Laser-induced incandescence for measuring soot particle emission from aero-gas turbines

J. Delhay[1], P. Desgroux[1*], E. Therssen[1], John Black[2],
[1]Physico-Chimie des Processus de Combustion et de l'Atmosphère (PC2A), UMR-CNRS
Université des Sciences et Technologies de Lille, Villeneuve D'ascq cedex, France
[2] Strategic Research Centre, Rolls Royce plc, Derby, UK

A compact device for measuring LII collected in the 'backward' direction, i.e. counter to the propagation of the laser, is described. This configuration is particularly well adapted to large scale practical application, such as in-situ soot volume fraction in aero-engine exhausts. Several tests were performed on different jet engines and we present results obtained on helicopter turbine within the framework of European project AEROTEST.

Set-up

The device presented in this paper, was developed during European projects (AEROJET 1 and 2) to measure the soot volume fraction in aero-engines in-situ. It is composed of a YAG laser pulsed at 10 Hz (Quantel CFR 400) at the fundamental wavelength (1064nm) to heat soot particles from their initial temperature to around 4000K. A rotating prism is used to scan the laser beam across the engine exhaust plume. The LII signal is collected through the same prism and diverted to an intensified CCD camera (PCO Dicam) using a dichroic mirror. Each element of this equipment is monitored via the same software developed in previous European projects.

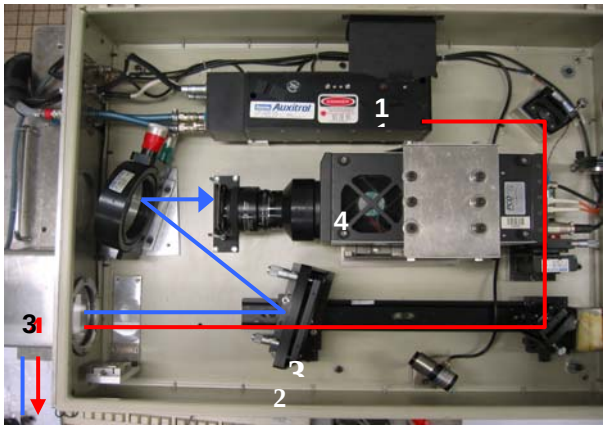

Fig. 1: Experimental set-up. (1) Nd/YAG laser; (2) dichroic mirror; (3) rotating prism; (4) Intensified CCD camera.

These elements are in a compact box and are easily transportable. A calibration procedure based on extinction is performed in a chimney where kerosene soot particles are produced by a 40 kW domestic burner. Application of the LII technique in the exhaust of a modified helicopter turbine demonstrates the sensitivity of this device for practical use for soot monitoring issued from aero-engines.

Measurements in helicopter turbine

Measurements were performed in a modified Rolls-Royce Gnome helicopter engine. Measurements were performed 1 cm downstream the cone of the turbine where the temperature of exhaust gases is around 620K at 20000 rpm. The exit diameter of the turbine is 28 cm.

Figure 2 shows the integrated LII signal from single laser pulse images taken during engine start up. The signal peaks on light-up and falls to a steady value after ~30 s. Similar behaviour has been observed on other engines elsewhere (*Jenkins [1]).*

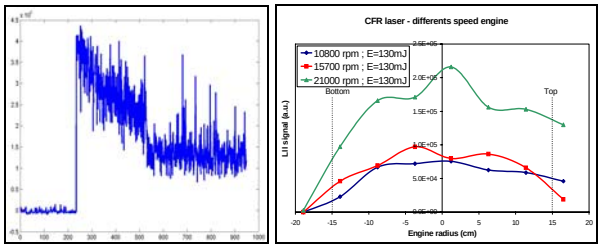

Fig. 2: start up of the turbine (at left) and signal recorded at 3 different engine speeds (at right).

The soot profile in exhaust gas was measured at different engine speeds. It is clearly visible that the quantity of soot increases with the engine speed.

Acknowledgements

This work is supported by Auxitrol S.A. and MEPACA (Pôle capteur, Conseil Regional Centre). The authors thank the European Community for financial support of this research under the 6th PCRDT, STREP 502856 AEROTEST. The authors thank P.E. Bengtsson and H. Bladh for fruitful collaboration within AEROTEST.

[1] Jenkins et al, AIAA 2002-0828, (2002).

* Corresponding author: pascale.desgroux@univ-lille1.fr