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Quasi-static uni-axial compression behaviour of hollow glass microspheres/epoxy based syntactic foams

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Hollow glass microspheres/epoxy foams of different densities were prepared by stir casting process in order to investigate their mechanical properties. The effect of hollow spheres content and wall thickness of the microspheres on the mechanical response of these foams is studied extensively through a series of quasi-static uni-axial compression tests performed at a constant strain rate of 0.001 s^{-1}. It is found that strength of these foams decreases linearly from 105 MPa (for the pure resin) to 25 MPa (for foam reinforced with 60 vol.% hollow microspheres) with increase in hollow spheres content. However, foams prepared using hollow spheres with a higher density possess higher strength than those prepared with a lower one. The energy absorption capacity increases till a critical volume fraction (40 vol.% of the hollow microspheres content) and then decreases. Failure and fracture of these materials occur through shear yielding of the matrix followed by axial splitting beyond a critical volume fraction.

1. Introduction

Syntactic foams are particulate composites consisting of hollow microspheres based on inorganic and polymeric materials dispersed in a resinous matrix which could be thermosetting or thermoplastic [1,2]. They are considered excellent candidate materials for light-weight structural applications since they exhibit isotropic physical properties, high specific compressive strength and stiffness, low moisture absorption, and reasonably high thermal stability [3]. They are also used as energy absorbing devices and as cores in sandwich panels. Syntactic foams based on hollow glass microspheres dispersed in a polymeric matrix are of immense technological interest and hence are being extensively investigated in recent times [4,5].

The ability to achieve desired properties by choosing an appropriate matrix and hollow spheres is one of the biggest advantages of this class of materials. The matrix material can be selected from almost any metal, polymer or ceramic and hollow spheres can be cenospheres, glass microspheres, carbon and polymer microspheres giving a wide range of possibilities to tune the properties. The most widely used and studied foam systems are glass microspheres/epoxy, glass microspheres/aluminium and cenospheres/aluminium [6]. The two main ways to tune the properties of these materials are, either by changing the volume fraction of the hollow spheres reinforced or, by using microspheres of different wall thicknesses.

Most studies on the mechanical properties of syntactic foams are based on maximum incorporation of hollow spheres since this helps in achieving high specific strengths [7,8]. Some of the earlier studies were focused on the strength as well as density dependence with volume fraction of hollow spheres and a linear model was proposed [9]. The effect of wall thickness of the hollow spheres on the strength values of these foams was also studied by using different types of microspheres keeping the average size constant [10,11]. In concomitant to achieving higher specific strength and stiffness, they exhibit immense potential as energy absorbing materials in light weight structures, in which sometimes along with glass microspheres even glass fibres or nano-clay is also incorporated. The system is then treated as a three-phase composite which helps in further strengthening of the material in addition to enhanced energy absorption capacity [12]. Studies on gradient structures based on creating a gradient in microsphere wall thicknesses but maintaining the same volume fraction has revealed 300% increase in the amount of energy absorbed per unit volume in contrast to plain syntactic foams [13]. The potential of these foams by sandwiching between fibre reinforced composites and incorporating surface-treated hollow microspheres were explored earlier by performing both quasi-static and dynamic loading tests including their fracture mechanical properties which resulted in improved performance [14–16].

However, previous studies have mainly focused on estimating the variation in strength of these foams as a function of volume fraction of the constituents and as a function of wall thickness of

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