Application of laser ultrasound to non-contact temperature measurement of high temperature metals

Background

In order to evaluate thermal degradation of power plant equipment operating under high temperature conditions, thermal analysis of equipment and components is conventionally used. For validation of the analysis results, the temperature distribution of the component of concern must be measured. Conventionally, thermocouples are used for temperature measurement, but many are required to obtain the temperature distribution. This results in limitations in the number of sampling points. Therefore, a non-contact method to measure the temperature of an arbitrary location is needed. Laser ultrasound has been applied for non-contact detection of surface flaws, and non-contact temperature measurement may become possible if laser ultrasound can be applied to temperature measurement.

Objectives

To perform temperature measurement of high temperature metals using laser ultrasound, and to clarify the applicability of laser ultrasound to such measurement.

Principal Results

1. Development of laser ultrasound device to measure high temperature metals

A laser ultrasound device for non-contact measurement of high temperature metals was developed (Fig.1). This device generates ultrasound on the surface or inside high temperature metals by laser irradiation, and detects the ultrasound waveform using a two-wave mixing interferometer. The generation point and measurement point are separated by a fixed distance, which can be easily adjusted. The use of a two-wave mixing interferometer allows measurement of ultrasound waveforms on non-machined or partially oxidized surfaces, which is not possible using conventional interferometers.

2. Measurement of temperature dependence of ultrasound propagation speed

Ultrasound waveforms generated by laser irradiation on SUS316 specimen were measured from room temperature to 700˚C. From the obtained waveforms, longitudinal wave, mode conversion wave, and transverse wave were observed (Fig.2). The following points were clarified:

(1) Longitudinal and transverse waves reflected from the back wall of the specimen were not affected by the surface condition of the specimen, so the temperature dependence could be measured accurately. In the case of SUS316, the propagation speed varied almost linearly with temperature (Fig.3). By using this result as a calibration curve, calculation of the temperature from the propagation speed is possible. In addition, similar results were obtained for 9-Cr composite, which is used for turbine parts.

(2) The waveform of surface acoustic wave propagated along the specimen surface showed large variation due to changes in the surface condition, such as oxidation. Therefore, accurate measurement of the temperature dependence of the propagation speed was not possible.

The above results showed that temperature measurement of high temperature metals is possible by measuring the propagation speed of the longitudinal and transverse waves generated by laser irradiation.

Future Developments

The applicability of this method to high temperature metals with temperature gradients will be investigated.

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Reference

T. Fukuchi et.al., 2007, “Application of laser ultrasound to noncontact temperature measurement of composites”, CRIEPI Report H06012 (in Japanese)

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*1：Two wave mixing interferometer: a device which measures the specimen surface displacement from the interference signal between the laser light irradiated onto the specimen and the reflected light from the specimen, which are mixed inside a special (photorefractive) crystal. It has the advantages of applicability to rough surfaces, immunity to mechanical vibration, and high sensitivity.

*2：Mode conversion wave: wave for which longitudinal wave is converted into transverse wave (or vice versa) upon reflection from the specimen back wall.

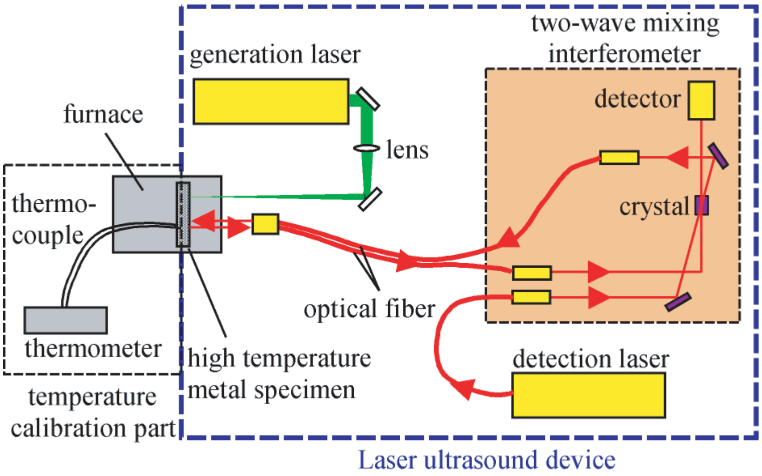

Fig.1 Experimental device for measurement of high temperature metals

Light from the generation laser is irradiated onto high temperature metal specimen and generates ultrasound. The ultrasound waveform is measured using a two wave mixing interferometer. The temperature calibration part has been added to obtain the calibration curve of the temperature dependence of the ultrasound propagation speed, and is ordinarily not used.

