Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 87 (2016) 79 – 84

Physics Procedia

44th Annual Symposium of the Ultrasonic Industry Association, UIA 44th Symposium, 20-22 April 2015, Washington, DC, USA and of the 45th Annual Symposium of the Ultrasonic Industry Association, UIA 45th Symposium, 4-6 April 2016, Seattle, WA, USA

Unusual applications of ultrasound in industry

George Keilman[a]*

[a]*Sonic Concepts, Inc., 18804 North Creek Pkwy #103, Bothell, WA 98011 USA*

Abstract

The application of physical acoustics in industry has been accelerated by increased understanding of the physics of industrial processes, coupled with rapid advancements in transducers, microelectronics, data acquisition, signal processing, and related software fields. This has led to some unusual applications of ultrasound to improve industrial processes.

Peer-review under responsibility of the Ultrasonic Industry Association.

Keywords: Ultrasound, pyrometry, fractionation, Lamb wave, wood, fiber, pulp, paper, scintillation, hydroelectric, turbine, flow.

1. Applications of ultrasound in industry

Ultrasonic technology has been applied in a wide range of industrial areas. This paper focuses on the novel operating principles behind some new and less common industrial applications. Three applications will be discussed that have their origins in the pulp and paper industry. In the first application, developed by EnerTechnix, Inc. (Maple Valley, WA), acoustic pyrometry is used to measure the temperature profiles in real time in high-temperature exhaust flues. By using sensors along multiple acoustic paths, the 2D thermal profile in the flue is tomographically reconstructed. This method provided continuous 24/7 measurements with high reliability, with no practical upper

* Corresponding author. Tel.: +1-425-485-2564; fax: +1-425-485-7446.
E-mail address: gkeilman@sonicconcepts.com

Peer-review under responsibility of the Ultrasonic Industry Association.
doi:10.1016/j.phpro.2016.12.013

limit on the temperatures that can be measured. In the second application, co-developed by the Institute of Paper Science and Technology (Atlanta, GA) and Sonic Concepts, Inc. (Bothell, WA) acoustic standing waves are used to fractionate wood fibers by length into different grades, in order to produce higher-quality paper products. In the third application, developed by the Institute of Paper Science and Technology (Atlanta, GA) with custom transducers from Sonic Concepts, Inc. (Bothell, WA), the use of Lamb waves to measure mechanical properties of fiber composite sheet materials will be discussed.

In an application from the hydroelectric industry, developed by AQFlow, Inc. (Victoria, BC) with review by Sonic Concepts, Inc. (Bothell, WA), acoustic scintillation is used to accurately measure the volumetric water flow at a large turbine intake. Accurate water flow measurements are needed under a wide range of operating conditions so that the facility operator can adjust turbine settings to optimize electric power production vs. water flow rate and hydrostatic head. Acoustic scintillation, i.e., the minor fluctuations in ultrasonic signal amplitude as pulses transit the flow channel, arise due to turbulent eddies in the flowing water. By spacing pairs of transducers a known distance apart, the scintillation that occurs on the two paths can be correlated to produce a time delay measurement for water flowing in the channel. By using multiple sets of transducers spanning the intake, the velocity profile of the flowing water can be measured and integrated to compute total volume flow.

1.1. Acoustic pyrometry

In an ideal gas, the speed of sound is related to the absolute temperature, as follows:

$$c = \sqrt{\gamma RT/M} \tag{1}$$

Where γ=specific heat ratio, R=gas constant, and M= molecular weight calculated from the gas composition. By measuring the time of flight along multiple paths through the region of interest, it is possible to tomographically reconstruct the temperature profile. This method can be applied in environments such as flues, furnaces and kilns, where temperatures are too high to use conventional thermocouple sensors. This technique is useful over a wide temperature range, from the gas liquefaction point to the gas dissociation point.

In Fig. 1, an acoustic pyrometer (Pyrometrix^{TM}, Enertechnix, Inc.) is shown. This system uses 12 transceivers to measure the sound speed along 132 paths in the flue of a recovery boiler. In this example, the minimum temperature is 860ºC (1580ºF) and the maximum is 1175ºC (2147ºF).

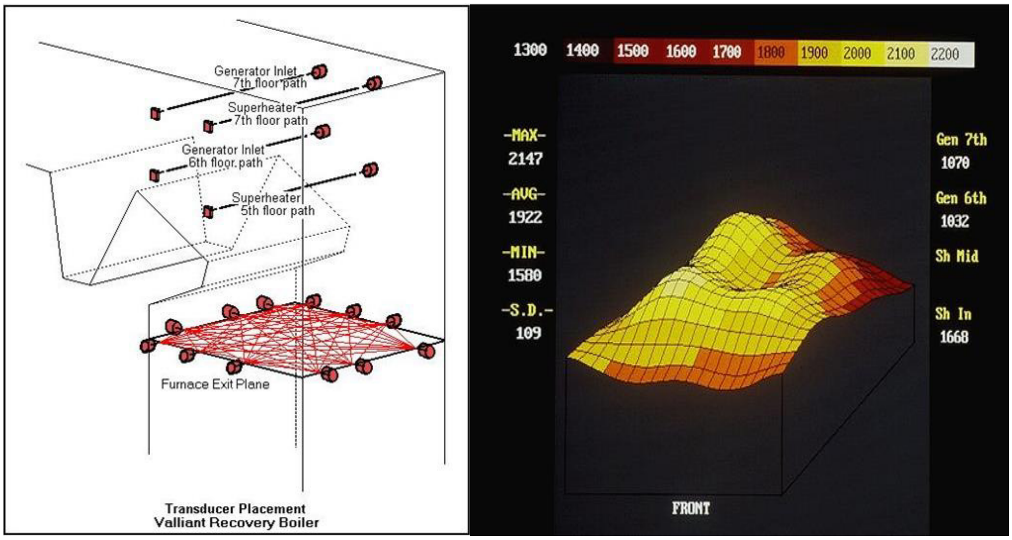

Fig. 1. Acoustic pyrometry. (a) Transducer locations in flue; (b) reconstructed temperature profile.