Available online at www.sciencedirect.com
SCIENCE DIRECT
Sensors and Actuators A 127 (2006) 332–339
SENSORS AND ACTUATORS A PHYSICAL
www.elsevier.com/locate/sna

Flame imaging using laser-based transmission tomography

Elmy Johana Mohamad[a], Ruzairi Abdul Rahim[b,*], Sallehudin Ibrahim[b], Shaharum Sulaiman[b], Mohamad Shukri Manaf[b]

[a] Mechatronic and Robotics Engineering Department, Faculty of Electrical and Electronic Engineering, Kolej Universiti Teknologi Tun Hussien Onn, Malaysia
[b] Control and Instrumentation Engineering Department, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Malaysia

Received 7 June 2005; received in revised form 1 December 2005; accepted 8 December 2005
Available online 25 January 2006

Abstract

This paper described the development of flame imaging system using laser-based tomography. The final aim of this project is to obtain the concentration profile of the flame to be incorporated in laser-based transmission tomography measurement system for combustion online monitoring. The system can be applied to produce cross-sectional images of flame such as that in a combustion chamber. Such a system can be employed to compare the effectiveness of different fuel additives and to monitor the onset of knock with various fuel formulations or cylinder head geometries. The ability of this system is to monitor the size, position and velocity of flame fronts in any combustion behavior and emissions. The system employs two orthogonal projections with one laser source. The concentration of the research is to determine the position and velocity of flame fronts in the pipeline by employing photodiode sensor and helium neon laser. The laser source will supply 12 light beams, so the cross-section of the pipe being interrogated by a total of 12 beams. The flame is placed in specific places in the measurement cross-section and voltage output will calculated by the individual sensor is modeled. Besides the hardware, the system will include an interface user friendly, Visual C++ to visualize the concentration profile of the flame.

Keywords: Flame imaging; Laser-based transmission tomography

1. Introduction

Process tomography provides several real time methods of viewing the cross-section of a process to provide information relating to the material distribution [1]. This involves by taking numerous measurement from sensors which placed around the section of the process being investigated and processing the data to reconstruct an image. The process involves the use of non-invasive sensors to acquire vital information in order to produce two or three-dimensional images of the dynamic internal characteristic of process system. Information on the flow regime, vector velocity, and concentration distribution may be determined from the images. Such information can assist in the design of process equipment, verification of existing computational modeling and simulation techniques, or to assist in process control and monitoring [2].

Process tomography refers to any tomographic method used to measure the internal state of a chemical process (e.g. material distribution in a reactor, multiphase flow fields in piping or concentration uniformity in mixers). By tomographic techniques can measure quantities such as the flow rate or solid concentration of material flowing through a pipeline and the distribution of material inside a chemical reactors or a mixer [4]. This type of information is not usually obtainable with the sensor traditionally used by engineer, therefore these techniques gives a better understanding of the flow of material through the plant and the data can be used to design better process equipment and to control certain processes to maximize yield and quality [5].

Basically, in a tomography system several sensors are installed around the pipe or vessel to be imaged. The sensor output signals depend on the position of the component boundaries within their sensing zones. A computer is used to reconstruct a tomographic image of the cross-section being interrogated by the sensors. Real time images can be obtained which measure the dynamic evolution of the parameters being detect at the sensors.

* Corresponding author. Tel.: +60 7 5535902; fax: +60 7 5566272.
E-mail addresses: elmy@kuittho.edu.my (E.J. Mohamad), ruzairi@fke.utm.my (R.A. Rahim).

0924-4247/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.sna.2005.12.031

This paper will describe how to reconstruct the image of the internal flows in the pipeline and display it online as the concentration profile over a cross-section by using photodiode as sensors. In this project a narrow laser light is emit through the cross-section area of pipe to a receiver, by using a fiber optic as transmitter and photodiode as a receiver then the amplitude of the received light is compared with the amplitude of light that achieved with no obstruction in the light path for the same sensor. The intensity of the transmitted beam is measured by the detector and the transmittance is the ratio of the transmitted intensity to the original beam intensity [3]. The ratio of light attenuated will be use to construct the cross-section image in the pipe. The resolution of such system is limited by the physical number of the components used as light transmitter and receiver.

