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Business, Accounting

Abstract: As theincreasing demand of the use of ultralight spacecraft structures using wovenfibre composites is put interest in the research of predicting mechanicalbehaviour of the woven fibre composites made of one or two plies. Lightnessassociated with the symmetrical and balanced properties made the material verymuch suitable for the weight sensitive applications.

In this paper, initiallyit provides the general overview of the thin woven fibre composite materialwhich is going to focus to have a better understanding and to familiarise withthe terminology. Then, the paper considers what are the researches carried onup to now, to predict the mechanical behaviour of the woven fibre compositesespecially for one and two plies. Also, this paper stating the theory andequations involved in predicting the mechanical behaviour, availableexperimental support to validate the research carried on the micromechanicalmodelling and discuss the limitations and shortcomings of the methodologiesused in the previous researches.

Keywords: Classical lamination theory; Wovenfibre composites; Mechanical behaviour; Non-linear bending; Micromechanical modelling; 1. IntroductionThe use of ultralight spacecraft structures using polymerfilms and ultrathin composite fibre materials is most trending in theaeronautic industry. There are various researches carried on the ultralightspace structures associated with advanced packaging techniques. This techniquewas often enthused by origami techniques (Caltec, 2015). The current curiosityon this technique are in applications of solar collectors and antennastructures. In aeronautic applications, the textile composites areused over other alternatives due to their high mechanical properties. Thinwoven fibre composite materials are anticipated to use in ultra-thin deployablestructures popularly because of their symmetrical and balanced properties. There are several studies on thin-walled tubular booms inthe current trend using carbon fibre composites.

It is very effective to usethese in the mechanism of deployable structures as the stored strain energyrelease will provides efficient operation. These structures made of thin-walledcomposite materials have quite a lot of benefits over the structures which arehaving mechanical joints. They are having high strength to weight ratio, they canbe made of several range of shapes at low cost due to lesser number ofcomponents and behave insensitive to friction. This paper presents an introduction to the thin wovenfibre composites, background to the study, equations involved, the summary ofwhat are the researches carried on the thin woven fibre composites in theapplication of aerospace and specifically on the behaviour of bending, the methodologythey had chosen and analyse the results obtained through the proposedmethodology. And finally, the conclusion.

2. Papers reviewed2. 1 GeneralThe fibre composite material is generally incorporatedwith two components as fibre and matrix.

Fibre is the main constituent whichcontributed to the mechanical properties of composites and the matrix usuallyresin, is to support and protect the fibres while transferring load between thebroken fibres (Jones, 1999). Obviously, the fibres are weak in bending due to its'high length to diameter ratio and therefore it is more flexible perpendicularto the fibre direction. So, the woven nature is increasing its' bending stiffnessin the composite material (Jones, 1999). The woven fibre in the sense, having two fibre bundles which called as yarnsweaved one over another in both warp and weft direction. The properties of thisis depended on the pattern of weave and number of fibres used in each direction(Soykasap, 2005). Figure 1: Plain weave fibreAs the woven fibre composites are predicted to use in theultra-thin deployable structures is mainly due to its' high strength to weightratio. So, the thin woven in the sense is especially considering one and twoplies woven fibres in these weight sensitive applications.

2. 2 BackgroundOver the years, to predict the behaviour of laminatecomposites, the Classical Lamination Theory is used with certain assumptions. Thetheory doesn't account the non-uniform interlaminar stresses which causingfailure (free edge delamination) in the composite laminate and signifies someof the stresses even those are not actually exists (Jones, 1999). CLT is postulatingthe following assumptions (Jones, 1999):· The plate is to be considered as thin and hasuniform thickness over.

· Only considered the in-plane stresses of thelaminate· Neglecting the through thickness shear strains· Assuming elastic approach i. e. the fibre bundlesobeys Hook's law· Considers the laminate constructed oforthotropic sheets.

It is symmetrical about the middle surfaceNow from the researches it has been shown that the CLThas enough accuracy in predicting the in-plane properties of thin laminates butdirectly using the CLT to estimate the properties of thin woven fibrecomposites of one and two plies end up with high error percentage. Through theexperiments carried out on thin woven composites it has been clearly statedthat CLT disagree with this. The CLT overestimate the maximum bending stress upto 200% and the bending stiffness up to 400% (Soykasap, 2005). Rather than going with the complicated finite elementmodelling to predict the bending properties, it is advantageous to introduce afactor that accounting the causes of the error in a simple way.

Someresearchers focused on possible causes to the above error percentage andcontribution of each causes to the error margin and introduced a modificationfactor to reduce the error margin (Herath & Mallikarachchi, 2016). This approach is a simplified method to predict the bending properties with acertain accuracy and even though this wouldn't predict the failure load of thecomposites accurately. 2. 3 Equations involvedFibre volume fraction can be expressed as follows (1) The longitudinal modulus, transverse modulus, shearmodulus and Poisson's ratio of the yarn can be calculated using the rule ofmixture and fibre volume fraction as follows (Jones, 1999) (Soykasap, 2005) (2) (3) (4) (5) In the above equations subscript ' f' refers the fibre andsubscript ' m' refers matrix. ABD (6 x 6) stiffness matrix is showing the relation inbetween the applied loads and the associated strains as follows2. 4 Research overview2.

