An Experimental Study of Thermal Buckling Behavior in C/SiC Thin-wall Composite Structures for hypersonic aircrafts

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Abstract. Hypersonic aircrafts will be exposed to an extremely thermal environment during the service life, which will induce the thermal deflection since it is compressed by the thermal stress and the structure boundary. This would induce the thermal buckling behaviour easily and change the load-bearing form of thin-wall structures, leading to challenges for structure integrity and safety of hypersonic aircrafts. In order to investigate the thermal buckling behaviour of thin-wall structures at temperature up to 300℃, 500℃ and 1200℃, a high temperature digital image correlation (DIC) system was established to measure the deformation of the thin-wall structures. All the above research work would provide a technical support for the design of anti-buckling thin-wall structures and the strength design of the structures for hypersonic aircrafts.

Introduction

Hypersonic aircrafts will be exposed to an extremely thermal environment during the service life, which will induce the thermal deflection since it is compressed by the thermal stress and the structure boundary. This would induce the thermal buckling behavior easily and change the load-bearing form of thin-wall structures in hypersonic aircrafts, leading to challenges for structure integrity and safety of hypersonic aircrafts[1].

The topics of thermal buckling behaviour have been studied widely in last two decades. Extensive research work has been undertaken to investigate thermal buckling in high-temperature environment. The typical research work is introduced as follow: Jin et al[2] used DIC and FE method to study the thermal buckling behaviour of a laminated composite plate under a uniform temperature distribution up to 120℃.Rakow and Waas[3] used high-temperature strain gages and a Rayleigh-Ritz method to study the thermal behaviour of metal foam sandwich panels (MFSPs) at temperature up to 300℃.Ounis et al[4] used finite-element method to investigate the effect of the boundary condition on thermal buckling behaviour of laminated composite plates. Li et al[5] used finite-element method to investigate the effects of non-uniform temperature distribution and locally distributed anisotropic properties on thermal buckling behaviour of laminated composite plates. Yuan et al[6] used DIC method to investigate the thermal behaviour of truss-core sandwich panels at temperature up to 800℃. From the above literature review, it can be seen that researchers have heavily focused on investigating the thermal buckling of laminated composite plates theoretically and analytically. At present, the experimental method used to investigate the thermal buckling behaviour is only at temperature under 800℃. Hence, in this paper, an experimental study of the thermal behaviour for thin-wall structures are present at temperature up to 1200℃.

Experimental Methodology

Specimen Preparation. The thin-wall panels used in this paper nominally 380mm wide, 260mm long, 1.5mm and 6mm thick were manufactured from C/SiC composite materials using a chemical vapor infiltration (CVI) processing route. The specimens were fixed on the clamp and the clamp was cooled by water.

Loading and Data Acquisition Methodology. The displacements of the specimens was measured using Digital Image Correlation, so prior to performing any experiments, the face of the specimen was spray-painted with a radam speckle pattern to resist heat and withstand deformation at high temperature. A commercially available alumina spray paint (Amerco, USA) was applied on the outer surface of the C/SiC composite panel to create a random speckle contrast pattern. A three-dimensional Digital Image Correlation system (VIC-SNAP and VIC-3D, CSI, USA) was used for 3D surface deformation measurement and consisted of two high resolution cameras (GRAS-50S5M/C, Point Gray) with matching 35 mm lenses. In order to eliminate the glow emanating from the heated specimens, the two cameras were then fitted with a blue band-pass filter. The centre wavelength of the filter was 450nm and the bandwidth was 40nm. Two LED blue lights were used to illuminate the sample which was placed between the two cameras. During testing, the two CCDs were triggered simultaneously and captured the pictures every 5℃. Quartz lamps were used to heat the specimens up to the temperature 1200℃ and the temperature was controlled by thyristor transformer. Thermocouples and point temperatures are used to monitor the temperature of the specimen. The experimental set-up is shown in Fig. 1.

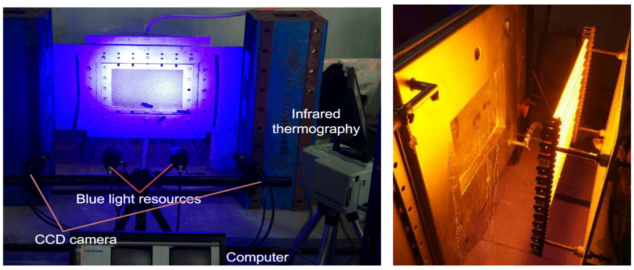

Fig. 1 the experimental set-up

Results and Conclusions

The Specimen with 1.5mm thickness. The critical buckling temperature was found to be around 170℃ (as shown in Fig. 2) and the corresponding out-of-plane displacement of the central point on specimen was 0.25mm. The maximum displacement at 300℃ was approximate to 1.59 mm and the maximum displacement at 500℃ was approximate to 3.9 mm.

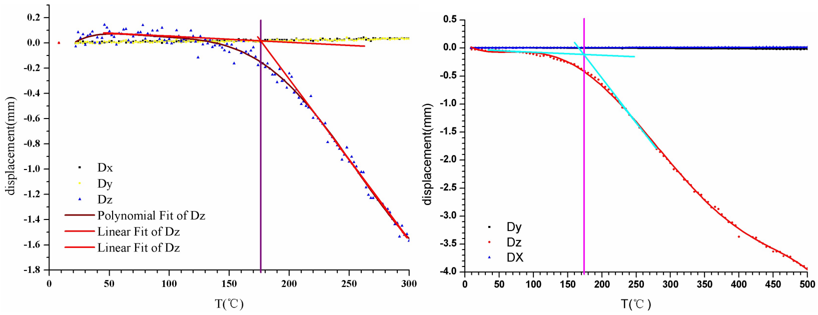

Fig. 2 typical relationship between temperature and displacement for a central point on surface of the C/SiC composite panels at the temperature up to 300℃ (left) and 500℃(right)

The Specimen with 6mm thickness. The specimen was heated up to the temperature 1200℃, however, the buckling behaviour haven't occurred. The reasonable reason is that the thickness of the panel is adequate to resist buckling behaviour. The out-of-plane displacement map at 1200℃ was shown in Fig. 3 and the maximum displacement was approximate to 0.48 mm.

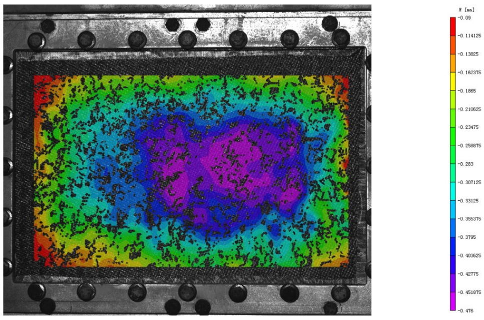
Fig. 3 Out-of-plane displacement for the specimen at the temperature of 1200℃

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