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Flying ballast resistance for composite materials in railway vehicle carbody shells

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Abstract

This paper describes a simplified practical approach to the impact damage assessment of flying ballast or debris in composite materials, which could potentially be used for passenger rail vehicles. With the development of high-speed lines in order to guarantee the safety of primarily the driver and passengers, the vehicle body shell must be strong enough to resist the penetration of these types of objects into the vehicle. Currently the EN12663 standard has insufficient information on missile impact requirements for car bodies. Using the requirements of British Railway Group Standard GM/RT2100, GFRP composite material was analyzed in both static and dynamic events. Impact events at high velocities (V>50 m/s) lead to difficulties in testing due to the requirements for specific and expensive equipment and safety issues in the test application process. The simpler assessment and testing method described in this paper aims to provide a more cost effective, less time consuming, easily applicable method, with accurate results compared to existing methods. Previous research found that high-velocity impact behavior of composite materials can be mimicked by quasi-static punch tests (QSP). In this study, QSP tests were performed with E-glass/polyester composite laminates and FE simulations were carried out to match the experiments. The resulting numerical material and modelling data was used to simulate high velocity impact cases to assess the response of the material and to determine the connection between static and dynamic cases.

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Keywords: composite materials; high-speed impact; railway vehicle

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1. Introduction

The interest in using composite materials for structural applications in many different industries has increased significantly in the past decades. Being lightweight (i.e. high strength/stiffness-to-weight ratio) as well as having other various advantageous properties such as heat/fire/corrosion resistance, cost-effectiveness, freedom of manufacture in accordance with the critical load paths, numerous combinations of fibre-matrix, etc. are making composites greatly attractive to use in almost every field.

Nomenclature

CF	circular flat
FE	finite element
GFRP	glass fibre reinforced plastic
H	hemispherical
HVI	high velocity impact
QSP	quasi-static punch
SPR	span to punch diameter ratio

Although they are not entirely new materials for the railway sector, it can be said that the sector itself is rather underdeveloped in terms of composite materials use compared to the marine, automotive, and aviation industries, which have magnificent huge-scale examples of composite material use. In the railway industry, composites have been in use since the 1980s for seats, carriage doors, cab fronts, as well as overhead structures (Batchelor and Wilson, 1984). However, application in primary load bearing structures is rather new, with a few good examples such as the Korean Tilting Train – TTX (Kim et al., 2007), and the Kawasaki efWING bogie with carbon fibre reinforced plastic (CFRP) leaf springs (URL1). There is a tendency in the railway sector towards using more lightweight materials in order to achieve a more energy efficient transportation, through both practical examples (Robinson et al., 2012) and with projects focusing on the modification of regulations. An example is the REFRESCO project, funded by the European Commission (EC), with the aim to generate regulations for implementing lightweight materials into railway rolling stock (REFRESCO, 2013). The reasoning behind the necessity for modification to regulations is basically due to the differences in mechanical responses of composites compared to metallic (conventional) materials and the anisotropic nature of composites requires detailed and careful analysis in many aspects before putting them to long term use. These aspects should include both material based analysis and application specific analysis since this pool of knowledge would encourage manufacturing and operational bodies to take appropriate action when using alternative lightweight materials. In addition, the specific changes that come with the technological improvements in the sector itself might also require the re-check of current regulations even if it is for the same materials. For example, and particularly in the last two decades, in order to achieve a more efficient transportation by decreasing traveling times, the operating speed of passenger vehicles has increased greatly. This in turn affects the interacting sub-systems such as infrastructure, braking systems, and safety systems. Safety is always the most important aspect of any transportation system including railways. One of the safety requirements for a rail vehicle relates to missile protection, which indicates that the carbody shell should not allow a flying object to penetrate and enter the vehicle. Flying objects can be any solid object or debris around the track that might become airborne – for example caused by snowfall under a train, aerodynamic forces generated by passing trains, or by deliberate actions of individuals towards moving vehicles. This requirement is mentioned in GM/RT-2100 British Railway Group Standard, but there is no clear information on this specific requirement in European Code EN12663 and both of these standards relate to metallic based materials. The present study will analyze the impact damage phenomena for composites, which have the potential to be used in car body shells, in parallel with the relevant standards requirement.

Mechanical behavior and damage mechanisms of composite materials can be very complex due to their direction dependency, the interactions between fibre-matrix phases and the behavior of the interface in between. Particular interest was given to impact responses by many researchers for years, with focus on different aspects such as the effects of impact speed, i.e. low-intermediate-high velocity ((Naik and Doshi, 2008), (Vaidya, 2011)), impacting geometry (Gellert et al., 2000), fibre/matrix type and different structure configurations, i.e. laminated or sandwich