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A Review of Polymer Based Laminated Composites for Flexural and Shear Properties

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ABSTRACT: In this paper, a comprehensive literature review on the flexural and shear properties of polymer based laminated composites has been presented. Since their introduction, fiber reinforced polymer composites have become an important class of composite materials owing to their high specific strength and specific stiffness. Fibers reinforced polymer matrix composites are being used extensively in automotive and aerospace structures due to their superior specific properties, which translate into low fuel consumption, higher passenger capacity and decreased maintenance cost, for example. The use of composite materials was limited only to secondary aerospace structures but with the development of knowledge about these materials, their use in primary aerospace structures has increased. Mostly, aerospace structures are based on thermosetting polymer matrices. However, use of thermoplatics is increasing everyday due to the excellent properties they offer such as unlimited shelf life, storage without freezing, improved toughness, possibilities for recycling and above all the short cycle productivity.

KEYWORDS: Flexural, Shear, Fibre reinforced, Laminates.

I. INTRODUCTION

Aerospace structures are often prone to bending loads, which can result in serious damage. Therefore, for structural integrity, aerospace structures must be efficient to resist bending. The first use of modern composite materials in commercial aircrafts was by Airbus in 1983 [1]. Flexural loading causes stresses in the composites, which vary through the thickness. These flexural stresses are the maximum at the outer surfaces and zero in the middle at the neutral axis. In pure bending, the composite failure initiates on either the tensile or compressive side depending upon whether the composite is stronger in compression or tension respectively. The stress in an individual ply depends upon the stiffness of that ply and its distance from the laminate's neutral axis. By including, one or more extra components having relatively better elastic properties in the laminate can help in improving the flexural properties of the composite structures. This class of composite materials consisting of more than two types of constituents is commonly known as a hybrid composite [2]. Hybrid composites having two or more types of reinforcing fibers in a polymer matrix can be classified according to the way their constituent fibers are mixed such as; sandwich hybrids, interply hybrids, and intermittently mixed hybrid composites. Interply hybrid composites are gaining attention because hybridization facilitates the tailoring of mechanical properties according to need by having a selective amount of extra reinforcement at some selective position in the laminate [3]. Kertesis3 has presented a comprehensive review on the properties of hybrid composites. The relative volume fraction of reinforcing fibers and their positioning in the hybrid layup act as the determining factors in the enhancement of flexural properties. Therefore, for structural laminates under flexural loading, material can be designed for better flexural properties by investigating the effect of the stacking sequence [3]. In a hybrid composite, the two reinforcing fibers differ in their mechanical properties and the interface they make with the matrix [4]. Banerji and Nirmal [5] reported an increase in flexural strength of unidirectional carbon fiber/ Poly(methylmethacrylate), composite laminates having polyethylene fibers plies at the lower face. Li and Xian[6] showed that the incorporation of a moderate amount of carbon fibers into ultra-high-modulus polyethylene (UHMPE) fibers reinforced composites greatly improved the compressive strength, flexural modulus while the addition of a small amount of UHMPE fibers into a carbon fiber reinforced composite remarkably enhanced the ductility with only a small decrease in compressive strength. Rohchoon and Jang[7] studied the effect of stacking sequence on the flexural properties and flexural failure modes of aramid-UHMPE hybrid composites. The flexural strength depends upon the type of fibers at the compressive face and dispersion extent of the fibers. Matteson and Crane [8] reported increase in flexural strength by using unidirectional steel wire tapes in glass fiber composites and carbon fibers composites. They

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showed that the increase in flexural strength was due to a change in failure mode from compressive buckling to nearly ductile tensile failure. Bradley and Harris [9] used unidirectional high carbon steel wires to improve the impact properties of epoxy resin reinforced with unidirectional carbon fiber reinforced. By having steel wire on the compression side of the specimen, the energy of fracture was increased by 200% by elimination of compressive failure mode. Flexural strength was increased particularly when the wires were placed in the compression side of the specimen and also as the volume fraction of the wire was increased. The objective of this paper is to provide an in-depth literature review on the flexural properties of fiber reinforced thermoplastic composites under 3-point & 4-point bending tests as shown in figure – 1.

