Numerical Methods for the Study of the Impact Behaviour of Composite Laminates Reinforced with Basalt Fibre

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Summary: *Low velocity impact tests were carried out on composites reinforced by basalt fibres, up to complete penetration. Indentation tests at different energy levels were add at the experimental campaign, at the aim to investigate about the damage initiation and propagation. A simplified numerical procedure in LS-Dyna was studied to simulate the impact behaviour of the basalt laminates. By comparing the results, a good agreement was found.*

1 INTRODUCTION

For today's composite structures in fibre reinforced plastics, the mechanical behaviour after an impact is often the limiting performance criterion. There is a long standing evidence [1] that composite materials suffer damage during low energy impact events and this cause a reduction in the in-plane loads strength, above all in compression. The problem is that the impact damage is difficult to detect during in-service inspections [2], in particular way for carbon fibre laminates that are dark in their aspect. This results in the need for design limit factors to be applied in structural design where the difficulty related to impact damage exists. These factors are also classified in terms of damage severity and are introduced to take into account the potential strength reducing impact damage which could be present without the knowledge of the user. The barely visible impact damage (BVID) is one of the most important damage visibility criteria, adopted in particular in aeronautical field. This is defined as the largest damage which may remain undetected in the structure. So, performance in the presence of BVID defines the ultimate strain for the design. The compression strength of FRPs should be halved in the presence of BVID [3]. Of course, this increases costs a lot. For this reason, the problem of understanding the impact behaviour in composite materials has received a huge amount of research effort for long time.

In the present research, basalt fibre were immersed into a SX10 epoxy matrix to fabricate laminates different in thickness. These fibres, not largely investigated under impact conditions, present very good mechanical properties, without degradations at the high temperatures of about 500°C, together with lower costs than carbon fibre. In a recent paper [4], the authors showed the opportunity to replace glass fibres in applications where glass composites are already largely applied. Basalt fibres reinforced plastic laminates, in fact, showed a higher Young's modulus as well as a better compressive strength and flexural behaviour. A quite good interfacial adhesion between fibres and polymeric matrix was confirmed too.

Square laminates 300 mm in side, were obtained through infusion technology following the stacking sequence: $[(0,90)/(+45,-45)/(+45,-45)/(0,90)]_n$, with n=2 to 4,

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leading to nominal thicknesses of 1, 2 and 3 mm. The fibre volume fraction was V_f = 50%. From the plates, specimens 70x70 mm were cut by a diamond saw and destined to low velocity impact tests. At a first light, basalt fibre seems to limit the extension of the delamination which was found more concentrated under the impactor-material contact zone.

Indentation tests were carried out at four different characteristic energy levels, selected on the complete load curve recorded during impact tests at complete penetration, at the aim to investigate about the damage start and propagation. After impact, the indentation was evaluated according to EN 6038 standard whereas a deeply technique [5] was adopted to investigate about internal damage.

The response of composite materials under low velocity impact loads depends on a large number of factors such as thickness, stacking sequence, fibre and matrix type. Moreover, it is very difficult to understand the complex mechanisms of damage interaction, really important in understanding damage mode initiation and propagation [6]. A lot of studies are about analytical and/or empirical models for the impact behaviour prediction in terms of both damage and residual mechanical properties [7, 8]. However, most of them are strongly related to boundary conditions that is not possible to take into account in an analytical model. A possible solution is represented by generic FEM models modified for the particular situation under investigation [9, 10].

At this aim, a simplified numerical procedure in LS-Dyna able to predict maximum force, impact energy, strain velocity, delamination extension and its location along the thickness, was studied. The results of the simulations were validated by the experimental investigations and the agreement found was quite good.

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