major categories for 200 series and 300 series [4]. The higher Ni content (usually 8 wt% or higher) of the austenitic stainless steel is called the 300 series, while the use of Mn and N instead of the partial Ni element is called 200 series stainless steel [5]. With the growth of Ni prices, people are increasingly interested in 200 series stainless steel and more economical high Mn substituted Ni stainless steel [6,7], the Ni content of these austenitic stainless steels are lower than the 300 series stainless steel, and the Cr content of these lower Ni stainless steel must be lower than the 300 series stainless steel in order to maintain the austenitic structure, thus the corrosion resistance of these austenitic stainless steels will be lower [8].

SCC is a typical cracking of austenitic stainless steel in hazardous environment. The sensitive materials, specific media and sufficient static stress are three necessary conditions for SCC [9]. In addition, the sensitive medium that causes stress corrosion cracking of stainless steel is mainly Cl^- [10] and H_2S [11–13] in petrochemical industry. Moreover, the stress corrosion failure caused by wet H_2S is generally hydrogen-induced cracking. Due to the low hydrogen diffusivity of austenitic stainless steel, it is thought to be little susceptible to hydrogen-induced cracking [14]. But the unstable austenite produces induced martensite during large deformation of cold working, which will greatly increase the susceptibility to hydrogen-induced cracking [15]. In mechanical manufacturing, welding [16–19], forging [20], and casting [21] often produce residual stress. In addition, cold working is an important technical means for equipment production, but cold working will produce dislocations, twins and significant residual stresses

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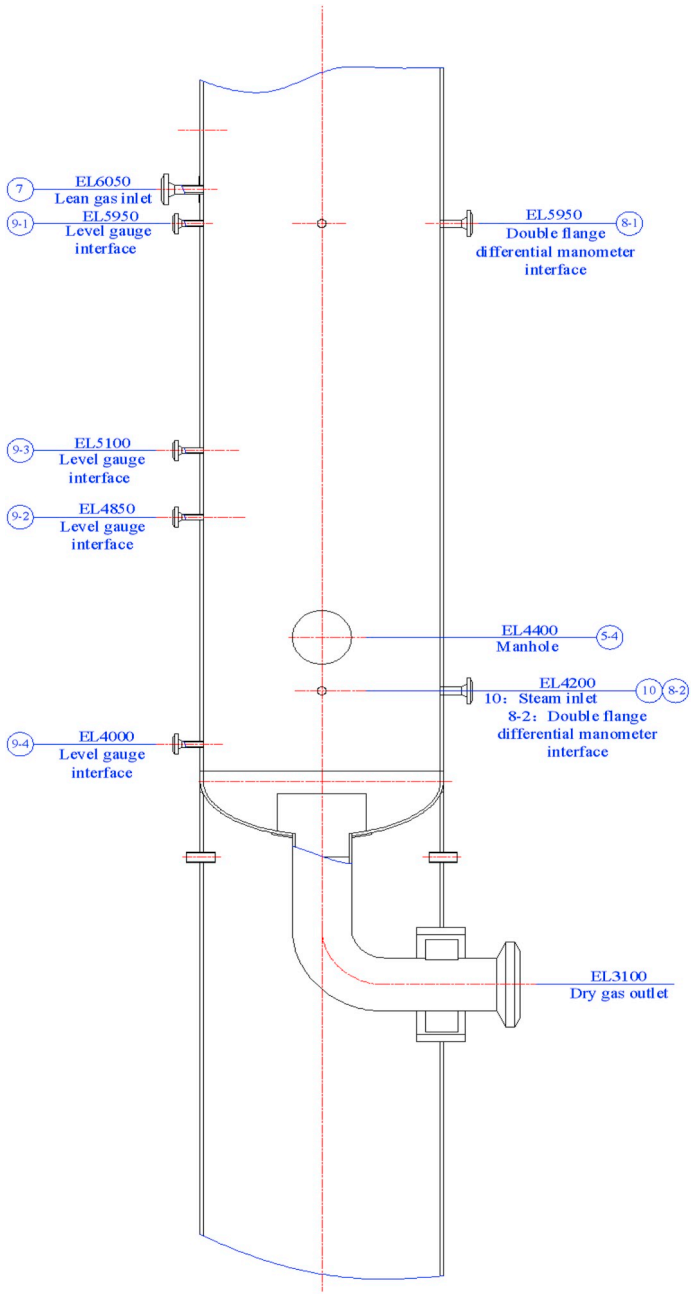

Fig. 1. The position diagram of level gauge of the reabsorption tower.

[22], which will promote stress corrosion susceptibility and accelerate crack propagation [23–26].

Therefore, the high Mn substituted Ni steel undergoes a great plastic deformation of cold working, in the combined action of H_2S and Cl^- will easily lead to SCC. In this paper, the failure cause of stainless steel threaded joints of level gauge in the reabsorption tower was studied by the analysis of macroscopic examination, chemical composition, microscopic appearance, metallurgical structure and energy spectrum, etc.

2. Descriptions of the failure case

The leakage was found at the level gauge valve of the reabsorption tower, which was caused by the fracture of the stainless steel threaded joint of the level gauge. The level gauge had been put into use since February 2017 and had been used for 3 months. There were two level gauges used in series. Their relative position in the height direction of the reabsorption tower as shown in Fig. 1, the level gauge 9-1～2 at the top of the 9-3～4. The leakage threaded joint of level gauge was 9–4, and the elevation was EL4000.