Advancing Asset Reliability and Process Monitoring using Fiber Optics Technology

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Abstract

The pressure letdown area of alumina high temperature Digestion facilities is subject to highly erosive flow conditions emanating from elevated velocities of flashing/boiling abrasive slurry. As part of continued improvements in the design and asset reliability of these facilities, advanced measurement techniques using optical fiber have been employed to refine our understanding of the fluid mechanic behavior across critical components such as control valves and chokes. Incorporation of these findings into current mathematical models allows for real-time, accurate assessment of flow conditions within the piping system which can then be used to predict rates of erosive wear. Following this primary focus, other areas of application for fiber optic measurement techniques were explored, including alternative level/interface detection methods and detailed temperature profiling of piping and equipment. This paper reviews the application of fiber optic sensor technology in the execution of these aims.

Keywords: Asset Reliability, fiber optics temperature detection, two-phase / three-phase flow, level measurement.

1. Introduction

This paper introduces advanced fiber optic measurement techniques, and summarizes two trials that apply Fiber Bragg Grating technology to two industry challenges.

Firstly, Fiber Bragg Grating technology is applied to provide detailed thermal profiling of the interconnecting flash tank slurry piping of Bayer Digestion facilities. Results of this trial are used to study the fluid dynamic fundamentals of two-phase flashing slurry systems, with focus on the flow characteristics of mechanical chokes/orifices. Findings are then incorporated to provide accurate slurry piping velocity profiles, detailing the onset and development of abrasive two-phase flashing flow throughout the piping system. This forms the basis of a Digestion Asset Reliability System, where real-time piping component wear rates and residual life are graphically and interactively provided.

Secondly, Fiber Bragg Grating technology is assessed for its suitability as an alternative level detection method for process tanks or vessels. Here, the fiber sensors are mounted on the external wall of a vessel, providing a non-intrusive alternative to traditional level detection methods. Two vessels of varying wall thickness are trialed, and the impact of wall thickness on level responsiveness is assessed.

2. Technology Overview - Fiber Optics Based Sensing

Various fiber optics based sensing technologies are commercially available and widely used in industries such as oil & gas, structural health monitoring, aerospace, space and marine. Commonly, optical sensor based technologies are deployed for applications requiring long distance pipeline or structural monitoring, allowing detection of leaks, deformation (strain) of structures or vibration. Hatch has previously applied fiber based sensor technologies for shorter distance & detailed applications such as furnace refractory condition monitoring via tap-block temperature profiling [1].

Fiber optic sensing technologies take advantage of one or more properties of light to allow measurement of various external environmental parameters throughout the length of the fiber cable itself. That is, temperature, strain or vibration may be profiled over large distances using passive optical fiber cable.

Broadly, there are three categories of established optical fiber based sensing technologies:

1. Single-point, where a single sensor is typically located at the end of the fiber cable (Fabry-Perot),
2. Multi-point, where two or more discrete sensors are positioned at the required points along the fiber cable (Fiber Bragg Grating),
3. Distributed, where the entire fiber cable length is 'profiled' for the particular measurement (Rayleigh, Raman and Brillouin).

Table 1. Comparison of optical sensing technologies [2].

Technology	Topology	Range	Temp.	Strain	Pressure	Vibration
Fabry-Perot	Single-Point	< 10 km	Yes	Yes	Yes	Yes
Fiber Bragg Grating	Multi-Point	< 50 km	Yes	Yes	Yes	Yes
Rayleigh	Distributed	< 70 km	Yes	Yes	No	No
Raman	Distributed	< 20 km	Yes	No	No	No
Brillouin	Distributed	< 50 km	Yes	Yes	No	No

Hatch performed a review of the various technologies listed in Table 1, and took part in laboratory trials to witness temperature and vibration measurement capabilities and accuracies. Following this technology review, Hatch selected a highly accurate Fiber Bragg Grating (FBG) based system for this trial campaign. FBG technology offers a lower cost option for shorter distances at a much higher spatial accuracy, enabling specific point measurements at any required location or interval along the length of the optical fiber.

2.1. Fiber Bragg Grating Technology

Fiber Bragg Grating technology provides a high-speed, multi-point sensing method that allows for discrete point temperature measurements at any predefined location along a fiber cable. Bragg Grating refers to the modification of optical fiber where a series of 'mirrors' are inscribed into the fiber core at each required measurement location. This creates a refractive index perturbation that reflects light back up the fiber cable at a wavelength specific to each inscription. Therefore, by inscribing each Bragg Grating with a different signature wavelength, multiple sensors can be located along a single fiber cable or a series of cables daisy-chained together.

The selected FBG technology provider utilizes a highly precise tunable laser that sweeps through the measured wavelength spectrum at a rate of up to 8 kHz. With every sweep, each sensor location (Bragg Grating) along the fiber cable reflects its specific wavelength back up the cable, generating an array of discrete wavelength peaks for interpretation. The reflected wavelength of each Bragg Grating will deviate from its signature in response to thermal expansion or physical stretching (strain) of the glass fiber core, and this deviation may then be accurately converted to temperature or strain data via well-established correlations [3]. Figure 1 demonstrates this mechanism, where change in temperature or strain can be seen to deviate (increase) the wavelength of the reflected light.

This trial campaign also provided highly encouraging results in the application of FBG technology for level detection applications where a temperature gradient exists across the level interface. This method has the key advantage of being externally mounted to the vessel wall, ideal for applications where traditional level detection may be problematic (due to aggressive process conditions, convoluted vessel internals, or process interference) or intermittent (such as settler interface divers). The ability to externally mount the sensors provides a maintenance/accessibility advantage, potentially leading to reduced vessel downtime that may be experienced due to failures of traditional internally mounted sensors. Results of this trial encourage further trials of additional level detection applications, including settler solids interface detection.

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7. References

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