Measurement of Surface Pressure with Pressure Sensitive Paint in a Detonation Tube

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Abstract

Pressure sensitive paint will be used in a detonation tube to measure a surface pressure of the detonation wave and make a visualization to see its structure. A conventional method to see detonation structure is with a pressure transducer or a smoked foil. The method was available to roughly measurement and observation, not detail. The pressure sensitive paint technique is developed and used mainly in aerodynamics recently and this technique will be also useful for combustion and other phenomenon. The purpose of this study is to make a use of the pressure sensitive paint for measuring detonation structure.

Keywords: pressure sensitive paint, detonation, combustion

Introduction

One of the techniques received attentions in aerodynamic field is a measurement of pressure on a surface coated with pressure sensitive paint. Pressure sensitive paint system incorporates with a phenomena that the intensity of phosphorescence emitted from the sensing dyes is inversely related to the oxygen concentration (oxygen quenched). It is capable to convert to the oxygen concentration distribution that determines the intensity of phosphorescence on a test surface coated with pressure sensitive paint. If oxygen mole fraction is assumed to be constant, Henry's law can state that oxygen concentration is proportional to pressure. This means that the intensity of phosphorescence can convert to the pressure on the test surface. This fundamental method was established by McDonnell Douglas, DLR and NASA, etc in primary 90’s. In recent years, many methods of coating with pressure sensitive paint has been proposed with anodized aluminum or silica gel plate for thin layer chromatography (TLC).

Detonation wave, the combustion wave which propagates on supersonic speed, has been studied since more than a hundred and twenty years. Though detonation has been measured using a pressure transducer and a smoked foil, it is difficult to record the phenomenon in detail due to high speed phenomena and multiple dimensions. It can be expected that the low pressure part of detonation structure, which can never be determined by a pressure transducer and a smoked foil can be measured by pressure sensitive paint.

When pressure sensitive paint system is used to detonation, there are various problems such as response time, measurable pressure range, durability of coating, and changeable oxygen mole fraction. Baron et al. proposed coating method on the silica gel plate for thin layer chromatography (TLC), which response time is semi-milli second. Since adhesion of a silica gel particle is weak, its

durability easily broken. In the research group MOSAIC, it is confirmed that the response time with a physical coating is 10 microsecond and that with chemical coating is under 10 microsecond.

Test for Calibration Curve

Description of Experiments

Calibration Data, which is the intensity of luminescence under static pressure, are needed for measuring pressure with pressure sensitive paint. Pressure range is under 160 [kPa]. Fig. 1 shows the apparatus of fundamental experimental system.

A mercury-xenon lump at 200-watt power is a light source. I-CCD camera made by LaVision is used. This camera has a 12bit and high resolution with 640x480 pixels. And the exposure time is 10msec and its gain is 30. A filter on the light source is blue-filter, which can through range about 350 to 450nm wave length and a filter on the camera is sharp-cut filter, which can cut under 580nm wave length.

To measure in this experiment need a fast response paint. Then, we use a silica gel plate for TLC in this time.

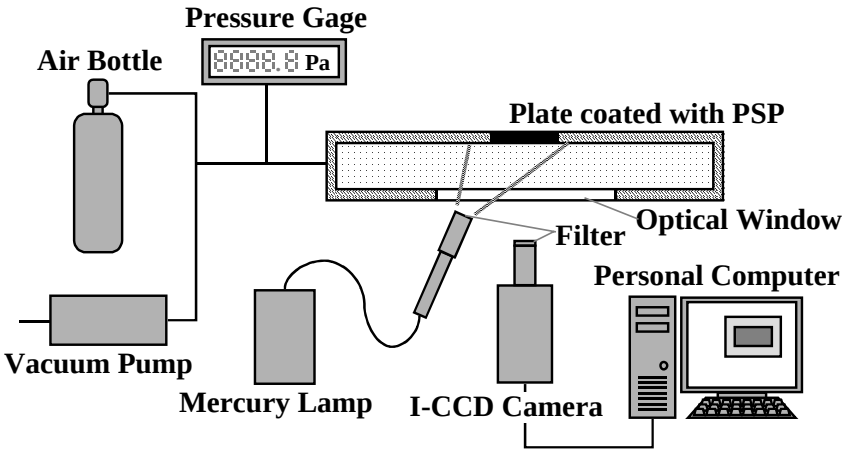
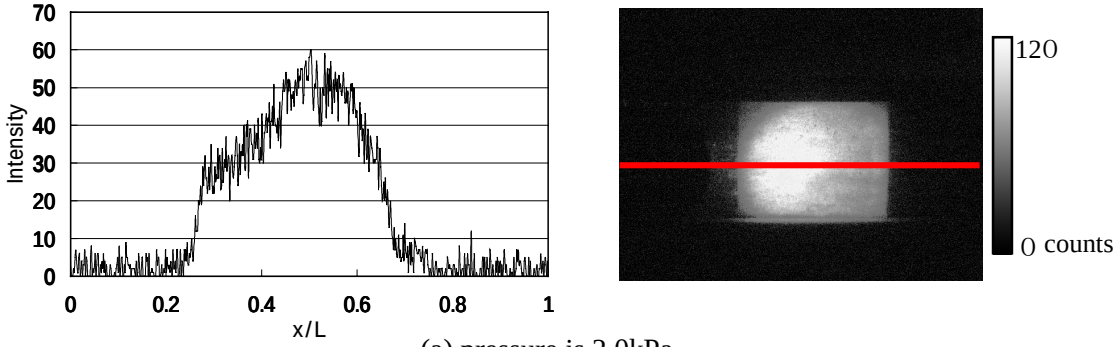


