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Research Article

Influence of Matrix Modifications by Nano-Clay on the Mechanical Characteristics of Sandwich Panels

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Abstract

Composite Sandwich panels find wide applications in areas like aerospace, automobile, marine, and civil infrastructures due to its exceptional properties like high specific strength, flexural stiffness, resistance to corrosion, specific energy absorption, acoustic and damping features. However, the de-bonding of face and core is the most critical failure in sandwich panels. In this study, the interfacial bonding between glass-fiber face sheets and aluminum-honeycomb sandwich composites and their mechanical behavior was investigated under flexural load. The influence of loading rates on the flexural properties of sandwich panels was also assessed. The viability and influence of resin-fillet reinforcement and interfacial toughening by the inclusion of nano clay in the glass-fiber face sheets and aluminum-honeycomb core were studied. The presence of resin and nano clay at the interface and fillet of honeycomb core effectually act as a composite. The concentration of nano-clay in the face sheet and honeycomb core sandwich laminates had increased the interfacial toughness, thereby increased the flexural properties of the panels. Furthermore, increasing the content of nano-clay had a higher effect, whereas, the loading rate had a moderate effect on the failure load of sandwich panels.

Keywords: *Glass fiber, Debonding, Sandwich panels, Resin fillet reinforcement.*

Introduction

Composite sandwich structures are very useful in developing high strength and low weight structures. These structures are used in many applications such as marine, automobile,

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aerospace, and civil infrastructures. Sandwich panels consist of two thin and stiff face sheets bonded to a lightweight core. The face sheet usually composite, aluminium, or steel materials, depends on the application. The core may be aluminium honeycomb core, balsa, foam, and organic or inorganic materials. The core of sandwich structures helps to increase the thickness without an increase in weight, increase strength, and bending stiffness.

By modifying the thickness and material of the face sheet and the core of sandwich panels, it is feasible to achieve different and desired properties [1,2]. The mechanical behaviour and characteristics of aluminium honeycomb sandwich panels have been studied by many researchers. For example, the mode of failure of honeycomb sandwich structures under flexural, compression, edgewise compression, indentation, and low-velocity impact was studied [3-7]. The type of applied load to the sandwich panels and its failure modes were mostly depending on the properties of constituent materials, load distribution, and interfacial bonding between face-core [8-9]. The behaviour of sandwich panels under flexural and in-plane compression load revealed commonly occurred failures are cell wall buckling, face-core debond, and fracture [10-11]. From the studies on the mechanisms of failure of honeycomb sandwich panels, it is obvious that the structural performance of the panel depends on the bonding between the interface of the face sheet and core [12]. In order to improve interfacial toughness between the face-core of different sandwich composites, various toughening methods have been revealed. The common method to improve interfacial toughness is Z-pinning of face sheet and core [13] and tufting [14] which means stitching the face sheet and core. Mechanical behavior of polymer pin reinforced honeycomb sandwich panel were studied and reported that reinforcing foam-filled honeycomb with polymer pins increases In-plane and Out-plane compression, bending, low-velocity impact, and Compression After Impact (CAI) properties considerably [15-17]. Z-pinning and stitching process can induce core damage during the repetitive stitching action, and thereby reduce the structural integrity of sandwich structures [18].

The usage of nano-clay as additives in polymer composites leads to enhanced mechanical, thermal, and flame retardant property. This is due to the high surface to volume ratios and the nanometer size dispersion of nano-clays in polymers, it shows improved properties when compared to the pure polymers [19]. Bending properties are enhanced by nano-clay inclusion due to the improved interface between fibers and matrix [20]. Manola et al [21] studied the effect of gluing composite sandwich panel under flexural load, the result showed that, gluing results in an improvement in structural integrity. Shahverdi et al [22] studied the post-buckling analysis of geometrically perfect/imperfect honeycomb core sandwich panels having graphene platelet (GPL)reinforced face sheets experimentally and numerically, showing that GPL dispersion in the face sheets improved the post-buckling load. Furthermore, still, now, there is no work carried out on the mechanical characterization of Aluminium honeycomb-glass fiber reinforced sandwich composites laminates with nano-clay matrix.

In this study, nano-clay reinforced polyester matrix material is used for the manufacturing of aluminium honeycomb-glass fiber reinforced sandwich panel. Bending and the effect of strain rate on the sandwich laminates manufactured with nano-clay containing polyester resin are investigated.

