12th International Conference on Sandwich Structures (ICSS-12) Lausanne - Switzerland, 19–22 August 2018
DOI: 10.5075/epfl-ICSS12-2018-270-272

IMPROVEMENT OF THE IMPACT BEHAVIOUR OF FOAM CORE SANDWICH THROUGH THE USE OF A CORK LAYER AS IMPACT SHIELD

M. Adli Dimassi[1], Tim Dunker[2], Christian Brauner[3] and Sawsane Nakouzi[4]
[1]Faserinstitut Bremen e.V., Germany. dimassi@faserinstitut.de
[2]University of Bremen, Germany. tdunker@gmx.de
[3] University of Applied Sciences Northwestern Switzerland, Switzerland. christian.brauner@fhnw.ch
[4] University of Applied Sciences Northwestern Switzerland, Switzerland. sawsane.nakouzi@fhnw.ch

1. INTRODUCTION

Foam core sandwich structure made of two stiff and strong face sheets and separated, by a low-density closed cell foam core, exhibit higher specific stiffness and strength compared to monolithic composites [1]. Since standard sandwich structures with honeycomb or foam core are susceptible to low-velocity impact and foreign object damage (FOD), its use in aerospace is limited to non-carrying structures like the elevator and the high lift devices [2].

Impacts on foam core sandwich may create invisible damages consisting of skin delaminations, face sheet debonding, core crushing and core shear cracks. Most critical are shear cracks, as they degrade the residual compressive strength of an impact-damaged composite structure and could lead to the loss of the structure integrity [3].

Substituting traditional foam materials with a cork core has a high potential to be used in FOD endangered sections of an aircraft. Cork core sandwich structures show better impact damage tolerance, remarkable natural damping behaviour and higher energy absorption compared to Polymethacrylimid (PMI) foams [4]. Thanks to the cellular structure and the viscoelastic properties of the cork, cork core materials show superiority when used as thermal/sound insulating panels or for vibration damping purposes [5]. Moreover, due to its high temperature withstanding property the use of cork agglomerates is very well established in rocket boosters and re-entry space vehicles [6]. Nevertheless, because of lower specific properties of cork composite compared to foam core sandwich with PMI foams (for instance Rohacell®) the use of cork in aircraft structures is very limited.

In order to make benefits of the impact damage resistance of the cork and to fulfil the stiffness requirements of an aerospace structure, a new hybrid sandwich layout is proposed. In this work, sandwich specimens made up of two CFRP-facings and a core composed of foam material and a cork layer on the impact loaded side of the test specimens have been manufactured, the impact behaviour was investigated and compared to a reference sandwich configuration without cork layer.

2. EXPERIMENTAL TESTS AND MATERIALS

Materials and Manufacturing

The vacuum assisted resin infusion (VARI) process was used for the manufacturing of the sandwich specimens. The face skins consist of two layers Toho Tenax HTS40 carbon fibre Non-Crimp Fabrics (NCF) impregnated by EPICOTE™ RESIN MGS™ RIMR035c. All the tested specimens have a face sheet thickness of about 0.75 mm. The PET100 3D|Core™ foam core with integrated honeycomb structure was chosen as reference core. The Amorim CoreCork NL 20 with a thickness of 3 mm and a density of 200 kg/m³ was used to manufacture the hybrid sandwich. The cork layer was perforated at predefined intervals to ensure the bonding of the cork to the foam core during the resin infusion. Moreover, the honeycomb perforation of the 3D|Core™ enables a better bonding of the cork layer compared to standard foam core.

Fig. 1 shows the VARI-setup to manufacture the hybrid sandwich panel. Two resin inlets were used to ensure the impregnation of the face sheets and the bonding of the cork layer. For the manufacturing of the reference panels without cork layer, only one resin inlet on the top face of the sandwich panel was used as the honeycomb-like perforation in the 3D|Core™ enables the resin to flow from the top face to the bottom face of the sandwich.

