Differential Infrared Thermography (DIT) for Dynamic Stall Detection

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HIGHLIGHTS

• A new method has been applied for the detection of dynamic stall on rotating blades in cyclic pitch.
• The method works robustly on carbon fiber composite blades and does not require contact with the surface, any kind of surface treatment or instrumentation and can produce maps of the surface on which stalled and attached flow areas are detailed.
• The standard deviation value, \( \sigma_{\text{DIT}} \), is high for separated flow and low for attached flow and this has been verified by comparison to unsteady pressure distributions.

ABSTRACT

The sinusoidal cyclic pitch of the rotor blades under investigation was set to a geometric root pitch angle of \( \theta(t) = 23.7^\circ + 6^\circ \sin(2\pi f_{\text{rotor}} t) \). The rotation frequency was \( f_{\text{rotor}} = 23.6 \text{Hz} \) resulting in a blade tip speed of \( u_{\text{tip}} = 96.4 \text{m/s} \), a blade tip Mach number of \( M_{\text{tip}} = 0.28 \). The DIT setup is depicted in the left figure. The rotor blade was radiatively heated by seven halogen tungsten lamps with 2kW electrical power each to obtain a temperature difference of approximately 17K between the blade surface and the air flow. The infrared camera was mounted above the rotor blade upper side and recorded via a rotating mirror to avoid motion blur.

The spatial standard deviation of eleven consecutive differential infrared images (\( \sigma_{\text{DIT}} \)) was calculated in smaller regions of interest. These regions were scanned radially to achieve continuous distributions of \( \sigma_{\text{DIT}} \) along \( r \). This method leads to a distribution of \( \sigma_{\text{DIT}} \) over the entire azimuth and within a radial region between 73% R and 99% R as shown in the right hand figure. The dynamically stalled region can clearly be seen.

Fig. 1 DIT set up for rotor blade dynamic stall detection (left) and derived stall map (right).