Materials and Experimental Procedure

For face sheets, two layers of glass fiber woven fabric with areal density 600g/m^2 and nano-clay/polyester resin. Catalyst and accelerator used are Methyl ethyl ketone peroxide and cobalt naphthenate, respectively. Aluminium honeycomb core with 6.2 mm cell size, cell wall thickness 0.068 mm and height 10 mm is used are core material. In this study, nano-clay used was Cloisite Na+. Sandwich laminates are molded by hand layup techniques. The concentration of nano-clay in polyester resin is maintained at 0, 2, and 4 wt%.

Polyester resin is applied over two layers of glass woven fabric in order to form a lower face sheet and then honeycomb core material was placed on the lower face sheet, the upper face sheet was laminated with two layers of glass woven fabric on the core [23]. After the lamination procedure was completed, sandwich composites were allowed for a setting period of 24 h. Sandwich specimen HS prepared with face sheet of glass fiber/polyester matrix. Specimen NHS2, NHS4 were prepared by varying the nano-clay content of 2 and 4 wt. % on the polyester resin of face sheet materials.

Bending tests were conducted as per C-393/393M standards using Kalpak Computerized Universal Testing Machine with a loading rate of 1mm/min. The sample size is 240 x 30 mm^2 with a span length of 180mm.

Results and Discussion

Effect of Nano-clay in Flexural Properties of Sandwich Panels

The flexural test is conducted to determine the bending properties of sandwich panels with and without the concentration of nano-clay in the face sheet materials. Figure 1 shows the load vs deflection curves of HS, NHS2, and NHS4 sandwich panels. The curves contain two vital regions that signify the behavior of sandwich panels in elastic and plastic regions. The initial failure load of the panel is provided by the flexural stiffness in the elastic region. In the plastic region, the loss of stiffness had occurred from the permanent deformation of the constituents in the sandwich panel. For all the panels, there is a gradual rise in load up to failure load, then it drops progressively. The failure load of the HS panel is 522.2 N, NHS2 panel is 779.72 and NHS4 panel is 948.61 N. The deflection at the failure load of HS panel is 2.06 mm, NHS2 panel is 2.48 mm and NHS4 panel is 2.86 mm.

The sandwich panels with nano-clay of 2 and 4 wt. % such as NHS2 and NHS4 panels failure load is 49.87% and 81% higher than HS panel. The outcomes of NHS2 and NHS4 panels show that the inclusion of nano-clay has more influence on the enhancement of flexural strengths. The nano-clay in the face sheet material act as resin fillet reinforcement in the aluminium honeycomb, which in turn provides strong interface adhesion between the face sheet and honeycomb core, improves flexural property significantly [24]. While there is no reinforcement in the resin fillet of HS panel and hence the flexural property is low.

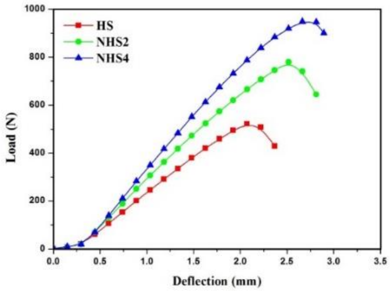

Figure 1. Flexure Load-deflection Curves of HS, NHS2 and NHS4 Sandwich Panels

Effect of Strain Rate in Flexural Properties of Sandwich Panels

To evaluate the effect of strain rates on flexural characteristics of HS, NHS2, and NHS4 sandwich panels, the flexural test is conducted at the strain rates of 1mm/min,10mm/min, and 100mm/min. Figure 2 depicts the flexure stress vs deflection curve of HS panels under flexural test, it can be seen that the flexural behavior of HS panel is influenced by the strain rate.

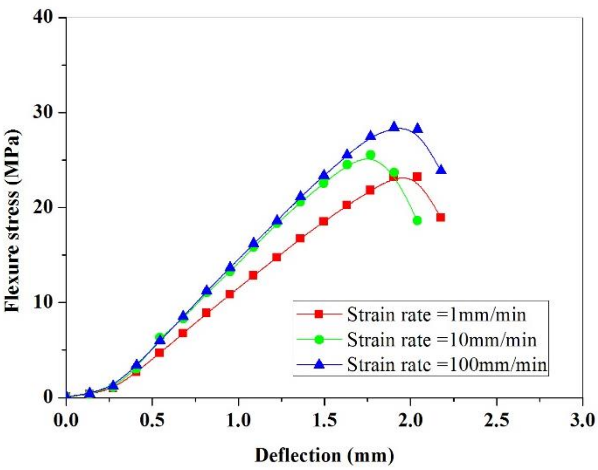

Figure 2. Flexure Stress–deflection Curves of HS Sandwich Panels

Increasing the flexural strain rate from 1 mm/min to 10 mm/min and 100 mm/min, the flexural strength increases by 8.04 % and 18 %. Similar behavior was observed from a study on a composite sandwich panel with foam-filled core [25].

