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TIRÉ À PART

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Un dispositif expérimental novateur pour l'impact de glace sur panneau composite.

par

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Résumé traduit :

L’objet de ces travaux vise à développer un protocole expérimental fondé, d’une part, sur l’utilisation de la méthode de corrélation d’image numérique (en stéréo-vision) pour analyser le point d’impact et obtenir, sur l’ensemble du panneau, une mesure des champs cinématiques (déformations et déplacements), et d’autre part, sur l’utilisation d’un nouveau dispositif pour les conditions aux limites permettant une certaine accommodation du panneau au lieu du cadre fixe et rigide usuel. Des essais d’impact sont réalisés sur des panneaux raidis en carbone renforcé de polymères à l’aide d’un canon à gaz et d’impacteur en glace extrait d’un bloc homogène. Ces projectiles de glace ont été par ailleurs produits en collaboration avec un laboratoire spécialisé dans l’élaboration de ce type de matériau spécifique.

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AN INNOVATIVE EXPERIMENTAL DEVICE FOR ICE IMPACT ONTO COMPOSITE PANEL

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1. INTRODUCTION

Dynamic impact problems have always been of interest for the commercial aviation. During the last decade, they have become of greater importance due to the more significant use of composite materials, such as carbon fiber reinforced epoxy, in primary structural components, that can be exposed to severe impact loads, such ice or hail. The numerical modelling is very challenging due to the complexity of both the ice [1] and the composite materials behaviour at high strain rate [2]. Numerical and experimental comparison concerns usually local displacements or local strains by gauges in few positions of the structural component and global force [3], while numerical model can provide full field local data such strain, stress states or damage initiation, etc. For validation purpose, it is necessary to know the exact position of the measurements in a reference frame centred at the impact point. The expected and experimented impact points can be however different and for ice impacts the position of the impact point can not be analysed post-mortem. Validation tests with elaborated boundary conditions can better experiment panels closer to the real loads, instead of the usual rigid fixing.

The work presented here aims at developing an experimental protocol based firstly on the Digital Image Correlation (DIC) method (with stereo-vision) to analyse the exact impact point and deliver full field measurements (strains and displacement) over the specimen area; and secondly on improved boundary conditions that makes it possible a structural accommodation during the impact instead of the usual rigid embedding. Impact experiments are performed on composite stiffened panels in Carbon Fiber Reinforced Polymers (CFRPs) using a gas gun and hail projectiles taken from homogenous ice blocks. One should note that ice specimens were produced in collaboration with a laboratory specialised in the elaboration of such specific materials.

2. DEVELOPMENT OF THE INNOVATIVE EXPERIMENTAL PROTOCOL

Figure 1 presents the gas gun and the test facility used at Onera to perform the high velocity impacts. The structural component to be tested consists in a composite curved panel with stiffeners. The innovative boundary conditions developed for impact tests are most representative of the full barrel (Figure 2). Rigs are mounted on the specimen to ensure a fully clamping condition and the gaps around the specimen flanges are filled with fusible alloy. The assembly parts are finally freely supported on two rigid cylinders. The ice material is made from a random mixture of snow grains and water, which, along its freezing, leads to an aggregate without specific crystalline orientation. Consequently, the ice can be considered as a macroscopically isotropic and homogenous material (Figure 3). The ice projectiles are cylinders with hemispherical head. The projectile is supported and guided in the gas gun thanks to a foam sabot specifically designed to ensure the ice material does not suffer of any damage during the acceleration phase up to the ejection from the gun. The distance between the gas gun exit and the target is 300mm. The impact point is expected in the middle of the panel.