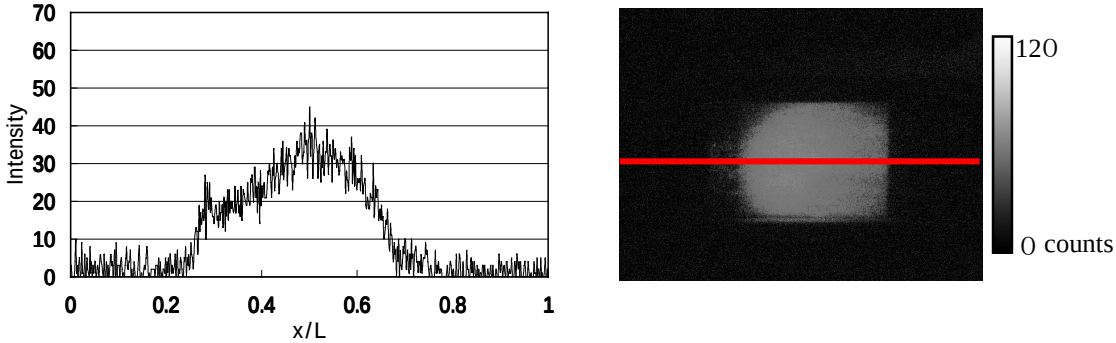
Fig. 1 Apparatus of fundamental experimental set up

Results

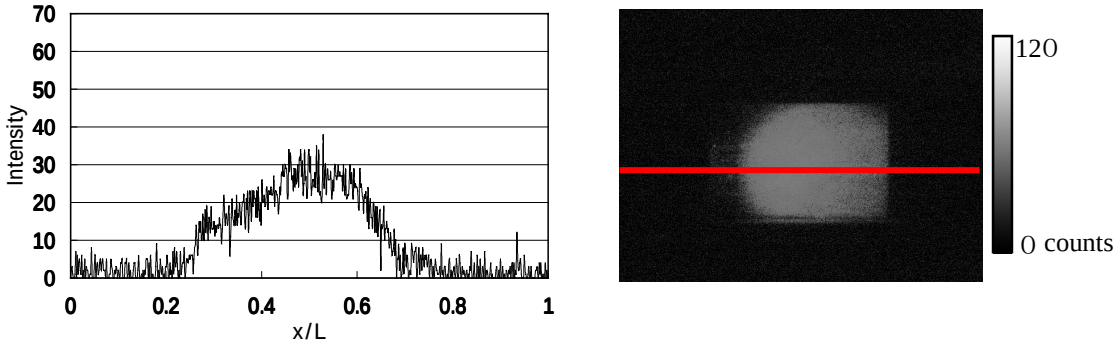
Fig. 2 shows the phosphorescence from the plate under static pressure and the intensity on the reference line (red line) in the image. Since the irradiation of light and coating pressure sensitive paint are in non-uniformity, all photos are also non-uniformity. The problem must be solved before the detonation experiment starts. But in the present time, a calibration curve is first obtained in this condition. The result is shown in Fig. 3.



