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High temperature indentation behaviors of carbon fiber composite pyramidal truss structures

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ABSTRACT

The composite sandwich panels with pyramidal truss cores were fabricated by the hot-press method. Subsequently, the experimental studies were performed to investigate the quasi-static indentation response of composite sandwich panel at high temperature. The quasi-static indentation tests of composite sandwich panels were conducted at temperatures ranging from 20 °C to 200 °C. The damage mechanism, load–displacement curves, indentation load and absorbed energies at high temperature were investigated and compared with that at room temperature. The results showed that high temperature induced a change in the failure mechanism and had the significant effect on the load–displacement curves, indentation load and energy absorption. The indentation load and absorbed energies decreased as temperature increased. Especially at 200 °C, the reduction in indentation load and absorbed energies was more severe, which was are mainly due to the degradation of matrix properties and fiber–matrix interface properties at higher temperature.

1. Introduction

Composite sandwich panels with lattice truss cores present attractive characteristics for aerospace and marine industries where light-weight materials with high stiffness and strength are needed [1–3]. These panels possess three-dimensional periodic cores (e.g. pyramidal, tetrahedral and Kagome cores) which provide new opportunities for designing lightweight multifunctional structures [4]. The interest in such panels has stimulated recent efforts to develop new fabrication methods [5–7]. Significant work have also been done to investigate the compressive, shear and bending properties of lattice truss core sandwich panel at room temperature, and the superior mechanical properties have been revealed [8–11]. Composite sandwich panel with lattice truss cores may be subjected to local loading and thermal loading instead of uniform loading at room temperature during their service life, the severe degradation of the mechanical properties will occur in this extreme environmental condition [12–14]. Thus, a good understanding of the high temperature indentation behaviors of lattice truss cores sandwich panel is necessary in order to avoid the catastrophic failure.

Unfortunately, the indentation response of composite sandwich panel with lattice truss cores has not been reported yet, especially for high temperature indentation response. However, a few studies have been carried out on sandwich panel with honeycomb cores and foam cores under quasi-static indentation loads. Flores-Johnson et al. [15] studied the quasi-static indentation behaviors of foam core sandwich panel. They found that both nose shape and foam core density have large influence on the indentation response of sandwich panels. Du et al. [16] investigated the effects of configurations of Z-pin, including inclination angle and pinning density, on the indentation response of Z-pin reinforced foam core sandwich panel. Ruan et al. [17] studied the mechanical response and energy absorption of aluminum foam sandwich panels subjected to quasi-static indentation loads. The results showed that the load–displacement curve was affected by face-sheet thickness, core thickness and boundary conditions. Li et al. [13] investigated the effect of temperature on the indentation behavior of closed-cell aluminum foam. They found that the plastic collapse strength, tear energy and energy absorption are strongly dependent on temperature. Zhou et al. [18] studied the mechanical behavior of honeycomb core sandwich panel under quasi-static loading. The core crushing, top skin delamination and top skin fracture are identified as major damage mechanisms. Composite sandwich panels with pyramidal truss core are susceptible to local loading and high temperature, the high temperature indentation

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response must be thoroughly investigated before they can be used with confidence in load-bearing structures.

The aim of the present study is to investigate the high temperature indentation response of composite sandwich panels with pyramidal truss cores. The quasi-static indentation tests of composite sandwich panels were conducted at temperatures ranging from 20 °C to 200 °C. The effects of temperature on the failure mechanism, load–deflection curves, indentation load and energy absorption were studied and analyzed.

2. Panel fabrication

The unidirectional carbon/epoxy prepregs were used to fabricate composite sandwich panel with pyramidal truss cores by the hot-press method. The detailed fabricate process are given as follows. First, the unidirectional carbon/epoxy prepregs were cut to required dimension and made into composite struts as truss members. In order to fully exploit the intrinsic strength of the fiber reinforced composite by the truss structure, all the continuous fibers of composite were aligned in the direction of truss members. Second, the unit molds were assembled into the completed mold, and the composite struts were inserted into the holes of the molds, as shown in Fig. 1(a). In order to separate easily the structures from the mold after the curing of the resin, the unit mold was divided into three parts. Third, the carbon/epoxy prepregs were placed on the surface of the molds. The ends of the composite struts were dispersed and embedded gradually in the mid-plane of the top face sheet, as shown in Fig. 1(b). The bottom face sheet was fabricated in the same way. At last, the preformed sandwich panels were cured at 125 °C with constant pressure of 0.5 MPa for 1.5 h, as