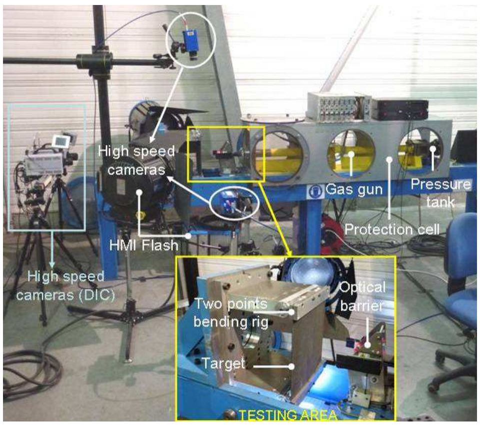


Figure 1. Test facility

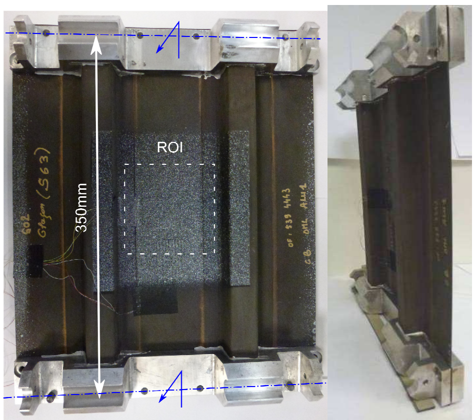


Figure 2. Specimen rigs

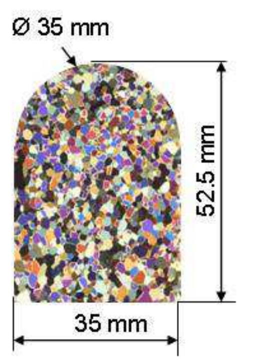
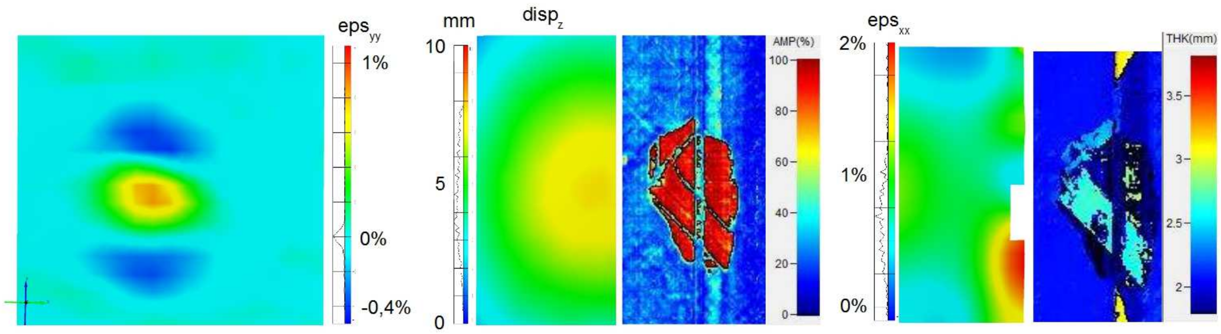


Figure 3. Ice material

Flats panels have been used first to set-up the DIC and to assess the perforation limit velocity of the composite skin. The velocity of the hail just before impact and the projectile kinematic during the impact are measured by two optical barriers and two high speed cameras. The experiments have shown that the flat panel is not perforated by the hail up to 180m/s.
Impact tests, with the previous PLV, were performed on the stiffened panels (Figure 2) with different manufacturing process. The displacement and the strain fields over the rear face of the target are measured during the impact using two others high speed cameras and the DIC method (stereo-vision). The frame rate is 36000fps and the resolution is 256^2 pixels. The Region Of Interest is covered with a random black/white spray pattern. All specimens are equipped with strain gauges bonded on the rear face in the ROI to compare the strains measured by both methods. Non Destructive Inspection has been done after each impact with B-scan and C-scan control in order to highlight their internal damages.
The impact point can be easily determined when using the DIC method. One should note that the maximum distance between the expected and the real impact points is about 3mm. It can be significant all the more the distance between two consecutive stiffeners is 75mm.
The strains obtained by the DIC and the gauges have been compared. A strong correlation between both kinds of measurements is demonstrated. The analysis of the strain and displacement fields shows a first indentation phase on the composite in contact with the projectile. Then a wave propagates from the impact point on the composite structure. This phenomenon appears clearly using the strain fields by the DIC method, while strain gauges do not. After the equilibrium, the panel is subjected to a bending dynamic load which is measured by the DIC method. Such results are illustrated in Figure 4. It is observed that the maximum deflection of the composite structure always appears during the bending phase. The debonding of the stiffeners is associated to a local strain gradient which is observed using the DIC method. Strain field results makes also possible the analysis the debonding propagation during the impact. Comparison was also made with B-scan and C-scan results after the test impact (T_f).



DIC (t=66µs) *DIC (t=100µs) / CSCAN (t=t_f)* *DIC (t=133µs) / CSCAN (t=t_f)*

Figure 4. Hail impact at 175m/s onto composite stiffened panel

3. CONCLUSION

An experimental protocol is developed to assess the strength of composite fuselage sub-structures (stiffened panels) to the hail impact. The Digital Image Correlation method was successfully applied to measure the local distribution of strain or displacement in high velocity impact conditions. The DIC results are efficient to analyse the different events appearing during the test: indentation, bending and debonding of the stiffeners. The experiment method and the results were useful to select the manufacturing process towards hail impacts.

Acknowledgments

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References

[1] D. Jeffery, D. Tippmann, K. Hyonny, D., Jennifer. P. Rhymer, Experimentally validated strain rate dependent material model for spherical ice impact simulation, International Journal of Impact Engineering, 57, pp. 43–54, 2013.
[2] G. J. Appleby-Thomas, P. J. Hazell, G. Dahini, On the response of two commercially-important CFRP structures to multiple ice impacts, Composite Structures, 93, pp.2619–2627, 2011.
[3] D. Delsart, J. Fabis, A.Vagnot Ice impacts modelling using Smooth Particle Hydrodynamic method, 4th European Conference for AeroSpace Sciences, Saint Petersbourg, Russie, 2011.

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