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Laser Ultrasonic Furnace Tube Coke Monitor

ERIP

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1.0 INTRODUCTION

This report summarizes the technical progress achieved during the third quarter of the ERIP project entitled, "Laser Ultrasonic Furnace Tube Coke Monitor." The focus of work during this reporting period was the construction of an automated probe that will be used to measure the thickness of coke deposits in thermal cracking furnaces. A discovery was made during the last reporting period, which indicated that a conventional NDE broadband transducer could be used in conjunction with a sacrificial standoff composed of a fusible alloy to efficiently couple the transducer to a rough surface operating at high temperature. A probe was constructed that incorporates the recent discovery and initial testing of the probe is now underway.

Because of other project commitments, the manpower available to allocate to the coke detector project was limited during the most recent quarter. As a result, the project is somewhat behind the original schedule. However, project expenditures are consistent with the project progress to date. The total program budget is \$98,670 and the current project expenditures are approximately \$24,000. The original contract budget period ends on April 30, 1999. We intend to request a six-month no-cost extension to the contract so that we may complete the project objectives.

2.0 BACKGROUND

The overall aim of the project is to demonstrate the performance and practical use of a probe for measuring the thickness of coke deposits located within the high temperature tubes of a thermal cracking furnace. This aim will be met by constructing a probe that will be tested using simulated coke deposits that are positioned inside of a bench-scale furnace. Successful development of the coke detector will provide industry with the only available method for on-line measurement of coke deposits.

The coke detector will have numerous uses in the refining and petrochemical sectors including monitoring of visbreakers, hyrotreaters, delayed coking units, vacuum tower heaters, and various other heavy oil heating applications where coke formation is a problem. The coke detector will particularly benefit the olefins industry where high temperature thermal crackers are used to produce ethylene, propylene, butylene and other important olefin intermediates. The U.S. is the world's largest ethylene producer and accounts for about 30% of the total world production with a product value of over 10 billion dollars.

3.0 PROJECT OBJECTIVES

A key project objective will be to verify that the coke detector can meet specific end-user criteria needed for successful commercialization of the device including the following:

1. Sensitive measurement of coke deposits ranging in thickness from 0-1/4"
2. Suitable for use on coils of 1 1/2"-4" diameter
3. Suitable for use at coil temperatures up to 1050°C
4. Suitable for use on rough oxidized metal surfaces
5. Instrument reliability under practical operating environments
6. Measurement reproducibility
7. The instrument is operator safe
8. The probe can be used to make random measurements down the coil length at various access angles from available furnace ports
9. The probe can operate at stand-off distances of at least 10-20'
10. The instrument package can be assembled for less than \$50,000-\$75,000

4.0 PROJECT WORK

4.1 High Temperature Pulser/Receiver

Conventional ultrasonic transducers used to investigate the internal structure of materials can not be directly exposed to high temperatures. High temperature ceramic stand-offs can be used to thermally isolate the transducer from the hot surface. However, effective transmission of energy from the stand-off to the hot surface requires the use of a gel-like couplant. Unfortunately, these couplants can not typically withstand temperatures above about 550 °C.

To overcome this problem, we have developed an automated device to introduce a mechanical wave into the material surface using a transducer standoff composed of a fusible alloy. The device was originally intended to be coupled with a fiber optic laser interferometer that would measure the response of the mechanical wave echoes. However, it was found that the transducer could be operated in the transmission and receive mode to record the pulse echo response directly without use of the standoff laser detector. This requires use of an automated probe that briefly contacts the sacrificial standoff against the hot surface, thereby melting the tip to form a molten metal couplant. The device requires timing circuits to initiate recording of the pulse echoes at the proper time interval following initial contact. The probe must have the following features:

1. Provide a standoff to thermally isolate the transducer from the hot tube surface.
2. Provide a couplant media capable of withstanding 1000°C for intermittent use.
3. Automatically conform to a rough, convex, tube surface, even at an angle of attack that is not perfectly normal to the tube surface.
4. Initiate contact and pulse echo recording at desired time intervals.

In order to test the feasibility of the concept, a mold was fabricated to form a sacrificial standoff using fusible alloys composed of bismuth and tin. This alloy, which melts at 138°C, was chosen so that the initial work could be performed at modest temperatures. Figure 1 shows the mold and the fusible alloy standoffs produced in the mold. A standard ceramic standoff is shown to the right for comparison.

Figure 1. Mold and standoffs fabricated using fusible alloy

Figure 2 shows the sacrificial, fusible alloy, standoff installed in the transducer housing as a measurement is being made on a heated plate.

Figure 2. Sacrificial standoff mounted in ultrasonic transducer housing

4.2 Integrated Probe

An integrated probe tip was fabricated that incorporates the high temperature pulser/receiver device. The mechanical design of the probe tip is shown in Figure 3. The probe tip consists of the transducer and the sacrificial standoff, which is housed in a spring-loaded body. The transducer is connected to a miniature air cylinder that is actuated to push the transducer outward for a controlled period of time to initiate contact with the target object.

Figure 3. Schematic of Integrated Probe Tip

A schematic of the overall measurement system is shown in Figure 4. When a measurement is desired, a switch is thrown which activates a single shot timer. The timer opens an air solenoid to initiate contact of the sacrificial standoff with the hot surface. An air pressure regulator controls the force of the standoff against the hot surface. After a controlled time interval, a second single shot timer initiates data collection from the pulser/receiver module to the storage oscilloscope via a trigger signal. The recorded waveform is then processed in a computer using specialized software that identifies the pulse echoes and estimates the pulse time intervals. These pulse time intervals are then used to estimate material thickness, such as the coke layer. The integrated probe tip will be tested during the next reporting period.

Figure 4. Schematic of overall measurement system

5.0 PROJECT SCHEDULE AND BUDGET

The project expenditures to date are approximately \$24,000. The current project schedule is behind the planned schedule, however the project expenditures are in line with the project progress. A request will be made for a six-month no-cost extension in order to complete the project objectives.