Application of Fluorescence Lifetime Imaging to Pressure Sensitive Paint Measurements

by

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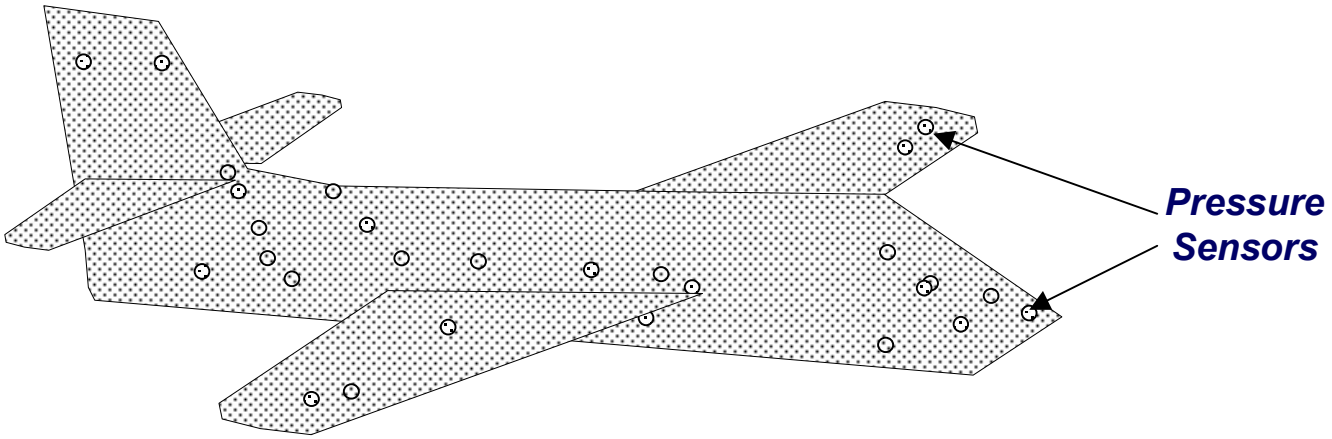
Introduction

The properties of aircraft surfaces in flight can be investigated using scale models of the aircraft in high speed wind tunnels. Traditionally the pressure variations which occur across the model are measured using hundreds of pressure sensors built into the model surface. The information from these sensors is fed into a central computer to show pressure variations across the surface of the model as it is subjected to airflow

Aerodynamic testing of aircraft models in a wind tunnel



- Model has hundreds of individual pressure sensors
- It can take up to a year to build and test
- Costs can be as much as £1million

Pressure Sensitive Paint

An alternative approach involves the use of a special fluorescent ***'Pressure Sensitive Paint'.*** *The paint contains a fluorescent compound that is sensitive to oxygen. Both the* ***Intensity*** *and the* ***Fluorescence Lifetime*** *of the paint change in response to oxygen. By measuring either of these parameters it is possible to create a map of surface pressure.*

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Aerodynamic testing with Pressure Sensitive Paint

Model coated with Pressure Sensitive Fluorescent paint

- ***PSP can be applied in a single day***
- ***PSP offers continuous coverage of model surface***
- ***PSP reduces development costs considerably***

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'Radiometric' PSP Measurements

In regions of high pressure dissolved oxygen concentration in the paint increases and fluorescence from the paint is reduced or 'quenched'. Standard PSP measurements involve recording one 'wind-on' image while the wind tunnel is running and another 'wind-off' image while the wind tunnel is switched off.

The ratio of the two images can then be related to pressure differences across the model surface. The 'wind off' measurement is required to correct for any variations in paint thickness and light intensity across the model. Unfortunately, the positioning of the model is not always the same with the wind tunnel on as it is with wind off. This gives problems of image registration and can cause errors in the resultant pressure data.

Also, the time associated with powering-down the wind tunnel can lead to increased costs. The time required to accurately align the model and take the matching 'wind-off' images can effect the productivity of the wind tunnel.

'FLIM' PSP Measurements

Fluorescence lifetime *in pressure-sensitive paint is affected by oxygen pressure; as the pressure increases the* ***fluorescence lifetime*** *of the paint becomes shorter. However, the fluorescence lifetime of the paint is not sensitive to variations in paint thickness or light intensity across the aircraft model.*

This allows pressure images to be collected without collecting the 'wind off' images. Image registration problems are eliminated and wind tunnel time can be used more effectively. In addition, the camera can be panned and zoomed to visualise interesting pressure characteristics in real time.

