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ORIGINAL RESEARCH

Crashworthiness characteristics of natural ramie/bio-epoxy composite tubes for energy absorption application

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Abstract

Using metallic materials in automotive structures increases weight, fuel consumption and cost, therefore, certain trends have begun to use lightweight and cheaper materials. Fibre composites are used in automotive applications because they are stiff, lightweight and stronger than bulk material, as well as they have a comparable energy-absorbing capacity to that of metallic materials. The aim of this study is to investigate the potentials in natural ramie/bio-epoxy composite in crash energy absorption applications. Cubic specimens consisted of 12, 24 and 30 plies of ramie/bio-epoxy laminates with 50, 80 and 120 mm long which were prepared by hand layup method. Static axial compression load was then applied and the energy-absorbing capability of the ramie/epoxy composite was evaluated. The crashworthiness characteristics of the composite tubes were evaluated by measuring the average and peak crushing load, specific energy absorption, total absorbed energy and crush force efficiency in quasi-static axial compression. The failure mode and behaviour of the tubes were investigated by taking photographs and recording the load–displacement curves during the test accomplishment. The test results indicated that natural ramie/bio-epoxy composite tube has the great potential to be used as an effective energy-absorbing device.

Keywords Natural fibre · Composite tubes · Energy absorption · Crashworthiness · Mechanical properties

Introduction

Environmental protection and passenger safety are drawing increasing attention in recent years by improving the crashworthy performance and reducing the emission of vehicles. The lightweight characteristics of transport vehicles have become an important factor in material selection to address these concerns [1]. Thin-walled structures made of composite materials and conventional metals have demonstrated the effectiveness of crashworthiness, especially for energy-absorbing components [2, 3]. Crashworthiness studies have attracted much attention, particularly to evaluate the deformation behaviour and to determine the energy-absorbing efficiency of various thin-walled components of different composites. In automotive engineering, crashworthiness is defined as the capability of a vehicle to protect its occupants during crash and prevent serious damage in case of accidents of a given proportion [1, 4]. Crashworthiness is concerned with the energy absorption through controlled failure modes that enable the maintenance of a gradual decay in the load profile during energy absorption. To reduce the overall weight and improve the fuel economy of vehicles, an increasing number of component parts made of fibre-reinforced plastic (FRP) composites have replaced the conventional metal components [5].

Nowadays, much attention has been paid to the fibre-reinforced composites and the thin-walled composite structures have become ever more attractive as energy absorption components. Implementation of composite materials in crashworthy structures is attributed to Hull, who conducted extensive studies on the crushing performance of fibre-reinforced composite materials in the 80s and 90s. According to Hull, composite materials are able to absorb high energy by the mechanism of fracture surface energy rather than metal plastic deformation [6]. Moreover, axially crushed square tubes with thin walls have been extensively employed as energy-absorbing members due to their long stroke and high specific energy absorption (SEA) capacity [7]. The axially crushing

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