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Thermo-mechanical correlations to erosion performance of short carbon fibre reinforced vinyl ester resin composites

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ABSTRACT

Thermo-mechanical properties and erosion performance of short carbon fibre reinforced vinyl ester resin based isotropic polymer composites with four different fibre weight fractions have been investigated. The storage, loss and damping characteristics were analysed to assess the energy absorption/viscous recoverable energy dissipation and reinforcement efficiency of the composites as a function of fibre content in the temperature range of 0–140 °C. The composite with 30 wt.% of short carbon fibres has been observed to exhibit superior thermo-mechanical response with highest energy dissipation/damping ability accompanied with a constant storage modulus without any substantial decay till 60 °C. The erosion rates (Er) of these composites are evaluated at different impingement angles (30–90°), fibre loadings (20–50 wt.%), impact velocities (43–76 m/s), stand-off distances (55–85 mm) and erodent sizes (250–600 μm) following the erosion test schedule in an air jet type test rig. An optimal parameter combination is determined and subsequently validated for erosion rate minimization following Taguchi method and by conducting confirmation experiments. A correlation between the loss-modulus inverse and the erosion rate has been observed which conceptually establishes a possible mechanistic equivalence between erosion and dynamic mechanical loading modes. The morphologies of eroded surface are examined by the scanning electron microscopy to investigate the nature of wear-craters, material damage mode and other qualitative attributes responsible for promoting erosion.

1. Introduction

Short-fibre-reinforced polymers (S-FRP) are a unique class of composite materials since they not only provide superior mechanical properties, but they can also be easily processed via premixing of the short fibre and the liquid resin prior to being injection or compression molded giving rise to isotropic composites with spatially distributed short fibres in many complicated shapes for a varied class of structural, industrial, automotive and marine component applications unlike their continuous fibre analogues. Additionally, such composites with spatially distributed short fibres as reinforcing elements in the polymer matrix potentially offers a balanced set of properties, in the form of improved through-the-thickness stiffness/strength ratio combined with enhanced fracture resistance [1]. For example, glass fibre, carbon fibre and aramid fibre (unidirectional continuous fibres or woven fabrics) reinforced thermosetting composites (reaction injection molded/compression molded) based on epoxy, polyesters, vinyl esters and phenolic matrices have been reported to be successful in enhancing not only the mechanical properties such as elastic modulus, fracture and fatigue toughness but also the tribological properties in many cases. However, the potential of short fibre reinforced polymer composites has not been explored despite their wide success in thermoplastic matrix based composites, such as in automobile, aerospace, marine and energy applications [2]. Due to the seriously complicated and challenging operational requirements the application of many such composites remain largely restricted to light-duty components with exposure to low-stress situations. Typically the performance requirements of composites in harsh/extreme and dusty/slurry environments are very complex. In this regard solid particle erosion resistant polymeric composites may be of high relevance from several industrial and marine applications point of view. Literature widely reports on solid particle erosion behaviour of both thermoplastic and thermosetting resin based composites barring the rarely reported class of short fibre reinforced vinyl ester resin composites, despite the fact that vinyl ester resin is a promising binder with many inherently functional properties associated with it [3]. Erosion performance has been performed under various experimental conditions (erosive particle speed, erodent size, impact velocity, etc.) on various compositions of composite where it has been reported that erosive wear of

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