THE EFFECT OF MULTIPLE LOW-VELOCITY IMPACT ON FIBRE METAL LAMINATES

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Abstract

Due to excellent properties, FMLs have been applied in primary structures of several aircrafts. One of the most important advantage is high impact resistance of FMLs. The goal of the research was to carry out the analysis of the impact resistance of selected FMLs and investigation of influence of multiple impact on their failure after this kind of loads. The drop-weight tower and ASTM standards were used. FMLs has good impact resistance to multiple impact. Damage of fibre metal laminates is growing quite stably after each impact. Damage in fibre metal laminates after multiple impact is characterized by deformation and delaminations in composite and at the metal-composite interface.

1. Introduction

Fibre Metal Laminates are new kind of hybrid materials composed of thin metal and fibre reinforced polymer layers. There are used in the aerospace due to they high mechanical properties. The most commonly used and well known are GLARE (Glass Reinforced Epoxy Aluminum) and ARALL (Aramid Reinforced Aluminum Layers) types of laminates, on which there are numerous publications describing their favorable mechanical properties and performance [1,2,3], including high resistance to impact damage [4]. Laminates which combine aluminum with carbon composite are not yet widely used in industry. Still are being developed researching on these materials. They are characterized by higher strength properties compared to other types of FMLs, which makes them even more attractive in aerospace application [5,6]. Low-velocity Impact resistance is a one of the important issue for composite structures, particularly in aerospace. The authors [7] quoted that 13% repairs of primary structure in 71 Boeing 747 aircraft caused by impact damage.

Rajkumar et al. [6] investigated low velocity repeated impacts on property degradation of glass based FML and damage responses of glass and carbon based FMLs. Results show that glass based FMLs offer better energy absorption than carbon based FMLs, because carbon fibers allow the propagation of cracks within the structure and the size of the impact damage zone increases with increase in number of impacts irrespective of specimen systems.

The purpose of this study was to investigate the influence of multiple impact on some kind of FMLs.

2. Materials and experiment

Aluminum alloy 2024-T3 with 0,5 mm thickness was used. Composite were high-strength carbon fibers AS7J with epoxy resin matrix and R-2 glass fibers with epoxy resin (Hexcel, USA). The nominal fiber content was about 60vol.%. FMLs were manufactured with 2/1 system and 0/90 lay-up scheme of composite. For comparison Classic CFRP and GFRP with 0/90 lay-up scheme (1.5 mm thick) were impacted.

Specimen with dimensions of 150 x 100 mm were impacted with low velocity (3.7 m/s) in room temperature by using a drop-weight impact tester (INSTRON 9340). As a impactor used a hemispherical tip with a diameter of 12.7 mm (0.5”). Impact Energy was 5J. Each sample were impacted five times. Impact were conducted based on ASTM D7136 standard.

3. Results and discussion

On the figure 1 typical force-time curves of different types of FMLs are presented.

