Damage Mechanisms in the Petrochemical Industry: Identification, Influencing Factors, and Effective Monitoring Strategies

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ABSTRACT

In this paper, we identify critical technical issues relevant to the implementation of an effective asset integrity program for fixed equipment. We propose certain methodologies that can be employed to assist with the development of an asset integrity program and ensure consistency of program inspections and evaluations across circuits, processing units, and production facilities.

KEY WORDS: mechanical integrity; corrosion; damage; uniform corrosion; non-uniform corrosion; petroleum; production; refinery.

INTRODUCTION

In an increasingly regulated and scrutinized operating environment, upstream and downstream petrochemical operators should endeavor to become very cognizant of the various damage mechanisms (DMs) that might affect pressurized fixed equipment, including process piping, pressure vessels, and heat exchangers. Understanding and addressing these DMs is integral to maintaining the integrity and reliability of fixed equipment. In this paper, we provide an overview of various DMs affecting fixed equipment in the petrochemical industry, organized by common critical factors and factors that govern their severity. These factors include, but are not limited to, temperature, equipment metallurgy, composition of process stream, and fluid velocity. Drawing from our experience, we discuss the challenges and inherent uncertainties in quantifying these critical factors.

The emphasis of this paper is on process piping as opposed to pressure vessels and other equipment. Process piping is prevalent throughout a production facility and is potentially exposed to effectively all DMs identified in API 571, Damage Mechanisms Affecting Fixed Equipment in the Refining and Petrochemical Industries. By understanding the DMs affecting process piping, it is possible to obtain a representative understanding of the DMs that may be present in the pressure vessels and equipment connected by the process piping.

The authors recognize that there is a large body of industrial and academic research on the topics of identification, influencing factors, and monitoring of damage mechanisms within refineries. It is beyond the scope of this paper to discuss all these studies but citing a few pertinent examples is relevant in this regard. Milton and Gysbers (2010) identified a statistical approach to monitoring damage mechanisms in refinery process piping. Saab, Dias and Faqeer (2005) identified several coupled localized corrosion mechanisms in a carbon steel atmospheric crude distillation overhead line and proposed an effective supplementary inspection methodology that allowed continued operation until scheduled turnaround. Duggan, Rechtien and Roberts (2009) identified three distinct damage modes within a crude distillation overhead system, one of which was velocity accelerated corrosion. Finally, Al Arada, Al Otaibi, Al Refai, Haggag and Ray (2013) demonstrated a more effective corrosion management system for refinery process units utilizing integrity operating windows.

API PUBLICATIONS

The American Petroleum Institute (API) publication 579-1, Fitness-For-Service, lists the identification of DMs as a key first step in determining the integrity and projecting the remaining life of a component, by considering the service history, environmental conditions and material of construction. Advanced inspection strategies involving Risk-Based Inspections (RBIs) have also been addressed by API in API RP 580. API 580 lists the identification of DMs as one of the key steps towards applying the framework of RBI. Toward these goals, API RP 571 lists DMs that might affect fixed equipment in the petrochemical industry and summarizes available industry information regarding each mechanism. These mechanisms fall into broad categories, including mechanical and metallurgical failure modes, uniform or localized loss of thickness, high temperature corrosion, and environmental assisted cracking. The API publication also incorporates information from major incidents that have been reported by industry to inform and develop the understanding of these individual DMs. Predictive curves are provided to assist personnel associated with production and refining units in developing an inspection strategy for many of the listed DMs.

There are a number of key factors that dictate the severity or rate of corrosion from a given DM. Examples of such critical factors, as identified in API 571, include, but are not limited to, temperature, metallurgy, and process fluid velocity. A fundamental understanding of DMs that may be present within a circuit or system can influence asset integrity procedures at a production facility, including the determination of inspection frequencies and location of condition monitoring locations (CMLs). However, there is little discussion within API RP 571 on the potential coupling of certain DMs, which is known to occur. For example, due to economic reasons or supply constraints, some owners/operators increasingly produce or process opportunity crude slates, which may have higher concentrations of sulfur and naphthenic acid (Qu, Liu, Lan and Shan, 2011). Although naphthenic acid corrosion is separate and distinct from sulfidation corrosion,