Mechanical Properties of WSF Sandwich Composite Plate

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The woven spacer fabric (WSF) sandwich composite plate is mainly used in carriages, construction materials, shock absorbers, wind-turbine blades, etc., which require WSF sandwich composite plates with bending, compression, impact, shear, and peel performance. These properties are reviewed herein. More attention will be paid to mechanical research of WSF sandwich composite panels should use non-destructive testing technology.

Keywords: mechanical Properties ; sandwich structure ; compression Property

1. Bending Property

In regard to bending performance, the core pile structure–woven spacer fabric (WSF) sandwich composite plate is generally reported, including its core material, curvature, additional panels, core pile density, core pile height, and fiber material. The fiber material is diverse in regard to stiffness, modulus, and toughness. Consequently, the fiber-reinforced material studied, similar to glass fiber and carbon fiber, is inclined to breakdown and shear failure, but polyester fiber is easy to stratify. A combination of glass fiber and polyester fiber was studied by Jia [1] in which polyester fiber and woven glass fiber were used for ground fabric and core yarn, respectively. These methods improved core yarn stiffness, kept back the toughness of the ground layer, and improved the properties of the WSF sandwich composite plate. Moreover, the core pile height and density were considered. The regression analysis revealed an optimal bending strength in 1.99 ends/cm^2 for polyester fiber, and an increase in the core pile height decreased its bending strength, ultimately increasing its bearing capacity [2]. The property of the core material is the difference between PU foam and industrial core materials (such as concrete foam): the PU foam is flexible [3], but industrial materials cause shear fracture failure, which is more obvious with the narrowing of span [4].

At the present stage, the cross-linking structures–WSF sandwich composite plate has attracted less research attention than the cross-linking structures–hollow WSF sandwich composite plate. Specifically, the effects of ground-fabric structure, cell density, and height were examined for the cross-linking structures–hollow WSF sandwich composite plate. In the ground fabric structure, the crimped and non-crimped were researched. The results revealed that non-crimped structures yield a higher flexural resistance than crimped because of the stretched thread arrangement in the fabric structure, both in the warp and weft directions [5]. In addition, the cell wall is a major load-bearing unit [6]. The cell wall of a rectangular structure–hollow WSF sandwich composite plate has better optimal stress than trapezoidal and triangular ones, and when the space between the cell wall and height decreases, the stress increases [6][7]. A study of four types of structures by Manjunath et al. [8] found that the H-type structure's stress was higher than that of the rectangular type.

2. Compression Property

This section discusses core pile structure and cross-linking structure–WSF sandwich composite plates and the effect of compression properties. The specific properties that have been studied include flatwise compression, edgewise compression, and dynamic compressive for core pile structure–WSF sandwich composite plate and flatwise compression and edgewise compression for cross-linking structure–WSF sandwich composite plates.

(1)Core pile structure–WSF sandwich composite plate

In regard to flatwise compression, the core pile height, core density, and additional panels have been investigated in the literature. For a higher core pile height, the composite plate is inclined to instability, resulting in decreased compression strength [9]. As the stiffness with core density increases, the flatwise compression strength is also increased. It is also strengthened by toughening the core material or additional panels. Chinese researchers used resin and fiber to toughen the core material, concluding that the composite plate had higher compression properties. In additional panels, Hosur et al. [10] investigated glass fiber and carbon fiber plates to strengthen their dynamic compression, establishing that glass fiber plate has higher stress than carbon fiber plate, and core and integrated core pile provide a synergistic effect, but they are prone to shear deformation, causing delamination between additional panels and core pile structure–WSF sandwich composite plate.

