Distributed fiber sensing systems for 3D combustion temperature field monitoring in coal-fired boilers using optically generated acoustic waves

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OBJECTIVES

1. This poster presents a novel distributed optical fiber sensing system for the real-time monitoring of spatial and temporal distributions of high temperature profiles in the boiler of fossil fueled power plants.
2. According to the principle of pyrometer system, speed of the acoustic waves depends on the temperature of gaseous medium.
3. Photoacoustic material coated optical fiber sidewalls will generate acoustic waves. Fiber Bragg gratings (FBG) which can be multiplexed within one optical fiber will be used to detect acoustic waves. A 3D temperature distribution profile will be reconstructed using Gaussian Radial Basis Functions (GRBF) based on the sparse measurement data.
4. At this point, a simulation model for furnace temperature profile has been built, a sidewall ultrasound probe has been fabricated and tested, and a water temperature test has been performed.

Significance

1.Distributed fiber sensors utilizing optical-acoustic measurement techniques.

2.Allow for never before seen measurement of the boiler temperature field.

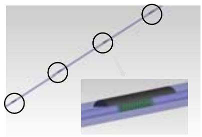

Fig.1 Distributed fiber sensor

Fig.2 Survive high temperature

RESULTS: GENERATION TEST

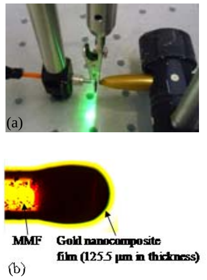

Fig. 4 (a) A photo of the photoacoustic generation experimental setup. (b) Gold nanocomposite coated fiber tip [1-3].

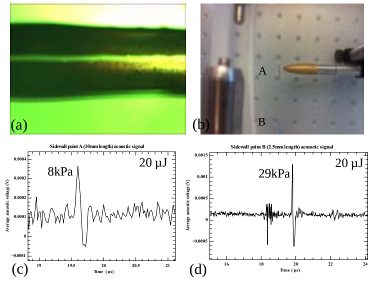

Fig. 5 (a) Coat gold nanocomposite on the sidewall of optical fibers. (b) Experiment setup on testing point A. (c) Sidewall Point A(10mm length) signal spacing. (d) Sidewall Point B (2.5mm length) signal.

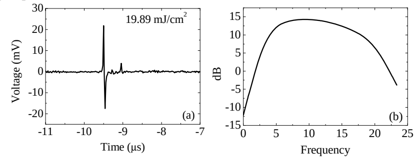

Fig. 6 (a) The generated photoacoustic ultrasound with pressure 88 kPa. (b) The bandwidth is wider than 20 MHz [4].

RESULTS: WATER TEMPERATURE

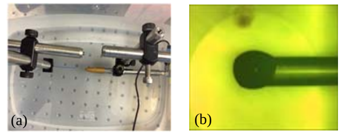

Fig. 7 (a) A photo of the water temperature test experimental setup. (b) Gold nanocomposite coated on fiber tip for this test.

This test demonstrates the lineal change between water temperature and sound speed.

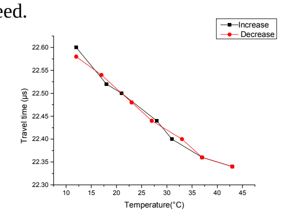

Fig. 8 Water temperature and the travel time relationship

PRINCIPLE

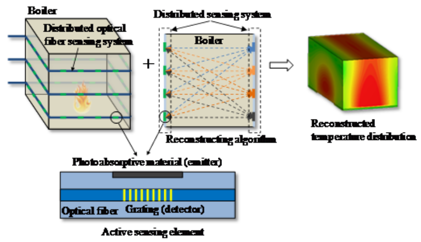

Fig.3 Reconstruct the 3D high temperature distribution within a boiler via a novel fiber optic distributed temperature sensing system using optically generated acoustic waves.

- Speed of acoustic waves depend on the temperature of gaseous medium.
- The TOF (time-of-flight) of an acoustic signal over a propagation path can be calculated as:

$$TOF(l_j)=\int \frac{1}{C(x,y,z)}dl_j=\int \frac{1}{Z\sqrt{T(x,y,z)}}dl_j$$

$C(x,y,z)$ the velocity of sound at position (x,y,z)

Z the heats ratio

$d(x,y,z)$ the reciprocal of velocity

j the number of paths;

RESULTS: SIMULATION MODEL

Unimodal Symmetric $T(x,y)=1000+600\sin(\pi x/length)\sin(\pi y/height)$

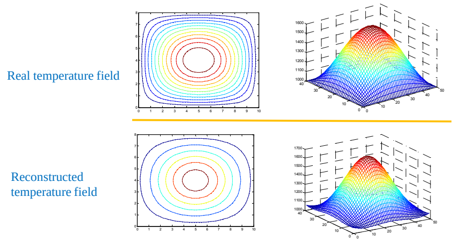

Fig. 9 In the simulation, 10 sensors are evenly distributed, 10 basis functiones are used and 24 paths are chosen. The matching error is 1.95%.

Unimodal Deflection $T(x,y)=600\exp((-(x-4)^2)/length-((y-3)^2)/(2*height))+1000$

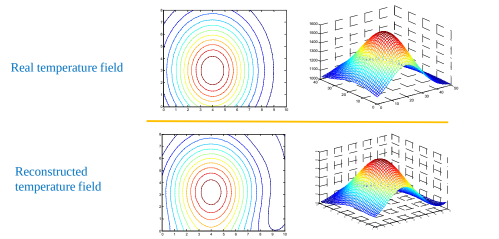

Fig. 10 In the simulation, 10 sensors are evenly distributed, 10 basis functions are used and 24 paths are chosen. The matching error is 0.8%.

FUTURE WORK

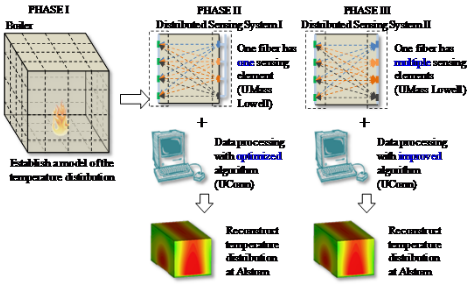

Fig. 11 Overall objective and objectives for each phase.

1. Establish a boiler furnace temperature distribution model and guide the design of the sensing system;
2. Develop the sensors with one active sensing element on each fiber as well as a temperature distribution reconstruction algorithm for proof-of-concept;
3. Develop the distributed sensing system to integrate multiple active sensing elements on a single optical fiber.

RELATED ACHIEVEMENTS

1. Support 1 Postdoc, 1 PhD student, 1 REU student.

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