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EDITORIAL

Special issue on 'mechanics of composite adhesive joints and repairs'

Adhesive bonding is almost ubiquitous and is increasingly being used in a wide array of industries, where innovative joints/repairs and a variety of material combinations are inevitable to realize more efficient, cost-effective and lightweight structural systems. The key aspect in the design of bonded systems is to enable a shear-dominated stress transfer through the adhesive and minimize the propensity of cohesive and/or adhesive failure owing peel stresses. Selection of an appropriate set of adhesive and adherend materials and modeling the response of bonded systems to external stimuli are critical in the design of efficient bonded structures. Much progress has been made in the past decade at micro-and nano-scales in improving macroscopic properties of adhesive materials. For example, the ultra-lightweight of 2017 GMC Acadia sport car is attributed to the use of 'ultra-superglue'. As a result, enormous research efforts are focused on developing new or improved models/methods at various length scales to design efficient bonded systems and to assess their in-service performance by effectively utilizing improved adhesive materials. The objective of the Special Issue (SI) is therefore to report on the advances in theoretical, computational and experimental aspects of: (i) adhesives and their nanocomposites; and (ii) metallic, hybrid and composite adhesive joints/repairs operating under a range of loading and environmental conditions. The SI comprises ten papers focusing on static, fatigue and fracture behavior of composite adhesive joints/repairs. The SI particularly sheds light on failure initiation based on generalized stress intensity factor approach, fracture behavior of nano-reinforced adhesives under cyclic thermal loads, influence of ply-layup orientations on the bending behavior, cohesive zone modeling combined with fracture tests for longevity assessment and for predicting environmental degradation, structural health monitoring via embedded optical fibers and the mechanics of stiffness-tailored bonded systems. The SI includes contributions from experts such as Prof A. Akisanya, University of Aberdeen, UK.; Prof F. Taheri, University of Dalhousie, Canada; Prof I. Ashcroft, University of Nottingham, UK; Prof S. K. Panigrahi, Defense Institute of Advanced Technology, India; Prof M.F.S.F. de Moura, University of Porto, Portugal; Profs. K.V.L. Subramaniam and M. Ramji, Indian Institute of Technology, Hyderabad, India; Prof L. Tong, University of Sydney, Australia; Prof. Tsouvalis, National Technical University of Athens, Greece and Prof H. Ozer, Yildiz Technical University, Turkey.

The paper by Akisanya examined the failure initiation from the interface corners of adhesively bonded brass-epoxy-brass butt joints subjected to combined remote tension, remote shear and uniform change in temperature based on generalized stress intensity factor approach. The failure loads were experimentally measured and the corresponding stress intensity factor was determined. It was shown that the failure envelope in tensile stress-shear stress space is elliptical and the failure loads decrease with increasing cure temperature due to thermal residual stress associated with the curing process.

Mohamed and Taheri investigated the potential of graphene nanoplatelets (GNPs) for enhancing the mode-I fracture toughness of room-cured epoxy, used for bonding E-glass/epoxy composite adherends. Experiments were conducted to examine the performance and degradation of adhesively bonded joints subject to cyclic thermal loading by using standard double cantilever beam (DCB) specimens having different wt.% of GNPs. Scanning electron microscopy (SEM) technique was used to characterize the failure of the GNP reinforced epoxy nanocomposites.

A cohesive zone modeling technique was used for predicting the mechanical response of the adhesive.

The paper by Azam et al. examined the effects of various ply-layup orientations on the bending stiffness of a composite T-joint both using three dimensional finite element (FE) analysis and experiments. It was found that bending stiffness was primarily influenced by plies that came under tension during the application of the force. Symmetric layups with ply angles that minimize the tensile stiffening effects were found to reduce bending stiffness. It was found that the damage initiated from the stress concentration zone at the free-edges of the adhesive layer and propagated towards the middle of the T-joint. Their study indicates that the stiffness of a T-joint against intended bending may be adjusted by arranging the plies at appropriate angles.

