The Role of Indentation on Impact Damage in CFRPs

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Abstract. This study presents an investigation into the indentation formed during low-velocity impact. Inter- and intralaminar damage can also be formed during impact and these forms of damage can be measured through ultrasonic C-scanning and optical microscopy. By investigating the relationship between indentation depth and delamination damage, the potential of a quicker way to estimate damage within aerostructures may be found.

Introduction

To improve fuel efficiency, the aerospace industry is increasingly using composite materials to reduce weight. However, there are many potential impact scenarios aerostructures may be subject to, such as tool drop, hailstones or runway debris. Fibre-reinforced polymer composites (FRPs) are particularly susceptible to this type of low-velocity impact damage. The resulting damage is often difficult to see from the outside of the material, hence it is referred to as barely visible impact damage (BVID). To view the internal damage, specialized equipment and methods are usually necessary. Although this damage may not cause immediate failure of the structure, the residual strength can be significantly reduced [1]. If the working load exceeds this residual strength, catastrophic failure could occur. Therefore, an accurate estimate for any damage which has occurred within the structure is needed so that reliable safety decisions can be made, such as repair or replacement in serious cases.

Materials and Methods

The samples used in this study had two thicknesses – 2.3 and 4.6 mm. Both samples were formed from unidirectional CF/Epoxy prepreg laid up as a quasi-isotropic laminate with lay-up $[45/-45/0/90]_s$ and $[45_2/-45_2/0_2/90_2]_s$, respectively. The panels were cut to a size of 100 mm x 150 mm, in accordance with ASTM D7136 [2], with the 0° fibre direction parallel to the longer edge.

Low-velocity drop-weight testing was undertaken in accordance with ASTM standard D7136 [2] using an Instron CEAST 9340 drop-weight tower connected to a PC equipped with a CEAST DAS 64K data acquisition system, through which the tower was controlled and the data collected. A hemispherical stainless-steel impactor of diameter 16 mm was used for impacts in this study. Force-time data was acquired by a load cell in the forward section of the impactor. The resulting data allows analysis and comparison of sample behaviour and enables potential load drops, corresponding to damage initiation, to be identified.

Damage within the composite samples was examined using a portable 'Prisma 16:64 TOFD' ultrasonic C-scan device with a 5 MHz probe. A 16 /mm encoder allowed measurement of the position of the probe along the scan axis. Scanning was undertaken both before and after the impact tests to ensure any previous damage accumulated during manufacturing, transport and storage was identified separately from damage induced by the impact test. The resulting C-scan maps highlight the delamination damage area present at different depths through the sample thickness and allow a comparison to be made between samples.

Indentation measurements were taken following each impact using a handheld digital depth gauge. A Confocal microscope was also used to give a 3D surface scan of each sample, from which an accurate value of the surface indentation could be identified. The results from the Confocal microscope justified that the handheld depth gauge gives accurate indentation depth readings in a quick, easy and cheap process.

Optical microscopy of cross sections of the impacted samples allowed a detailed view of the intralaminar and interlaminar damage to be achieved. Samples were first sectioned using a diamond saw, ensuring a slow cutting rate was used to avoid cutting-induced damage, before being ground and polished on a grinding wheel with silicon carbide grinding paper and then diamond suspension fluid on a polishing cloth.

Results

The ultrasonic C-scans shown in Fig. 1 show the expected trend that an increase in impact damage causes a greater delamination damage area. Also, for a given impact energy, thicker panels exhibit a larger damage area than thinner panels.

Cross-sections produced from the Confocal microscope data (Fig. 2) and data from the handheld depth gauge show that indentation depth increases after every impact. Also, larger indent depths are seen after impact at a higher impact energy. In fact, the indentation depth was found to a follow an approximately linear