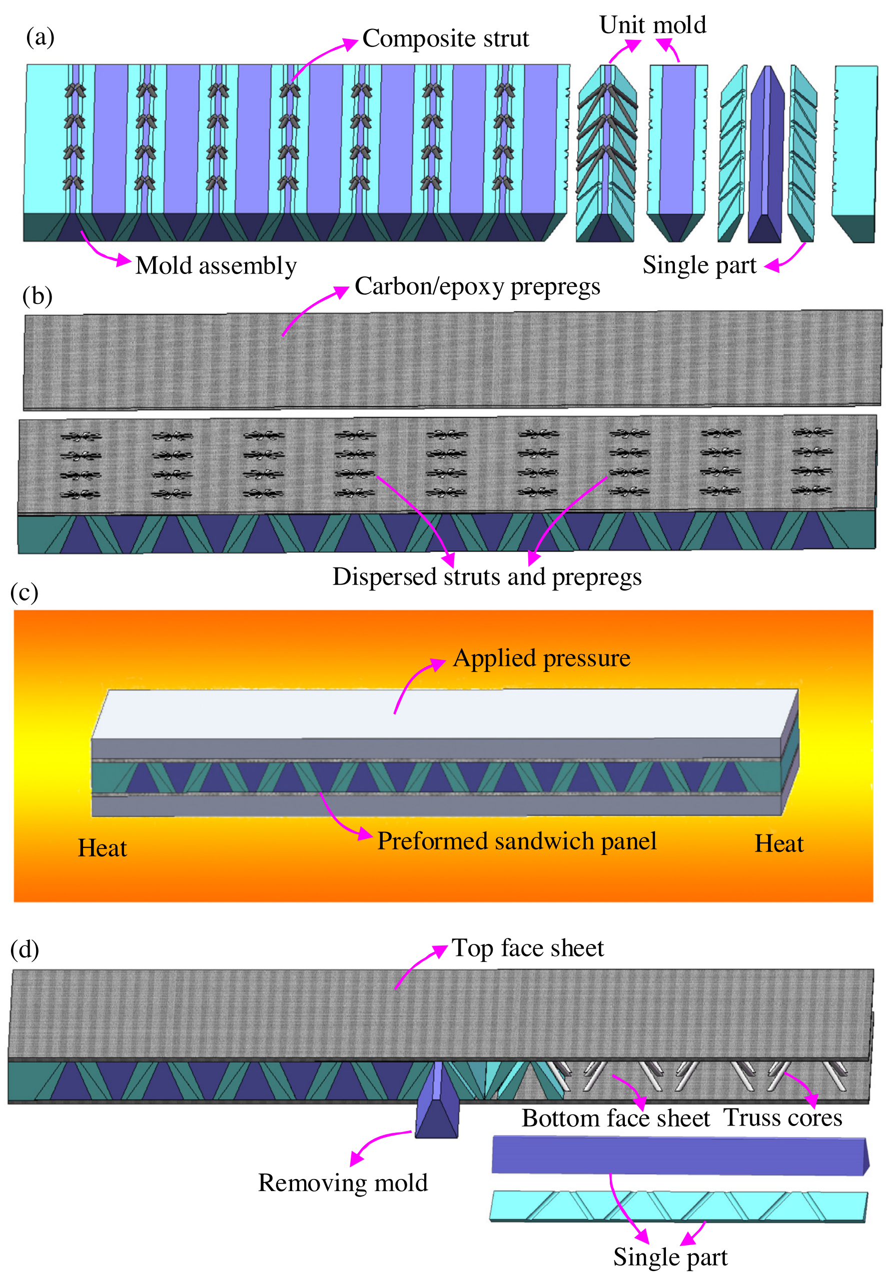

Fig. 1. Illustration of the manufacturing route for making composite sandwich panel with pyramidal truss cores: (a) the composite struts were inserted into the holes of the molds; (b) the ends of composite struts were dispersed and embedded into the face sheets; (c) the preformed sandwich panel was cured; (d) the molds were removed from the specimen after curing.