2. The measurement system

The system is being split into several parts. Fig. 1 shows how the systems work from the source until the final concentration. The photodiode is being used to detect the laser light through the optical fiber. The laser light was collimated by a lens before its passes through the optical fiber. The photo-detector will generate an electrical current within a range of micro Amperes that propagates to the intensity of the received light; then the current is being fed into electronic device to perform signal measurement. Nevertheless, the output signal is dependent on the position of the component boundaries within their sensing zone. The measured data are then being transferred to a computer through a computer data acquisition system. Computer software is being used to obtain the concentration profile regarding to the flow.

The source will supply 12 light beams, this result in the cross-section of the pipe being interrogated by a total of 12 beams. When the flame passes through the bottom of the pipelines, 12 sensors are mounted around the periphery at the middle of the pipelines will detect the flame. The 12 sensors are connected to the analogue sensing electronics (signal conditioning circuit to convert the information into an electrical signal) and then digitized (data acquisition system in order to convert the signal into computer codes) before its being reconstructed and visualized.

The display unit, data acquisition system (DAS) that will use in this case study is the Keithly DAS1802HC. It can be configured for 64 single ended or 32 differentials, 12 bit input

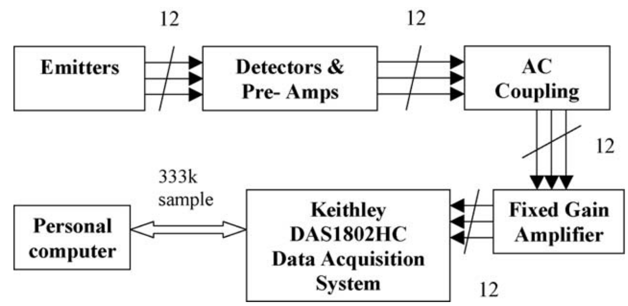

Fig. 2. Function block diagram of the system design.

and can measure up to 333 K samples/s maximum input rate. The DAS is responsible to obtain the quantitative data describing the internal flow pipeline. By using DAS data has to be collected quickly and accurately in order to track small changes of flows in real time thus enabling the reconstruction algorithm to provide and accurate indication of true flow distribution before it display the concentration of the image.

This system is design based on the ability of the transmitter and receptions of the sensors used, by using transmission mode method. In completing this research, the works to be carried out including: mounting 12 optical sensors on the outer surface of the 60 mm transparent pipe, designing the receiver circuit, and developing the online image reconstruction by using software, Visual C++.

The principle of this system is investigates the light attenuation level, thus the measurement that has been selected is measurement based on light attenuation intensity. To simplify the construction, dc constant source are used. The photodiodes are configured in photovoltaic mode (voltage-output operating mode) and a second current to voltage converter resister is added to the photodiode output and non-inverting input of the op-amp. This configuration results a differential-input current to voltage converter, which provides a better solution to noise sensitivity and dc offset error. Fig. 2 shows corresponding pre-amp circuit. The circuit is operated in parallel mode where each sensor will provided with its own pre-amp and amplifier system. A variable resistor include in each set of amplifier to provide an adjustable gain.

The laser light will emit light continuously, so the output from the electronics circuits are 12 V proportional to the inten-

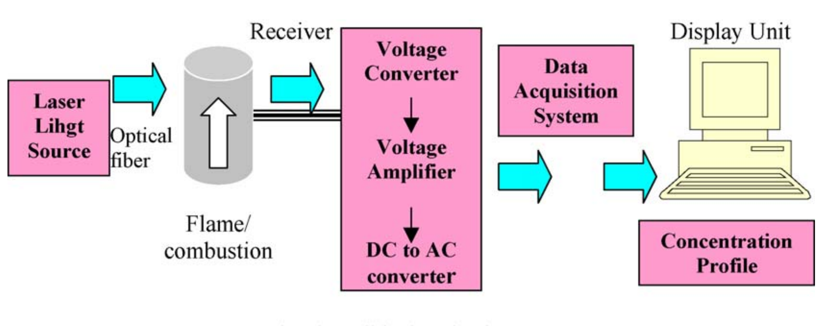

Fig. 1. Block diagram of process tomography system.