FLIM Data Collection

To collect a FLIM image of a PSP-coated sample the model was illuminated with a PRS100 modulated multiLED light source. The lightsource was square wave modulated at 100kHz with a 50:50 ON:OFF duty Cycle

Two Images were collected:

*1) **In Phase image:** The camera 'Gate-On' period corresponds with the 'Light-On' period of the lightsource.*

*2) **Antiphase image:** The camera 'Gate-ON' period corresponds with the 'Light-Off' period of the lightsource.*

Both Images are Collected with the Wind Tunnel switched ON

The ratio of these two images can then be related to pressure variations across the model by using previously collected pressure calibration data.

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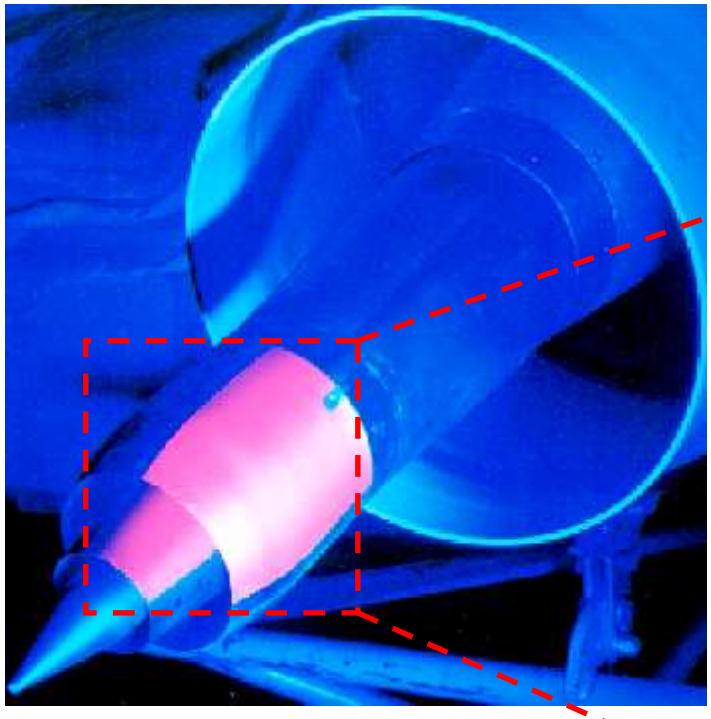
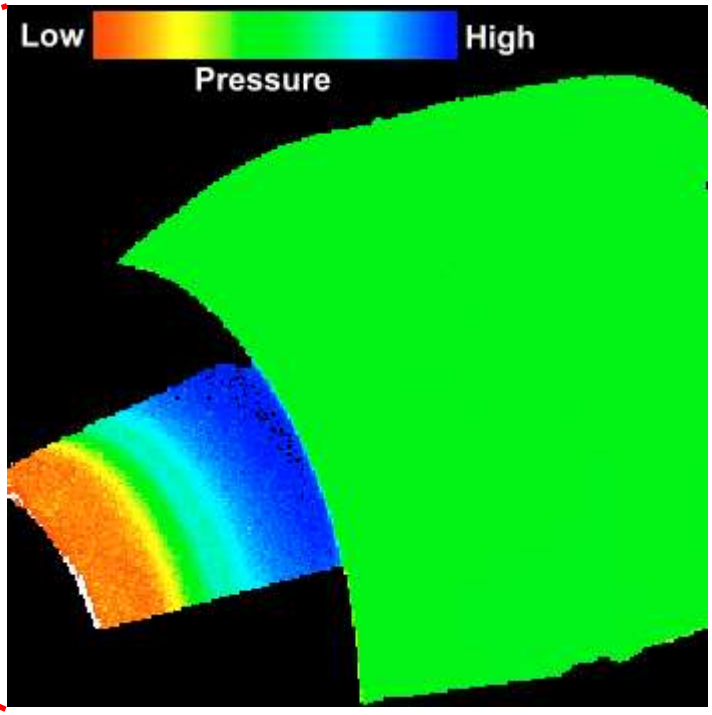
Example of 'FLIM' PSP Measurement using Imagex Camera



Nozzle Coated with Ruthenium-based PSP



FLIM image of PSP-coated region

Images courtesy of JW Holmes, The staff of DERA Pyestock, and Rolls Royce. This work was carried out at DERA Pyestock using exhaust models funded by the DTI CARAD Research Programme

References

J.W. Holmes ' *Analysis of Radiometric, Lifetime and Fluorescence Lifetime Imaging*' The Aeronautical Journal, Paper 2306 pp 189-194, April 1998.

J.W. Holmes '*Analysis of Radiometric, Lifetime and Fluorescence Lifetime Imaging*'. 27, 1-27,**B** Proceedings of LEAS, 'Wind Tunnels and Wind Tunnel Test Techniques' (Conference), Cambridge 1997