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Insight on Flax Fiber and Hybrid Composites in Helicopter Structures

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Abstract

The potential of hybrid natural and carbon fiber reinforced plastics (NFRP and CFRP) as structural composite materials used in helicopter and other aerospace applications should be investigated.

Flax is a natural fiber which has comparable mechanical properties to glass fibers. The main motivational aspect is the improved ecological footprint, which is due to the lower energy input in the production process, compared to carbon [1]. Another promising factor is the lightweight potential, as flax fibers have a lower density than the conventional fibers, carbon and glass, strength and stiffness properties are rather comparable to glass instead of carbon fibers. The energy dissipating properties are emphasized in different sources, including very good vibrational damping, crash absorbing and impact resistance properties. The analysis of the dynamic structural mechanical properties of flax and hybrids, and the comparison to the contemporary used carbon reinforced structures are part of this research.

The overall applicability of flax in aerospace structures were investigated at two sample components, a horizontal tailplane and a cockpit door. Both components in the size of ultralight weight helicopter parts.

Materials

Flax fiber pre-pregs are lightweight (density: 1.22 g/cm^-3), cheap (costs: 35 €/m²) and show appropriate strength and stiffness when cured as laminate (strength: 275 MPa, E-Modulus: 32 MPa). A special interest about natural fibers is their high inherent damping ratio (damping: 2-4 %), which is according to [2] about five times higher, than the damping of carbon fiber reinforced laminates.

In the investigated applications, flax fibers were used besides carbon fibers, Fig. 1 shows microscopic images of pure flax and carbon laminates and hybrid lay-ups. These were used in tubes for crash and energy absorption tests.

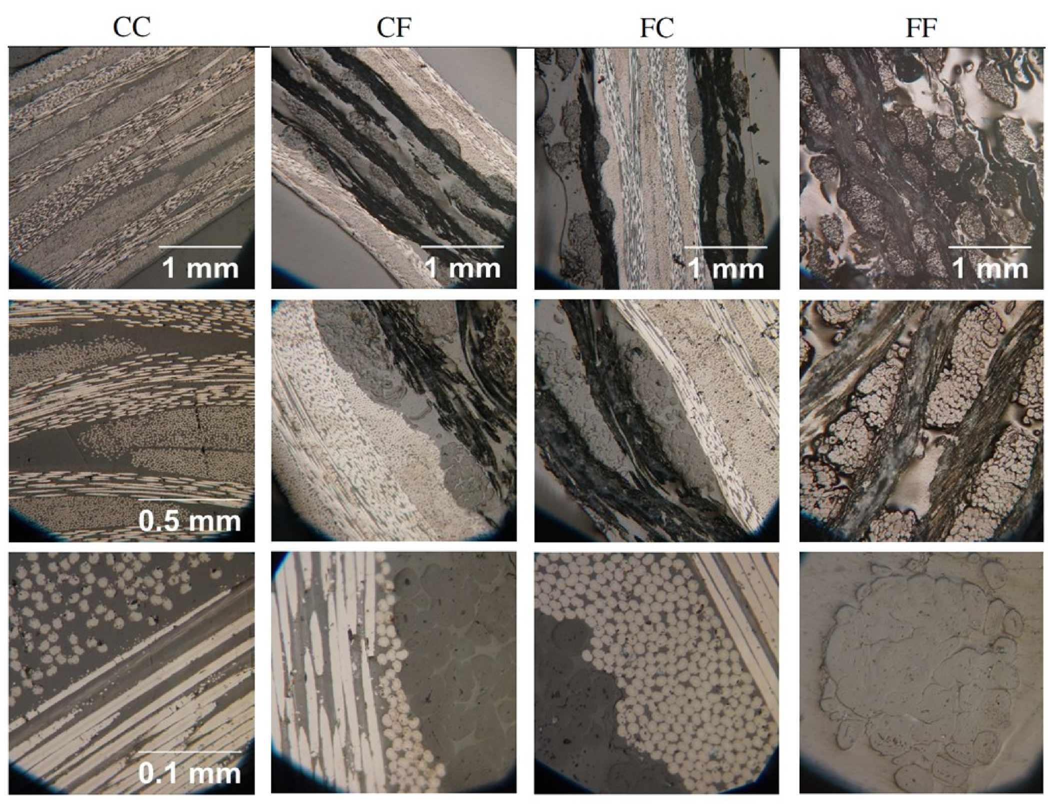


Fig. 1: Microscopic Images of Carbon, Flax and Hybrid Stacked Woven Laminates, with 4x, 10x and 50x Magnifications [3]

Additionally Balsa wood was used as a core material, due to its low density and being already certified as aviation material.

Methodology

Beginning with the specifications for aerospace certifications of new materials, problematic or uncertain properties of flax fibers were identified. Regarding these, the structural mechanical behavior was investigated respective to the test pyramid after Rouchon [4], including levels of coupons, elements and components. All subordinate of the aviation vehicle, in this case an ultralight coaxial helicopter. See Fig. 2 and Table 1.