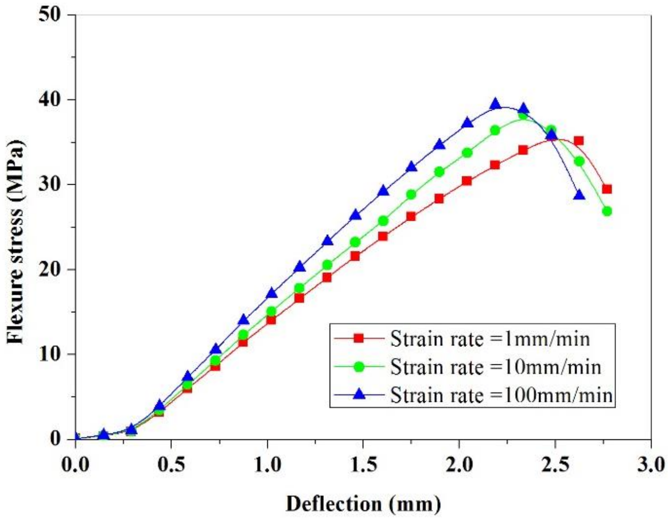

Figure 3. Flexure Stress–deflection Curves of NHS2 Sandwich Panels

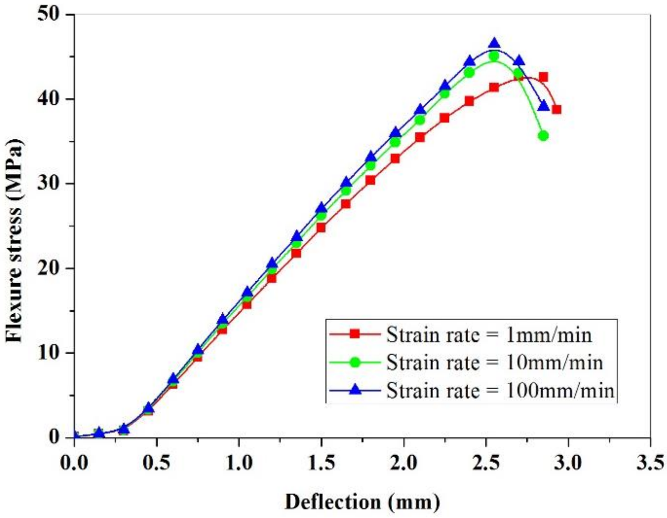

Figure 4. Flexure Stress–deflection Curves of NHS4 Sandwich Panels

Similarly, from Figures 3 and 4, it can be seen that NHS2 and NHS4 panel also influenced by strain rate. By varying the strain rate from 1 to 10 mm/min and 100 mm/min, the flexural strength of the NHS2 panel increased by 5.6 % and 11.31 %, respectively. While for NHS4 panel, flexural strength increased by 4.6 % and 10.12 %, respectively.

Table 1 depicts the effect of strain rates on flexural properties of sandwich panels, it is seen that the strain rate has an optimistic effect on the flexural properties of NHS panels than HS panel.

Table 1

Flexural Properties of HS and NHS Sandwich Panels at Different Strain Rates

Sandwich Panel type	**Failure load (N)**	**Deflection at failure load (mm)**	**Flexural strength (MPa)**
Strain rate at 1 mm/min			
HS	522.2	2.06	23.24
NHS2	779.72	2.48	35.63
NHS4	948.61	2.86	42.67
Strain rate at 10 mm/min			
HS	564.9	1.82	25.58
NHS2	823.6	2.29	38.34
NHS4	992.53	2.47	45.13
Strain rate at 100 mm/min			
HS	616.8	1.74	28.43
NHS2	867.64	2.11	39.46
NHS4	1044.4	2.23	46.49

Conclusions

Flexural tests of HS and NHS panels were carried out experimentally and it was found that, the inclusion of nano-clay in glass fiber face sheet and aluminium honeycomb sandwich laminates improved the flexural properties significantly. Increasing the concentration of nano-clay from 2 to 4 wt% increased the flexural properties of the NHS4 panel. The effect of strain rates on flexural characteristics of HS and NHS sandwich panels were evaluated, the result showed that the strain rate moderately influenced the flexural properties of sandwich panels. Increasing the strain rate, increased the flexural properties particularly NHS panels than HS panel. Thus the nano-clay included NHS panels are excellent compared to HS panels to make any engineering composite structures.

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