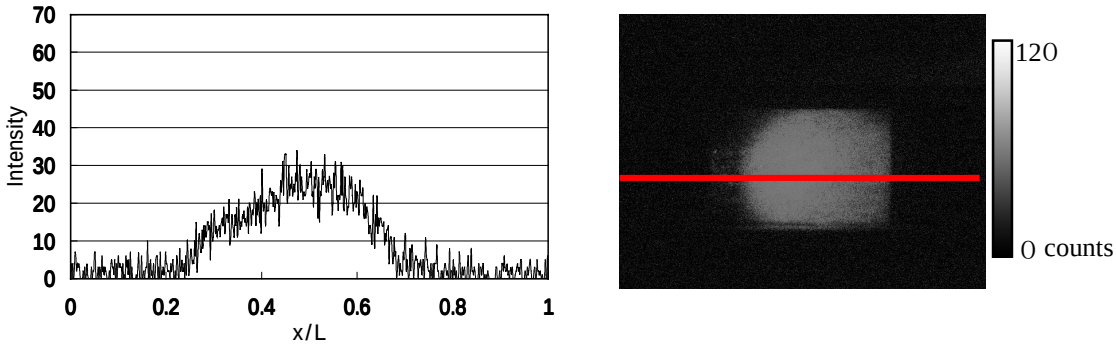
(a) pressure is 2.0kPa



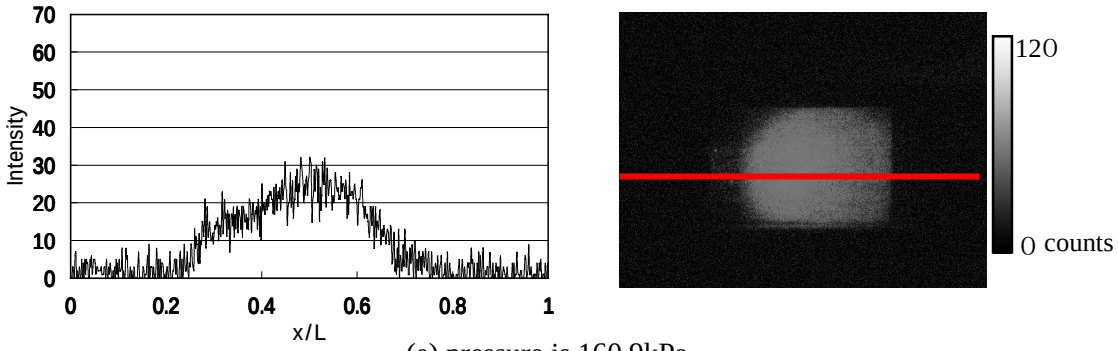
(b) pressure is 53.7kPa



(c) pressure is 101.4kPa



(d) pressure is 1333.3kPa



(e) pressure is 160.9kPa

Fig. 2 The image under pressure and the intensity on the red line

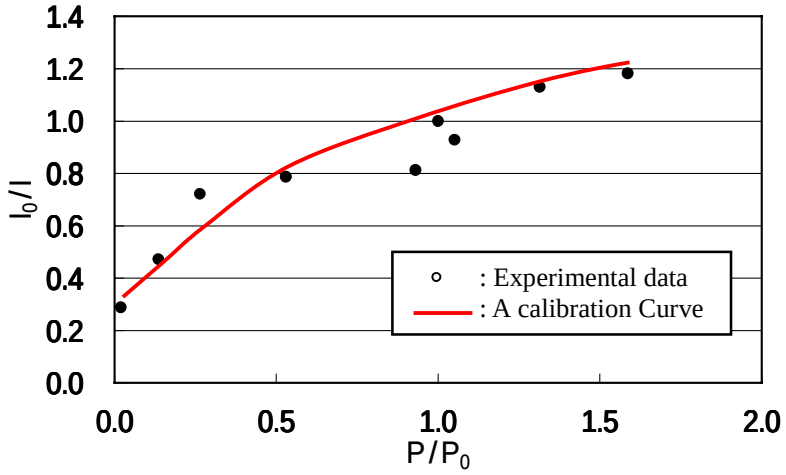


Fig. 3 A calibration curve

Summary

1. A calibration curve which relates the phosphorescence intensity with pressure is obtained at low pressure.
2. A consistent irradiation of light and coating are needed for measurement with pressure sensitive paint system, especially for high pressure and high speed.
3. Intensity of phosphorescence from pressure sensitive paint is weak. Light source may have to be changed with more powerful one, or camera system should be improved.

Prospects

Fig. 4 shows the pressure sensitive paint system with a detonation tube. Since the reduction of oxygen concentration by deflagration strongly affects the emission intensity from the plate, it may be useful to measure the emission intensity using the deflagration. The First step is measurement for deflagration. Some intensity data using the detonation tube and some useful discussions will be presented at the conference.

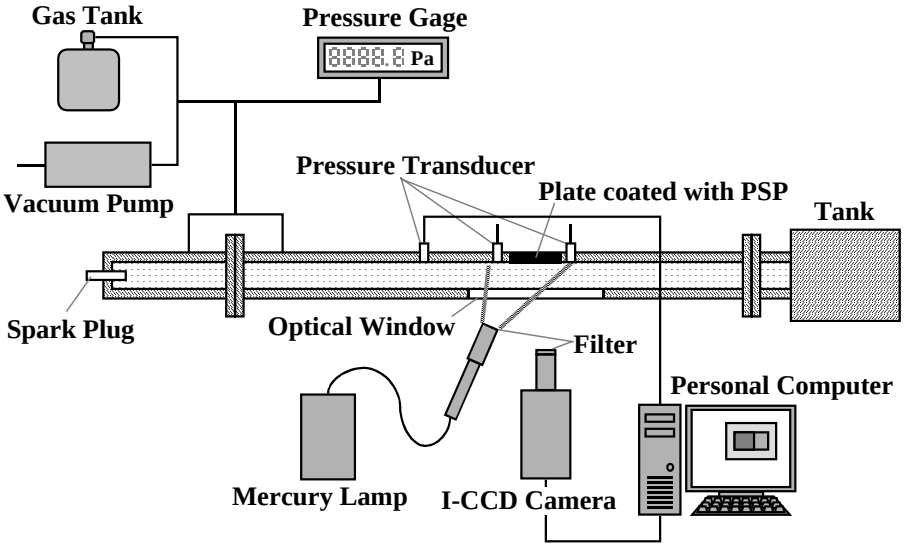


Fig. 4 Apparatus of Fundamental Experiment for Detonation or deflagration