KTH CCGEx

# Pressure sensitive paint (PSP) for rotating components

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Abstract

This project aims at solving the problem of measuring pressure in high-speed rotational components (i.e. IC-engine turbo-chargers). The measurement technique chosen is a fast type pressure sensitive paint (PSP), an optical technique measuring pressure through luminescent quenching by oxygen. It has been shown that fast PSP is a promising technique that can produce fast, spatial resolved and accurate pressure measurements in unsteady flows.

## Background

The pressure distribution on rotating surfaces, as for instance the turbo-charger compressor blades, is in practice impossible to measure using conventional pressure transducers. A new method is needed in order to be able to map the pressure distribution in these applications in order to make detailed investigations of rotational stall and surge phenomena.

Fast types of pressure sensitive paint (PSP) show promise in providing a solution to this issue, as well as a way of analyzing other engine related internal flows, such as pulsating flow in complex pipe systems.

## Method

PSP is an optical technique to measure surface pressure in aerodynamic applications. It is composed of sensor molecules, or luminophores, embedded in an oxygen permeable binder. The luminophores are excited by light of appropriate wavelengths and through the mechanics of photoluminescence, light is emitted at lower energies. The presence of oxygen reduces the quantum yield of the system, relating air pressure and luminescent intensity. The basic experimental setup is illustrated in figure 1.

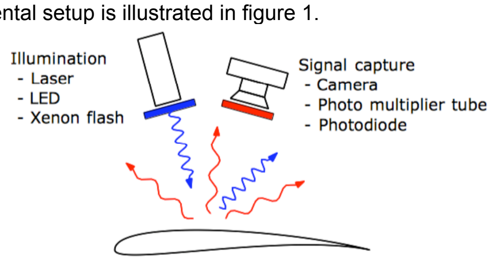


*Figure 1. Basic experimental setup of PSP.*

Due to the relatively slow diffusion rate of oxygen in the binder, traditional PSP is only able to resolve pressure fluctuations in the sub-Hz range. One method of overcoming this issue is by adding ceramic particles to the mix, effectively decreasing the binder thickness while maintaining the surface density of the luminophores. This mixture is a fast type PSP called polymer/ceramic pressure sensitive paint (PC-PSP) and is illustrated in figure 2.

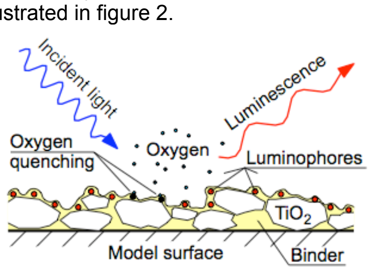


*Figure 2. Schematic of conventional PSP.*

## Results

A combined pressure and temperature computer controlled chamber for calibration of PSP has been designed. The chamber has been tested with respect to temperature and pressure control. The temperature can be set to an accuracy better than 0.3°C.

A formula of fast responding PSP has first been statically calibrated in the chamber and thereafter run in a shock tube in order to find out the dynamic pressure response of the paint. The response time (illustrated in figure 3) was found to be about 0.3 ms. A method to evaluate the dynamic pressure response of the paint has been developed and has been presented at ICFD 2010 and at a workshop at JAXA in November 2010 (both in Japan).

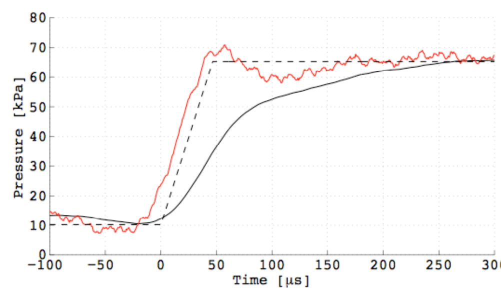


*Figure 3. Ramp response from PC-PSP in shock tube showing estimated pressure (--), measured pressure (−) and corrected pressure(−).*

The above-mentioned formula has been used to measure wall pressure inside a y-junction at periodic pressure fluctuations of between 40 and 80 Hz. An averaging phase locking technique has been used to increase the signal to noise ratio of the fast paint formulation and the results has been presented at Svenska mekanikdagar in June 2011 and at ISAIF10 in July 2011. An image showing a pressure pulse entering the y-junction (from the 45° branch) is shown in figure 4.

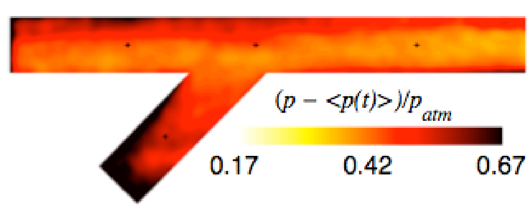


*Figure 4. A pressure pulse entering the y-junction from the 45° branch.*

## Additional information

TeknL is planned to 2011/2012.

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