Fig -1 Three point bend test on composite specimen

Damage characteristics of composite sandwich panels in bending were investigated by G.Zhou et.al [10] with both hemispherical (HS) and flat-ended (FE) indenters. The thickness of the cross-ply skins varies from 8 to 16 plies. Clamped panels with a 100-mm testing area are loaded quasi-statically either in bending or on a rigid base. The effects of varying these parameters on damage mechanisms were examined through response curves as well as cross sections of selected specimens. An investigation was conducted by Issac M Daniel et.al [11] on failure modes and criteria for their occurrence in composite columns and beams. They found that the initiation of the various failure modes depends on the material properties, geometric dimensions and type of loading. They reported that the loading type or condition determines the state of stress throughout the composite structure, which controls the location and mode of failure. The appropriate failure criteria at any point of the structure account for the biaxiality or triaxiality of the state of stress. Jeam Marc et.al [12] investigates the modeling of the flexural behavior of all-thermoplastic sandwich composite structures with improved aesthetic properties, manufactured by isothermal compression moulding. The aesthetic thermoplastic sandwich composites exhibit specific features such as thick multi-layered faces and significant core properties variation due to processing conditions. Considering these specific features, a three-step calculation methodology they developed an accurate analytic model, to predict the equivalent shear properties of the core after manufacturing and to take into account the influence of the glass veil layer used to improve the surface quality of the part. A four noded plate element based on a refined higher order shear deformation theory is developed by Topdar et.al [13] for the analysis of composite plates. This plate theory satisfies the conditions of inter-laminar shear stress continuity and stress free top and bottom surfaces of the plate. Moreover, the number of independent unknowns is the same as that in the first order shear deformation theory. The inter-elemental continuity, as desired by the plate theory, is fully satisfied in the present element. Numerical examples of composite plates were solved to validate the element & results are presented. An investigation on the effect of cross-sectional warping on the flexural response of laminates and sandwiches has been presented by Sanjib Go swami[14]. A simple C0 finite element formulation of a higher-order shear deformation theory for thick and thin laminated composite and sandwich plates have been put forward. The assumed displacement model accounts for nonlinear variation of in-plane displacements and constant transverse displacement through the plate

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thickness. Moreover, the theory does not require any fictitious shear correction factors generally associated with the first-order shear deformation theory. He suggested for thick laminated plates, the bending response is highly affected by the cross-sectional warping. The so-called Mindlin's theory cannot capture this warping phenomenon due to linear variation of in-plane displacements. Only higher order theories with higher-order terms in the in-plane displacement expression are required to compute displacements and stresses in the correct way. He showed that the free shear condition at the top and bottom bounding planes could be imposed in a simple way. Y.C.Shiah et.al [15] investigated an integrated sandwich composite adopting 3-D woven fabrics as the core material & thoroughly studied its effective elastic modulus. In spite of the extensive applications of 3-D woven sandwich composites due to their improved mechanical properties, no suitable theoretical model has been proposed to predict the elastic modulus for such composite structures in the open literature so far. In their work, a theoretical model by means of a micromechanics approach and the rule of mixtures is proposed to predict its effective in-plane elastic modulus. To verify the veracity of their prediction, unidirectional tensile tests were also carried out to determine the effective elastic modulus. Eventually, their experimental results turn out to agree with predicted values. Bending tests of a commercially available composite plate with CFRP fabric were conducted by Atsushi Kataoka et.al [16] primarily by means of a three-point bending. The effects of the span and the radius of the tip of the loading device on the bending modulus and strength were examined systematically. Test data on bending rigidity did not coincide with those calculated from a modified beam theory where the effect of the shearing rigidity was incorporated, although the tendency that the bending modulus increased, the span was the same for both experiment and theory. Based on these results, they proposed a desirable data reduction scheme by which the correlation between theory and experiment could be made clear. The applicability of a so-called compression-bending test was also demonstrated by the authors.

II. CONCLUSIONS

A comprehensive literature review on flexural properties of polymer-based composites has been made. This review may help the composite design community and the current trends on the flexural properties of polymer based composite. To improve flexural properties of fiber composite laminate previous researchers have recommended various methods, which have been presented here. However, in thermoplastic composites, high processing temperatures induce thermal residual stresses in the laminate. These thermal residual stresses induce warpage in the laminates if asymmetric hybrid configuration is used which results in a decrease in flexural properties of the hybrid composites.

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