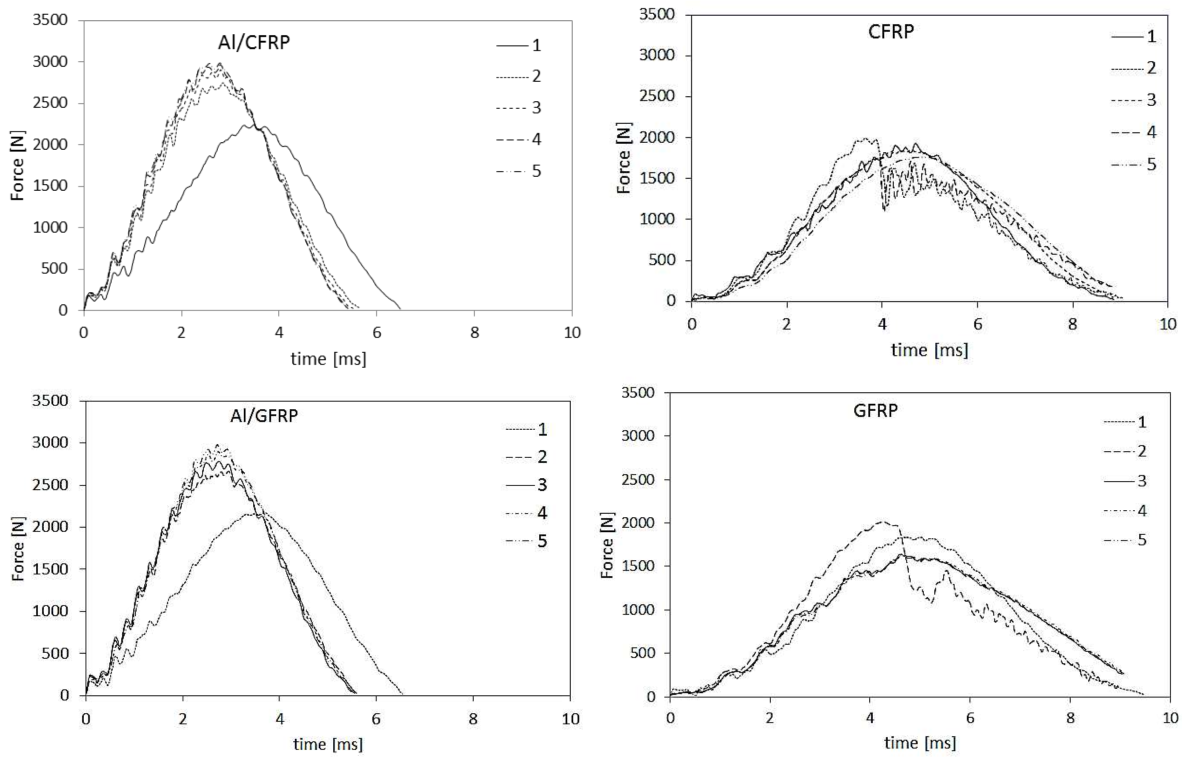

Fig. 1. Force-time curves after multiple impact of FMLs and composites.

Force-time curves are rather smooth and quite similar to each other in case of Fibre Metal Laminates. But on each one some fluctuations can be noted. It means that degradations is progressing after each hit. However this progress is developed stabile. In case of FML only first impact is different. They characterized by lower force level and longer time of sample-tip interaction. This is caused by first elastic-plastic degradation. In case of classic composites the second and third impacts has the highest importance in material degradation. In general FMLs have higher impact resistance then classic FRP composites. FMLs has good impact resistance to multiple impact. In figure 2 C-scan views after multiple impact of Al/GFRP laminates are presented.