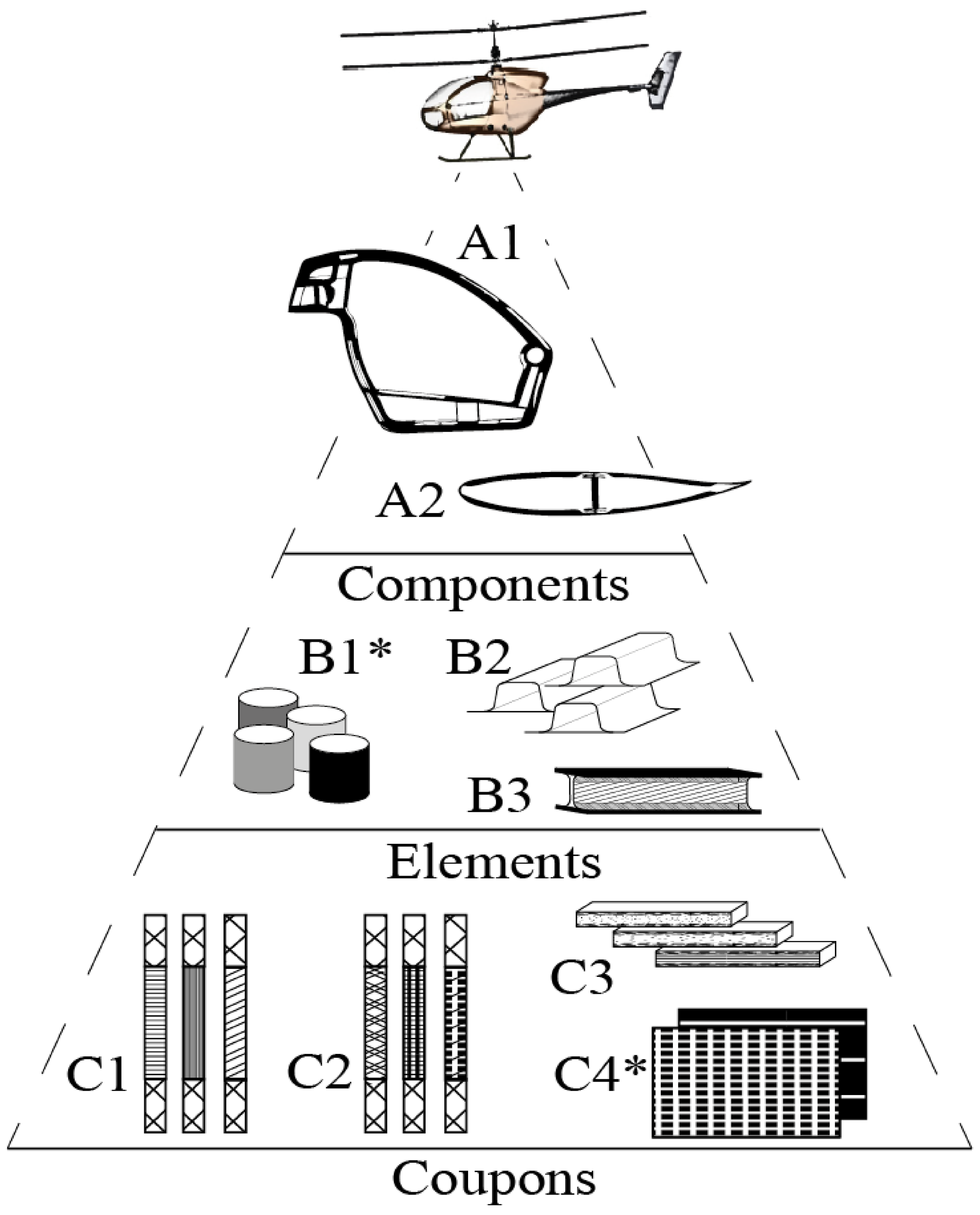


Fig. 2: Test Pyramid of Experimental Analyses and Numerical Modeling, (* only Experimental Investigations)

ID	Specification	Amount	Tests
A1	Cockpit Door	1	EMA, Static
A2	Tailplane	1	EMA, Static, Failure
B1	Crash Cylinders	4 x 3	Static, Dynamic
B2	Omega Beams	3	EMA, Static, Failure
B3	Double-T Beam	1	Static, Failure
C1	Tensile Tests UD Laminates	3 x 8	Static, Failure
C2	Tensile Tests Weaves	3 x 8	Static, Failure
C3	Bending Tests Sandwich	3 x 3	Static, Failure
C4	Impact Test Plates	10 x 4	Dynamic, Inspection

Table 1: ID Specifications and Test Amount as shown in Fig. 2

The performed tests are used for validation and verification of the design and the specifications sheet, respective to the methodology of a V-Model. Design and Analysis were done with FEA models and analytical approaches.

