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Effect of microstructures on SCC of steel: Field failure analysis case study and laboratory test result

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ABSTRACT

Based on continuum mechanics approach, the first step on the modeling of the stress corrosion cracking (SCC) is to understand the morphology of the cracks. Later on, it is followed by other considerations such as the chemical interaction, and electron diffusion. This paper investigates the morphology of the SCC behavior of steels with the main purpose of developing the basis of computational modeling. It also aims to give the basic sense for practical engineers in the fields as well. It mainly focuses on the morphology of the SCC on three basic common microstructures of steel: austenite, ferrite–pearlite, and martensite. The objects were taken both from real field works and from accelerated laboratory tests. The field samples were extracted from actual failed parts at known operating conditions and lifetimes. The laboratory test was an immersion in sodium hydroxide solution. The experimental parameters were controlled in such away to simulate accelerated field failures with all three microstructures. The crack depth and behavior of the stress corrosion cracking (SCC) were then analyzed after immersion test and subsequently, the mechanism of stress corrosion cracking was studied with the focus on their morphological observations. The result shows that each microstructure produces unique shape that can be used as a basis for computational model creation. Field engineers can also take advantage of the results for materials selection.

1. Introduction

Majority of papers discussing about stress corrosion cracking (SCC) focus only on the chemical composition of steels in various corrosive solutions [1–7], and not on their microstructures. Papers that discuss about SCC of the steel with the focus on the effect of microstructure are available only modestly. Most of the papers [8–13] discuss about the SCC from the chemical and mechanical point of views, such as erosion corrosion. These make the computational modeling progressing sluggishly, although recently some publications on SCC modeling are also available. Very few papers discuss about SCC quantitatively using commercial softwares [14], especially the ones that discusses about the stress state near the crack tip. Modeling using finite element analysis needs information on the morphology of the cracks. Conventional modeling usually only utilizes the mechanical properties and is deficient in further consideration on the shape and the characteristics of the cracks. Therefore, the fracture mechanics approach to the SCC problems cannot be done or can only be done poorly.

Although the most common SCC problems take place in austenitic steel, steels in other form of microstructures can also undergo SCC. In harsh environments of engineering such as refinery plant, it is reported that up to 25% of equipment failures

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