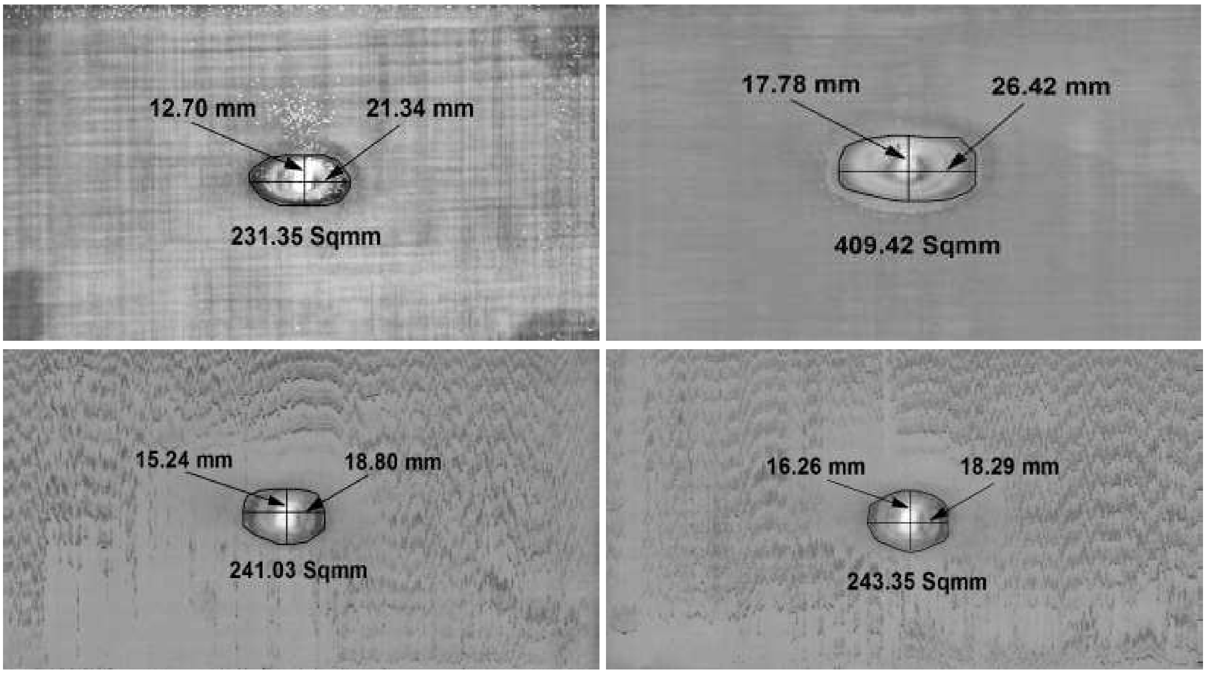

Fig. 2. C-scan view of Al/GFRP(top) and Al/CFRP (bottom) laminates after three (left) and five (right) times of impact.

According to Morinière F.D. et al. [8] damage progress in FML are e.g. plasticity and cracking of matrix with delamination and yielding of aluminum, disbonding at the interface between composite and aluminium, fracture of composite layers followed by aluminum cracking, penetration of the laminate and petaling of aluminum. the interaction of the aforementioned failure modes may be complex but the global flexural deformation of the laminate absorbs most of the impact energy in FMLs. According to Chakraborty [9] in case of multiple impacts, magnitude of contact force at various impact points depend upon the time interval between successive impacts in addition to mass and velocity of the imapactors. Depending upon the relative velocities of the plate and the impactor at the time of contact magnitude of contact force will be different. Rajkumar et al. [6] noted that after the first impact, there was some rebound due to the elastic recovery of FML. In the second impact, owing to a higher contact area between tup and FML impact, the curve becomes flatter and the specimen is partially damaged. In the third impact, area of contact is predominantly higher than the first two impacts, and hence, the peak is sharper and the time drastically reduces. Similar observations can be noted from figure 1. The fluctuations on f-t curves means that in structure local damage is growing. This damage is probably in the composite inside (matrix cracks and delaminations) and in the interface between metal and composite. The damage of Al/CFRP is growing slowly because of lower elastic-plastic range of carbon fibres and higher stiffness. However the same part of energy is absorbed on more significant damage, but with less area in comparison to Al/GFRP laminates. Similar conclusions were noted in few other studies [5,10,11,12]

4. Conclusions

1. Although study of single-hit low-velocity impact response of FML has been known quite well, only few studys is focused on the effects of repeated impacts on failure mode and damage growth of fibre metal laminates.

2. Fibre Metal Laminates have different behavior on repeated impact in comparison to classic polymer composites. In the case of FPR composites second and third impact in the same place causes high degradations (which can be seen as force fluctuations).
3. Multiple impact of Fibre Metal Laminates causes some degradations of them, but the damage growth is stable and not so extensive. The force fluctuations are not significant.
4. Al/CFRP laminates have higher stiffness then Al/GFRP laminates. It is one of the reasons why the damage after multiple impact has lower area. Impact energy is mostly absorb on degradation in the impactor area, e.g. matrix cracking. In case of Al/GFRP the impact energy is absorb mostly on delaminations.

Acknowledgments

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