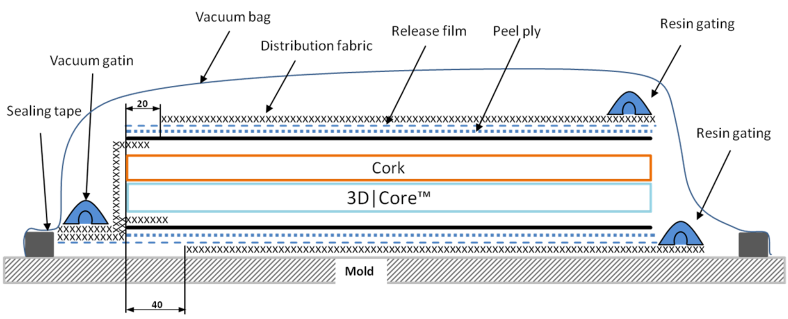

Fig. 1: Vacuum infusion set-up of the hybrid sandwich panel.

Test Setup and Specimen

Impact testing was performed using a stationary drop-impact testing machine custom-built at the Faserinstitut Bremen. The flat sandwich panels of size 330x220 mm were clamped at two edges with steel bars and impacted in the centre using a hemispherical impactor of diameter 25.4 mm. Three different configurations were investigated: "3D_7" with a 7 mm 3D|Core^{TM} core, "3D_10" with a 10mm 3D|Core^{TM} core and "cork" with a core consisting of 7 mm 3D|Core^{TM} and 3mm cork layer. Every test configuration was tested at 39 J and 53 J impact energies. After the impact, the damage was assessed using water coupled C-scan.

3. EXPERIMENTAL RESULTS

The aim of the impact tests is to investigate the effect of the cork layer on the impact behaviour of the foam core sandwich. The damage was inspected visually and using water coupled C-scan for the specimens with invisible core cracks. The detected damages are summarised in table 1. At 39 J-impact energy all the tested specimens have only local damages (small dent or/and face sheet rupture). The performed C-scans (Fig. 2) shows large damage areas in the foam core sandwich panels, which is typically a sign of shear cracks in the core, while the cork panel has no detectable damage. Moreover, a large rebound of the impactor was observed after the impact of the cork-panel.

Table 1: Summary of the detected impact damages.

Configuration	39 J-impact	53 J-impact
3D_7	Small dent; C-scan: core shear cracks	Small dent, visible core shear cracks
3D_10	Face sheet rupture; C-scan: core shear cracks	Small dent, visible core shear cracks
Cork	Small dent; C-scan: no core cracks	Face sheet rupture, C-scan: no core cracks

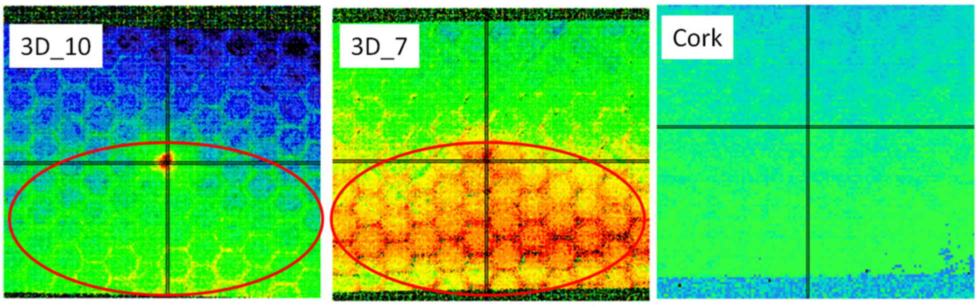

Fig. 2: Impact damages at 39J-impact.

At 53 J-impact visible shear cracks were detected in the panels 3D_7 and 3D_10 (Fig. 3) and a permanent global deformation could be observed. The impact energy was mainly dissipated by occurrence of damage mechanisms in the skins and the foam core. Considering the panel with the cork layer, only a small dent with minor face sheet damage could be observed and a rebound of the impactor took place. The C-scan in Fig. 3 shows a small damage surface in the centre of the panel and no sign of core cracks. The addition of the cork layer to the foam core led to the conversion of the impact energy mainly into elastic and rebound energy, which reduces the probability of catastrophic structure damages.