In regard to edgewise compression, a new type of core material was proposed by Wang et al. [4] and Hamid et al. [3]. Wang et al. [4] tested the cementitious-reinforced WSF sandwich composite plate and found that the peak load was sustained by the core, though multiple shear failures occurred. Compared with edgewise compression, flatwise compression had excellent properties because the enhancement plate and the core material improved its strength. In contrast, Hamid et al. [3] investigated foam-core-reinforced WSF sandwich composite plate and found that the composite had higher energy absorption because of the existence of the foam core, and it had a superior peak load compared to flatwise compression. The reason for these two different conclusions could be the difference in core material. Moreover, the research group discussed the impact property before and after, and the results indicate that, compared with the impact before, the impact of the WSF sandwich composite plate after was extremely prone to stress concentration rather than disperse, thus increasing the risk of integrity failure.

(2)Cross-linking structure–WSF sandwich composite plates

For both flatwise compression and edgewise compression, only the hexagonal WSF sandwich composite plates were investigated, which are elastic and have a cushion structure. In edgewise compression, Ruben et al. [11] investigated the effects of aromatic fiber, polyester fiber, and glass fiber on WSF sandwich composite plates. They found that aromatic fiber and polyester fiber–WSF sandwich composite plates contributed to the ductile failure and wrinkling of walls, thereby improved the edgewise compression strength. For the glass fiber, the failure pattern was the ductile buckling and the classic brittle tearing/breaking of the wall which decreased the compression strength. For flatwise compression, Zhu et al. [12] examined the compression behavior of the WSF sandwich composite plate by testing the cellular size and fabric layer. Based on the above results, it was concluded that the compression resistance was excellent, with a higher CV 65% (compression stress value when strain reaches 65%), which demonstrates the high allowable safe stress and cushion energy absorption of the composite.

3. Impact Property

A low-speed impact was adopted to explore the performance of the WSF sandwich composite plate. Several aspects of the core pile structure–WSF sandwich composite plate, such as the aspect of core pile density, additional aluminum plate, core material, and impact position, were explored. For core pile density, the WSF sandwich composite plate of carrying capacity increases with the core pile density. Hamid et al. [3] showed the impact: the impact property of the WSF sandwich composite plate layered phenomenon during the impact was strengthened by addition of natural zeolite in core material. The research group tested the effect of impact position on the core pile and non-core pile properties. Herein, it was found that the core pile position had a larger depression diameter during impact, and the lower ground plate was significantly damaged due to the impact energy passed down along the core pile. In comparison, for the non-core pile impact position, the damage was concentrated on the upper ground plate and small damage. Notably, the upper ground plate completely was penetrated when the impact energy was increased [13]. The addition of the aluminum plate caused delamination due to the increased impact energy, and the energy was absorbed mainly by crushing the vertical fibers and the supporting foam beneath the region of impact for the WSF sandwich composite plate [14].

To date, cross-linking structure–WSF sandwich composite plates have not been investigated. Most studies have focused on the impact properties of the cross-linking structure–hollow WSF sandwich composite plate. Mountasir et al. [5] tested the effect of ground structure, warp, and weft density. They concluded that the impact property of the crimp structure was superior to the non-crimp structure, and it had better impact behavior. In addition, the impact strength and energy absorption increased with the warp and weft density.

4. Shear and Peel Property

(1)Core pile structure–WSF sandwich composite plate

In the shear test, the stress increased linearly with the strain. Initially, the cracks propagated along the interface between core material and ground plate and stopped when they reached the core piles. The cracks increased tension on the piles, leading to fracture [9]. The study concluded that the shear and peel property resistance increased with ground density because more densely interleaving points improved adhesion between the core material and ground plate [15].

(2)Cross-linking structure–WSF sandwich composite plates

Currently, one study has investigated the cross-linking structure–WSF sandwich composite plates. Therefore, this section explores the effect of different junction methods, such as the cross-linking structure, stitched structure, and adhesive structure, on performance. The failure mode of the cross-linking structure was yarn breakdown, but stitched and adhesive structures underwent delamination in the test. The cross-linking structure's strength increased by 16% and 39% thanthe stitched structures for U and + types [16]. Compared with the T-type adhesive structures, the cross-linking structures showed higher stress and 3-fold higher peel force [8]. Consequently, it was concluded that the junction strength increased for the cross-linking structure, followed by the stitched structure and adhesive structure, in that order.

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