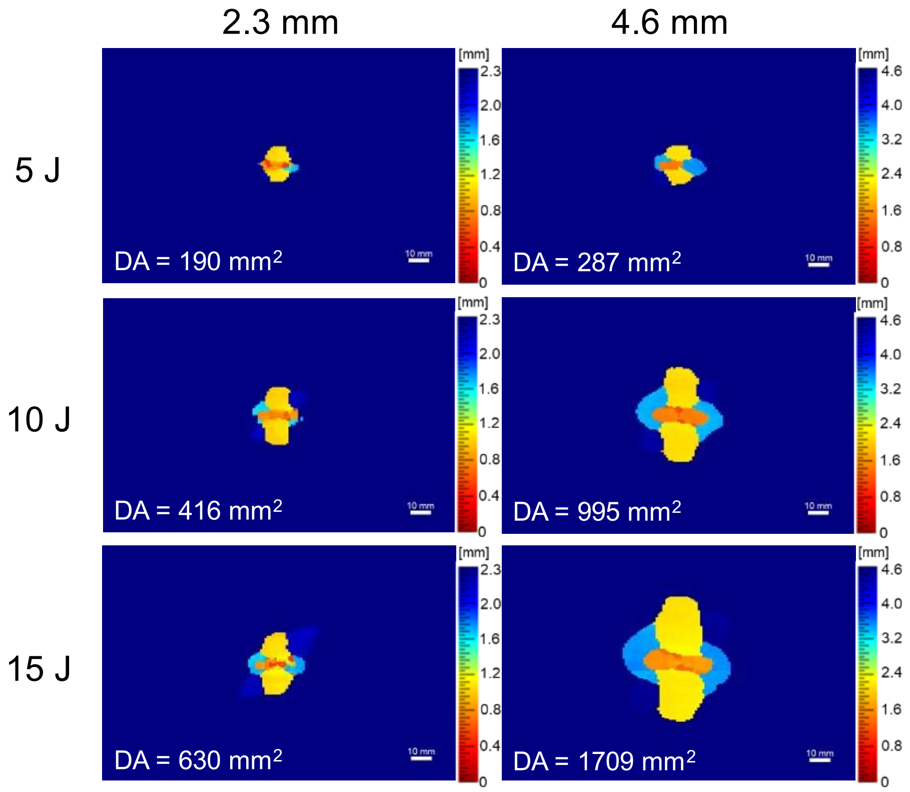

Figure 1: C-scans showing delamination damage area produced in 2.3 and 4.6 mm samples after a single impact at 5, 10 and 15 J (DA = Damage Area).

trend with damage area. For a similar level of impact damage, the thinner panel showed a greater indentation depth. This may be due to the greater level of support which the thicker panel gives to the surface layers, compared to the thinner panel. Therefore, it appears that measuring indentation depth is an accurate method for estimating damage area, but knowledge of the type and thickness of material is essential.

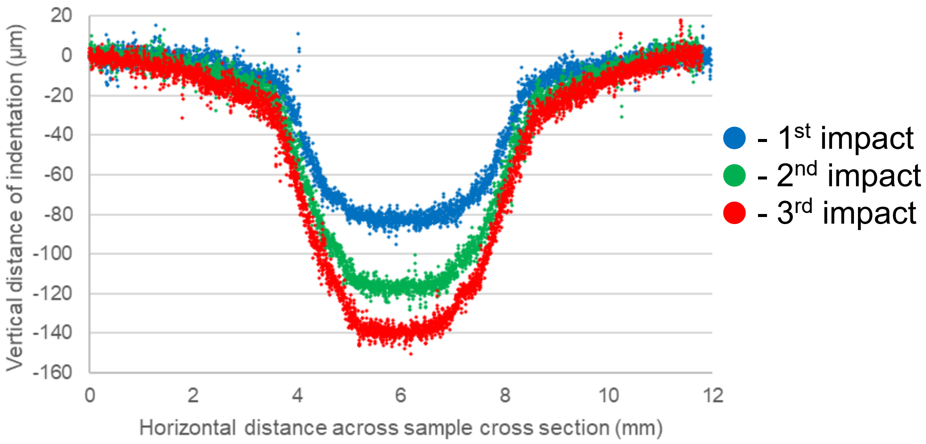

Figure 2: Cross-section showing sample indentation after 1st, 2nd and 3rd impact at 5 J.

Conclusion

This study has investigated the relationship between surface indentation and internal damage in CF/Epoxy composites. The results indicate that indentation depth can be used to give an estimate of the delamination damage within the material, provided that the type and thickness of material is known. Therefore, this method has the potential to provide a quick and simple way to estimate damage after an impact, without the use of expensive equipment which requires specially training personnel.

References

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