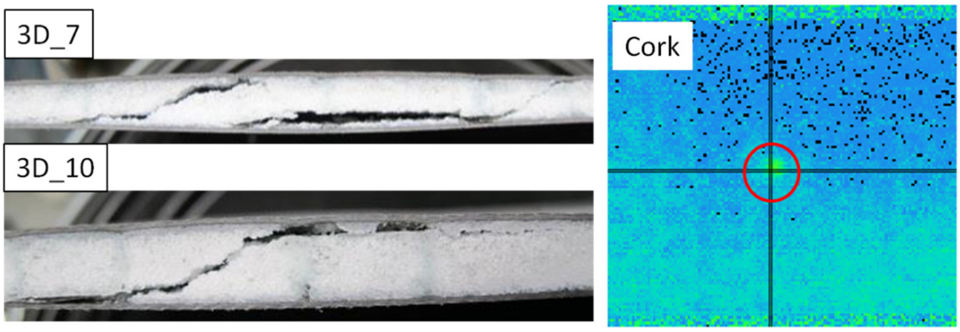

Fig. 3: Impact damages at 53J-impact.

These results shows that adding a cork layer to the foam core on the impact loaded side of the sandwich structure leads to a remarkable improvement of the impact behaviour. The core cracks were completely suppressed in the specimens with cork layer and only small dents with light face sheet damages were detected. While the impact energy is mainly dissipated through conversion in core cracks and face sheet damage for the foam core specimens, the hybrid specimens with cork layer dissipate the impact energy by impactor rebound, oscillation damping and elastic deformation, which reduce the amount of energy that has to be absorbed by the structure during the impact.

4. CONCLUSIONS

The aim of this work was to explore the feasibility of improving the impact behaviour of foam core sandwich by using a hybrid foam cork core layout. This design enables to benefit from the good energy absorption properties of the natural cork without significant increase of the structure weight or stiffness degradation compared to a sandwich with cork core. The performed impact tests showed that only a thin cork layer is sufficient to suppress the core cracks and to improve the impact resistance of the structure. The rebound effect during the impact and the high-energy absorption of the cork layer lead to significant energy dissipation, which reduces the amount of energy absorbed by the rest of the structure.

New impact tests with honeycomb cork core are necessary to verify whether the cork layer leads to the same effects observed with the foam material. Moreover, static tests are planned to investigate the effect of the cork layer on the sandwich stiffness.

The proposed design of the sandwich structure could be an efficient solution for aircraft structures susceptible to foreign object damage like the landing gear doors or the radome. However, further investigations are required regarding the manufacturing process and other mechanical properties of the sandwich structure like structure stiffness and debonding of the cork layer.

ACKNOWLEDGMENTS

The authors would like to thank the companies 3D|Core GmbH & Co. KG for delivering the 3D|Core foam panels and Amorim Cork Composites for delivering the cork material.

REFERENCES

[1] D. Zenkert, *The Handbook of Sandwich Constructions*, EMAS Publishing, 1997.
[2] A.S. Herrmann et al., "Sandwich structures technology in commercial aviation", *7th International Conference on Sandwich Structures*: 2005, 13-26.
[3] M.A. Dimassi et al., "Experimental study of the mechanical behaviour of pin-reinforced foam core sandwich materials under shear load", *18th Chemnitz seminar on materials engineering*: 2016, 268-275.
[4] J.M. Silva et al., "Cork: Is it a good material for aerospace structures?", *52nd* AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference: 2011.
[5] L. Gill, "Cork Composite: a Review", *Materials,* 2009; 2:776-789.
[6] J.M. Bouilly et al., "Ablative thermal protection systems for entry in Mars atmosphere. A presentation of materials solutions and testing capabilities", *4th International Planetary Probe Workshop*: 2006.