UNSTEADY PRESSURE AND DEFORMATION MEASUREMENTS USING PSP AT THE ONSET OF LIMIT CYCLE FLUTTER IN AN AEROELASTIC WIND TUNNEL MODEL

Kenichi Saitoh *, Tsutomu Nakajima and Hiroki Iwamoto

*Aviation technology directorate,
Japan Aerospace Exploration Agency,
Jindaiji-higashi-machi 7-44-1, Chofu, 182-8522 Tokyo
Japan

ABSTRACT

For validating Computational Fluid Dynamics (CFD) in aeroelastic analysis, wind tunnel test results are essential, including the elastic properties of the model and the flow conditions at the flutter onset. Furthermore, recent advances in optical measurement technologies have made it possible to obtain unsteady pressure distributions during flutter.

An aeroelastic wing model for wind tunnel testing typically consists of a spar that preserves elastic properties and formed materials that provide aerodynamic profiles to satisfy similarity laws with a full-scale aircraft. However, these formed materials often make it difficult for Pressure Sensitive Paint (PSP) to adhere to the surface. In addition, a laser triangulator is required as a reference for optical deformation measurements, which introduces light contamination to the PSP luminescence. Despite these challenges, we successfully measured both the pressure distribution and model deformation using PSP and a high-speed stereo camera system at the onset of Limit Cycle Flutter in transonic flow.

The wing model was based on a full-scale civil aircraft designed as a reference for research into several technologies. Aeroelastic similarity laws were maintained as closely as possible. The model featured an aluminium alloy spar, with the aerodynamic shape formed by urethane and reinforced with glass fiber tape. The wing had a supercritical airfoil and an engine nacelle mounted beneath the wing.

A lifetime-based measurement method was applied to capture unsteady pressure distributions using polymer/ceramic PSP[1)]. This approach is well-suited for measuring deformed surfaces, whereas the intensity-based method suffers from variations in illumination caused by surface deflection. The PSP was applied to the wing model, which was covered with urethane and glass fiber tape, along with several undercoat layers that both shielded laser light and improved PSP adhesion. Several target markers were placed on the surface for deformation measurements, captured by two high-speed cameras operating at over 10,000 frames per second. The PSP response exceeded 3,000 Hz, which is sufficient for a wing model exhibiting flutter around 100 Hz. The figure shows an image of the unsteady pressure distribution, which appears coarse due to the painted surface. Nevertheless, the characteristics of the unsteady pressure distribution during Limit Cycle Oscillation are clearly identifiable. Improved optical access to the wind tunnel would further enhance image quality.

The captured PSP images were mapped onto the wing surface, providing time-series data of unsteady pressure at each point. These pressure distributions were processed to extract harmonic components associated with Limit Cycle Oscillation. This enables comparison with CFD results and offers a deeper understanding of the physical phenomena than time-domain data alone.

reference

1) Sugioka, Y., Nakakita, K., Saitoh K., Nonomura, T., and Asai, K., “First results of lifetime-based unsteady PSP measurement on a pitching airfoil in transonic flow,” AIAA Scitech Forum, Kissimmee, FL, 8-12, Jan. 2018, AIAA-2018-1030.

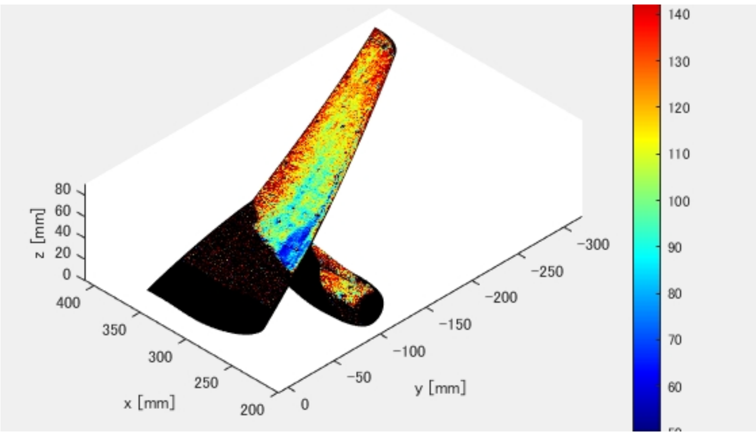

Figure: Captured Pressure Distribution During Flutter