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Experimental study of mode shifting in an asymmetrically heated rectangular plate

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ABSTRACT

Modal shifting and jumping in thermally buckled plates has been investigated previously using computational models; however, relatively few experimental explorations have been reported. In this study, the modal shifts and jumps in a simple rectangular plate or panel were investigated using digital image correlation to obtain detailed mode shapes. One face of the planar panel, which was 219 × 146 mm, was speckled and viewed with a stereoscopic digital image correlation system using pulsed-laser illumination and with a laser vibrometer at a single point. The other face was heated using a set of 1 kW quartz lamps to produce a non-uniform temperature distribution which progressively increased from room temperature to around 760 K. An infra-red camera recorded the time-varying temperature distribution on the panel while it was excited with an electrodynamic shaker. A waterfall plot, or time-frequency spectrogram, showing natural frequencies as a function of time was generated, which highlighted the shifting response of the panel with temperature. The heating sequence was repeated and the panel excited at the natural frequencies identified in the waterfall plot, which permitted the corresponding mode shapes to be measured. These data showed that mode shifting and jumping was present with asymmetric heating, but not with spatially uniform heating, and was associated with thermally-induced buckling.

1. Introduction

It has been recognised for some time that panels or plates subject to spatially non-uniform temperature distributions undergo buckling as the temperature distribution varies with time. In plates that are also subject to vibration, the buckling causes mode shifting [1] and mode jumping [2]. Mode shifting is the exchange of vibration modes when the plate is heated into the post-buckled state; while mode jumping is sudden transitions from one buckling mode to another. This type of behaviour could potentially occur in the panels that form the skin of aircraft designed to travel at hypersonic speeds or near the engine exhausts in more conventional aircraft as well as in fusion reactors. The presence of this type of behaviour could have a significant impact on the structural integrity and, hence, the service life of these structures.

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Table 1
Typical physical properties of Hastelloy X [from Ref. [23]].

	Temperature, °C	Metric Units
Density	22	8.22 g/cm3
Melting range	1260–1355	
Dynamic modulus of elasticity (heat treated at 1177 °C, rapid cooled)	Room	205 GPa
	93	203 GPa
	204	197 GPa
	316	192 GPa
	427	184 GPa
	538	178 GPa
	649	170 GPa
	760	161 GPa
	871	153 GPa
	982	141 GPa
Mean coefficient of thermal expansion	26–93	13.9 10^{-6} m/m-°C
	26–538	15.1 10^{-6} m/m-°C
	26–649	15.5 10^{-6} m/m-°C
	26–732	15.8 10^{-6} m/m-°C
	26–816	16.0 10^{-6} m/m-°C
	26–899	16.4 10^{-6} m/m-°C
	26–982	16.6 10^{-6} m/m-°C
Poisson's ratio	22	0.32

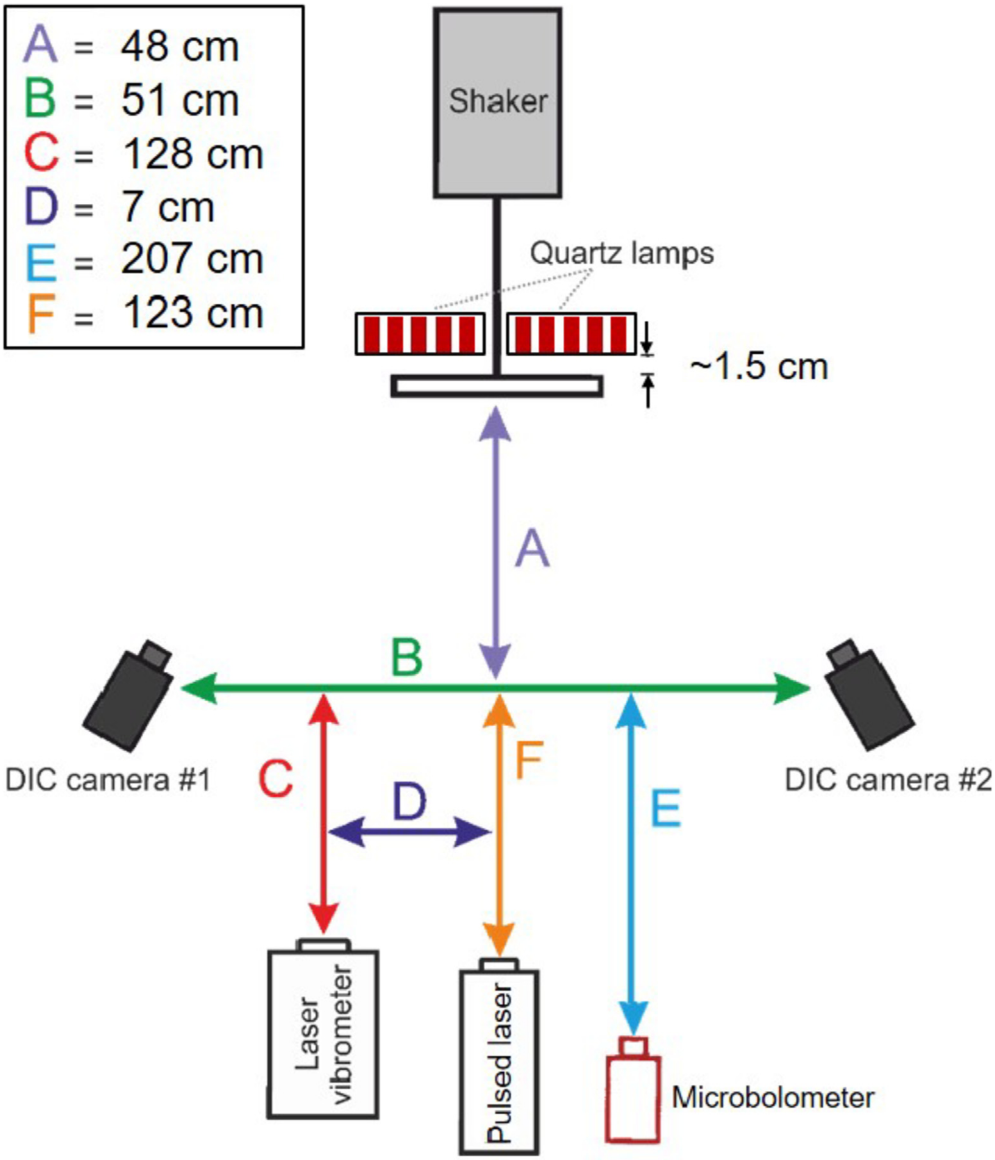

Fig. 1. Diagram showing the experimental arrangement.