4. 1 Unit cellgeometryAs a sequential pattern of weaving geometry can beobserved all over the surface of the woven fibre composite, a particularrepetitive cell can be represented as unit cell. At microscopic scale yarnsconsisting of thousands of fibres where they can't be modelled

individually. So, each yarn is modelled based on hypo-elastic approach since each fibre inthe yarn can slide with respect to each other (Badel, Maire, Vidal-Salle, & Boisse). Initially yarnswere modelled as curved shape beams with equivalent rectangular cross sectionand constraint along the centreline (Mallikarachchi, 2012). As it didn't recordthe Poisson's effect in an acceptable accuracy, many models were analysed andhere the researcher modelled the beam with fourth root of a sine wave. OverviewSoykasap (2005) carried out the research on the topic of'Micromechanical Models for Bending Behaviour of Woven Composites'. This paperwas focused on the micromechanical models for bending behaviour of woven fibrecomposites.

Before this research, many finite element models were developed inrelevance to this. Fujita (1992) and Dano (2000) studied the in-planeproperties of woven composites using beam element, Benarcyk and Arnold (2003)used three-dimentional repeating unit cell model and Page (2004) developed two-dimensionalfinite element model to study damage properties (Soykasap, 2005). Plain weave style T300/LTM45 composite was taken as thesample for the modelling. Material properties of a single yarn was estimatedusing fibre volume fraction and rule of mixture.

This study was considered the interaction between thefibre bundles and the matrix and carried out geometrically non-linear analysis topredict and analyse the behaviour of the one, two and three plies woven fibrecomposites. This research is concluded that, for one ply wovencomposite CLT overestimates both bending stiffness and minimum bend radius by afactor of 3. 9 and 2 respectively, and it was observed 82% and 33% differencefor two ply woven composite and 6. 6% and 0.

7% difference in bending stiffnessand minimum bend radius values respectively (Soykasap, 2005). According to the research of Soykasap (2005), in the caseof three ply woven composite, the material behaves as almost homogeneous andall the deviation in the estimated values is much occurs for one and two plieswoven composite. Therefore Mallikarachchi (2012) was focused on themicromechanical modelling of two ply plain style woven carbon fibre compositeto analyse the bending behaviour for small strains. A homogenized analyse wascarried out by neglecting the geometrical non-linear effects. Modellingtechnique was assumed periodic boundary conditions to an assembly oftransversely isotropic three-dimensional yarns and computed the 6 x 6 ABDmatrix. This paper concluded that even though 9% difference in bendingstiffness with experimental comparison, prediction of the axial stiffness andPoisson's effect with solid elements are having better accuracy (Mallikarachchi, 2012). The experiments were carried out to predict the bendingbehaviour of the thin woven fibre composites. From these experiments, it wasnoticed that the bending behaviour is not a linear as we expected earlier.

Itis showing a substantial reduction in its bending stiffness when going for highcurvature bends (Yapa & Mallikarachchi, 2017). Yapa (2017) modelled a homogenised Kirchhoff plate one-dimensionalunit cell with equivalent rectangular cross section. This model is notcorrectly representing the resin interface at the crossover points, it failedto estimate shear modulus and

Poisson’s effect accurately. Meanwhile, a homogenized Kirchhoff plate model with anassembly of transversely isotropic three-dimensional beam elements was capturedthe linear response of single ply triaxial woven fabric composites accuratelythus neglecting the geometric non-linear effects.

The fabric in the sense meanswoven tows in three directions, at 0 degrees and ±60 degrees and it impregnatewith resin like a general composite (Kueh & Pellegrino). Apart from these, there are several other researchescarried on the woven composites. One is, introducing three-dimensional mesoscopicfinite element analysis to determine the macroscopic mechanical behaviour andalso determined the deformed geometry of the reinforcement (Badel, Maire, Vidal-Salle, & Boisse). Further, there are several analytical models on plain wovenfabrics considering the yarn section at crossover, the shape of the yarn, thecontact condition at thread crossover and the set of yarn at mesoscopic scale (Bilbao, Soulat, Hivet, Launay, & Gasser, 2008). Other research was focused on to develop an opticalmeasurement based cantilever test to predict the bending behaviour of wovenfabric because already existing standard tests are not adequate. The researchconcluded that, prediction of the bending behaviour from the proposed method isnot possible by only considering yarns properties (Bilbao, Soulat, Hivet, Launay, & Gasser, 2008).

There is a possibility to associate semi discrete methodwhich is based on the specific finite elements made of discrete number ofcomponents that is proposed by (Hamila, Boisse, & Chatel) to bending stiffnesssuch as taken into account in three node plate or shell elements (Hamila, Boisse, & Chatel).

Tensile and shear deformation of the woven fabrics wasinvestigated the applicability of elastic theory using modelling technique (Ramgulam, Potluri, & Ciurezu). Further study should be carried out inthis research to include the effects of contact area and large sheardeformation modelling considering yarns transverse flattening. There are several researches focused on the forming ofwoven composites.

Vanclooster, Lomov and Verpoest compare an explicit finiteelement method and kinematic mapping scheme for simulations with theexperimental results. The main aim of this study was a kinematic mappingalgorithm can be used to investigate the complexity of the woven compositesbehaviour. And the research concluded that, due to initial conditions duringforming this approach fails (Vanclooster, Lomov, & Verpoest). 3.

ConclusionDue to increasing popularity of the use of thin wovenfibre composites in the ultra-thin deployable structure, this research is goingto focus on the micromechanical modelling to predict non-linear bending behaviourof thin woven fibre composite materials. After studied the previous researches, it is noted that bending behaviour is a non-linear for the thin woven fibrecomposites