Das et al. investigated the failure behavior of adhesively bonded tubular joints with FRP adherends simultaneously subjected to internal pressure and torsional loading. Tsai-Wu coupled stress criterion was used to predict the onset of failure in the adhesive layer.

The paper by de Moura and Moreira examined the fatigue and fracture behavior of single-strap repair of carbon-epoxy composites using cohesive zone model (CZM). A mixed mode CZM model was presented for the analysis of fatigue crack growth. Static and fatigue tests for bonded composites joints were conducted for DCB, end-notched flexure (ENF) and single-leg bending (SLB). The experimental results were combined with the CZM to predict the fatigue life of single-strap repair of fiber reinforced composites. The analysis and results discussed in the paper are of industrial significance especially in life extension and structural integrity enhancement of composite structures.

Sheshadri et al. conducted strain and damage analysis of a single-sided stepped-lap repaired carbon fiber reinforced polymer panel subjected to tensile loading both using experimental testing, including digital image correlation (DIC) and FE analysis. Their study concluded that the damage initiates at step corners leading to debonding of the adhesive layer.

Interestingly, Subramaniam et al. investigated the shear debonding mode of failure in concrete beams strengthened using externally attached FRP sheets. The variations in the local fracture parameters were quantified and were adequately represented using the normal probability distribution. FE analysis of the direct-shear debonding of FRP attached to concrete substrate was also performed and was observed that the variation in the local fracture properties do not influence the load carrying capacity or the intensity of snapback instability at ultimate failure.

The paper by Islam and Long investigated the influence of hygrothermal conditioning of the single-lap joint specimens on the adhesion in terms of energy release rate of the mild steel and glass fibre prepreg co-cured interface. Hygrothermal conditioning at 55 °C for 1000 h was carried out on the SLJ specimens to study the environmental effect on energy release rate of the joints. Conditioning of the specimens were found to reduce approximately 66% of energy release rate than the controlled specimens with less cohesive failure and higher amount of rust formation at the interface along with delamination of adhesive from glass fibre prepreg. The experimental energy release rate values obtained were found to correlate well with results from an analytical adhesive interface model.

Karatzas et al. interpreted initiation and evolution of damage in the composite patch repair of a notched steel plate under tension by strategically positioning optical fibers and strain gages on the repair. Experimental results were compared with FE results. Their study concluded that a limited number of optical fibers embedded in suitable positions can provide sufficient information for detecting the damage initiation. In addition, it was reported that the application of the composite patch significantly improved the performance of defected steel structure increasing the load bearing capacity by 65.6% compared to unrepaired cases.

Oz and Ozer experimentally investigated the effect of bond-length ratios and possible gains in joint strength using bi-adhesive bondline with ductile adhesive at the ends. Their study considered bi-adhesive joints with two different adhesive combinations and found that the strengths of bi-adhesive joints were higher than those of mono-modulus joints, even if ductile adhesive has a joint strength higher than that of the stiff adhesive. They identified an optimum bond-length ratio for the bi-adhesive joint experimentally and concluded that the adhesive types and the bond-length ratio play an important role in the bi-adhesive bondline. However, the mechanisms and the mechanics of stiffness-tailored joints that lead to improved performance of bi-adhesive joints need to be clearly understood.

The ever growing ability to produce complex multi-material interfaces even at micro- and nano-length scales mimicking the nature provides the opportunity to develop high performance bonded systems with strength and toughness properties, which are often mutually exclusive. Assembling this Special Issue has been an exciting and scintillating experience for the guest editors. The review process provided an opportunity to strengthen our insights into various modeling, fabrication and experimental aspects of bonded systems and to discuss the manuscripts directly with the authors in detail. We would like to express our sincere appreciation to the authors for their patience with the process and the reviewers for providing critical feedback on these manuscripts. We are grateful to the Editor-in-Chief, J. M. Martín-Martínez for inviting us to edit this SI. We hope that this SI may supplement the horizons of JAST and serve as a catalyst to foster further interaction and collaboration for research on the topic, not only for the mechanics of adhesively bonded systems, but also for the mechanics of multilayered systems in general. We hope you enjoy reading this SI of JAST.

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