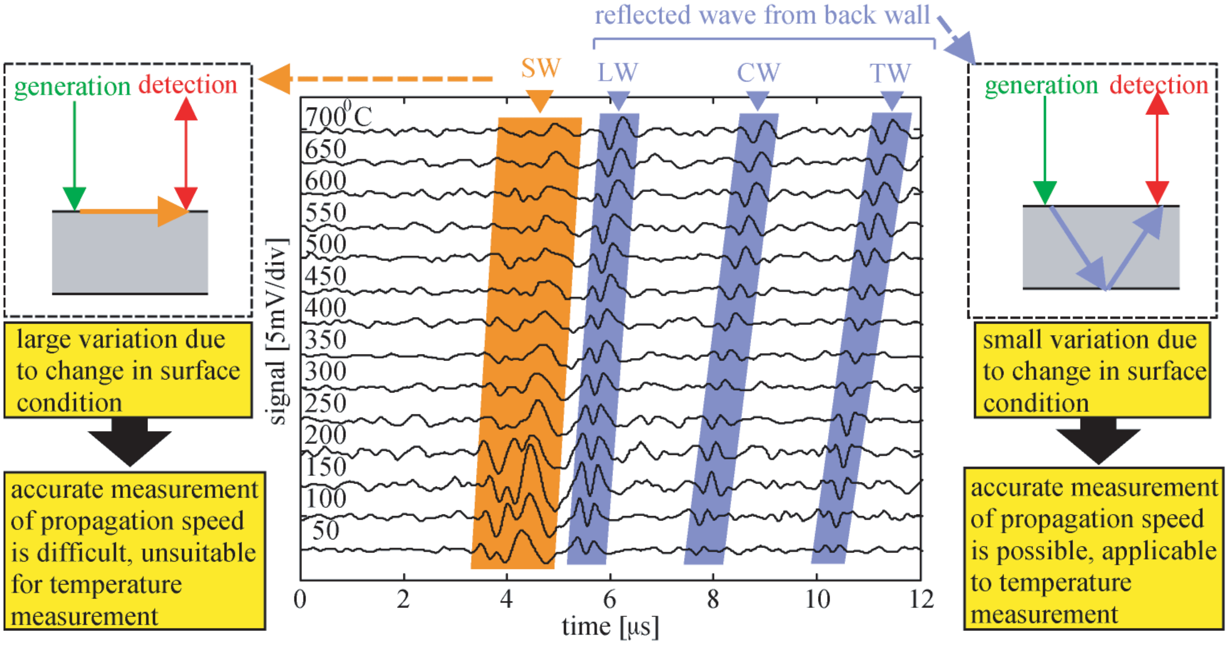

Fig.2 Ultrasound propagation waveforms in SUS316 specimen

Ultrasound waveforms obtained from room temperature to 700℃ are shown (SW: surface wave, LW: longitudinal wave, CW: mode conversion wave, TW: transverse wave), and the surface wave and reflected wave from the back wall are compared. The reflected wave from the back wall showed small variation resulting from changes in the surface condition. On the other hand, the surface wave showed large variation, which made accurate calculation of the propagation speed difficult.

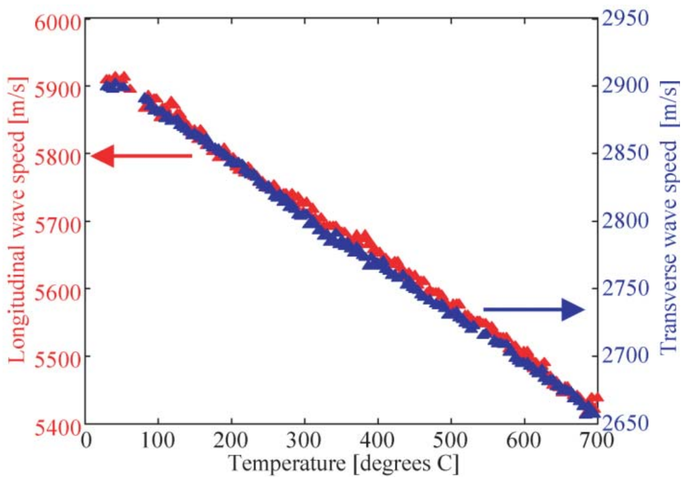

Fig.3 Temperature dependence of the ultrasound propagation speed

Measurement result of the temperature dependence of longitudinal and transverse waves propagating through SUS316. By using this result as a calibration curve, the temperature can be calculated from the measured ultrasound propagation speed.