The matters of interest were structural mechanical and dynamic behavior as well as energy absorption, which was analyzed by quasi-static and dynamical testing. Additionally hydrophilicity, fire resistance and of flax laminates was investigated. The applicability of the non-destructive inspection methods: Ultrasonic Inspection and Thermographic Imaging was analyzed from the impact damaged plates (C4 in Fig. 2), [5].

Results and Conclusion

UD-laminates showed good potential for structural applications. A fiber-volume content of up to 55 % was achieved and thereby a bio-based mass content of approximately 62 %. This material was used in the tailplane in combination with carbon, balsa and scotchweld glue, which resulted in a total bio-based mass-content of 55 %.

On the other hand, woven laminates were used in combination with a thin epoxy film, as the pre-preg itself did not show proper interlayer adhesion results. As a result, the bio-based mass content is only 32 %.

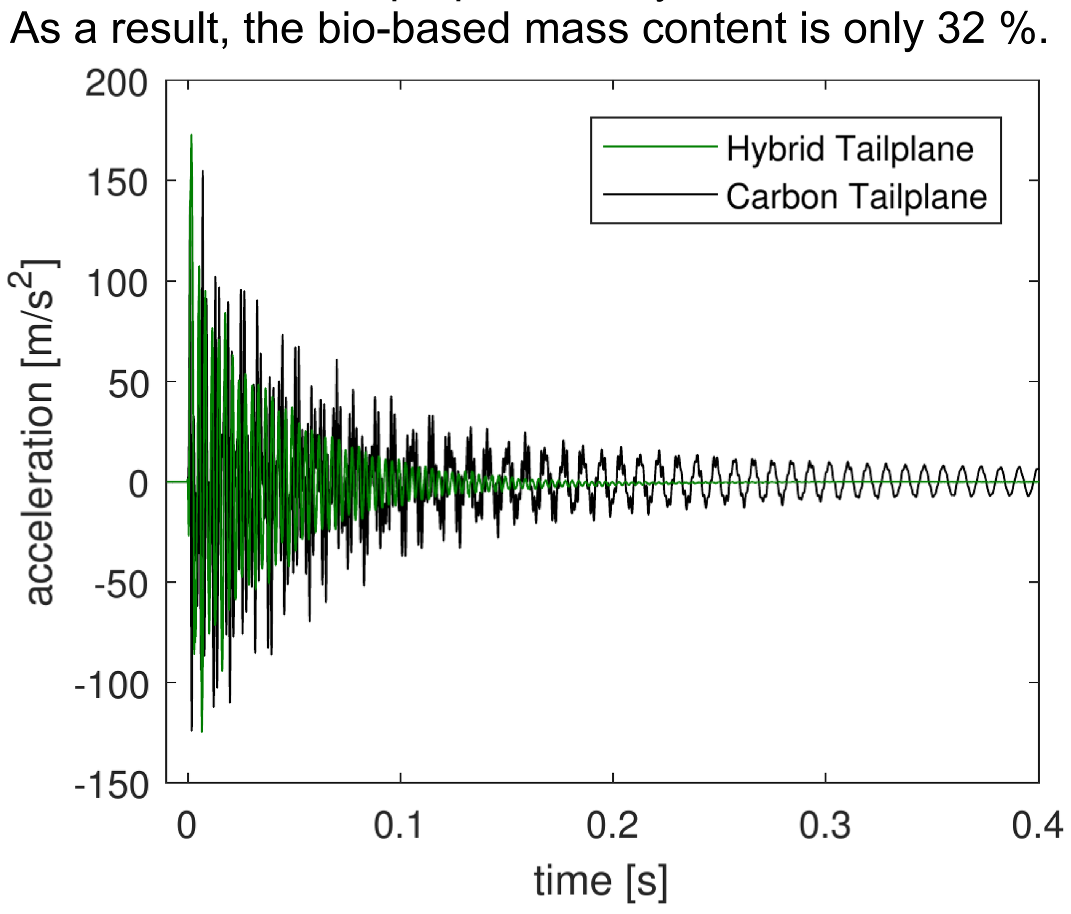


Fig 3: Acceleration after Impulse Excitation of Carbon Tailplane and Hybrid Flax Tailplane with 55 % Bio-Based Mass Content

The high damping ratio from the data sheets was verified and does still show a positive effect in the hybrid component of the tailplane. The logarithmic decrement can be estimated from Fig. 3. Also, a high acoustic absorption using hybrid laminates, made from vacuum infused laminates, was measured and is shown in [6].

The FEA modelling shows good agreement with the tests in the linear elastic tensile response. But flax fibers show a non-linear, rather bi-linear behavior, which is not implemented for composite modeling in most of FEA codes. Exemplary a MAC plot is shown in Fig. 4.

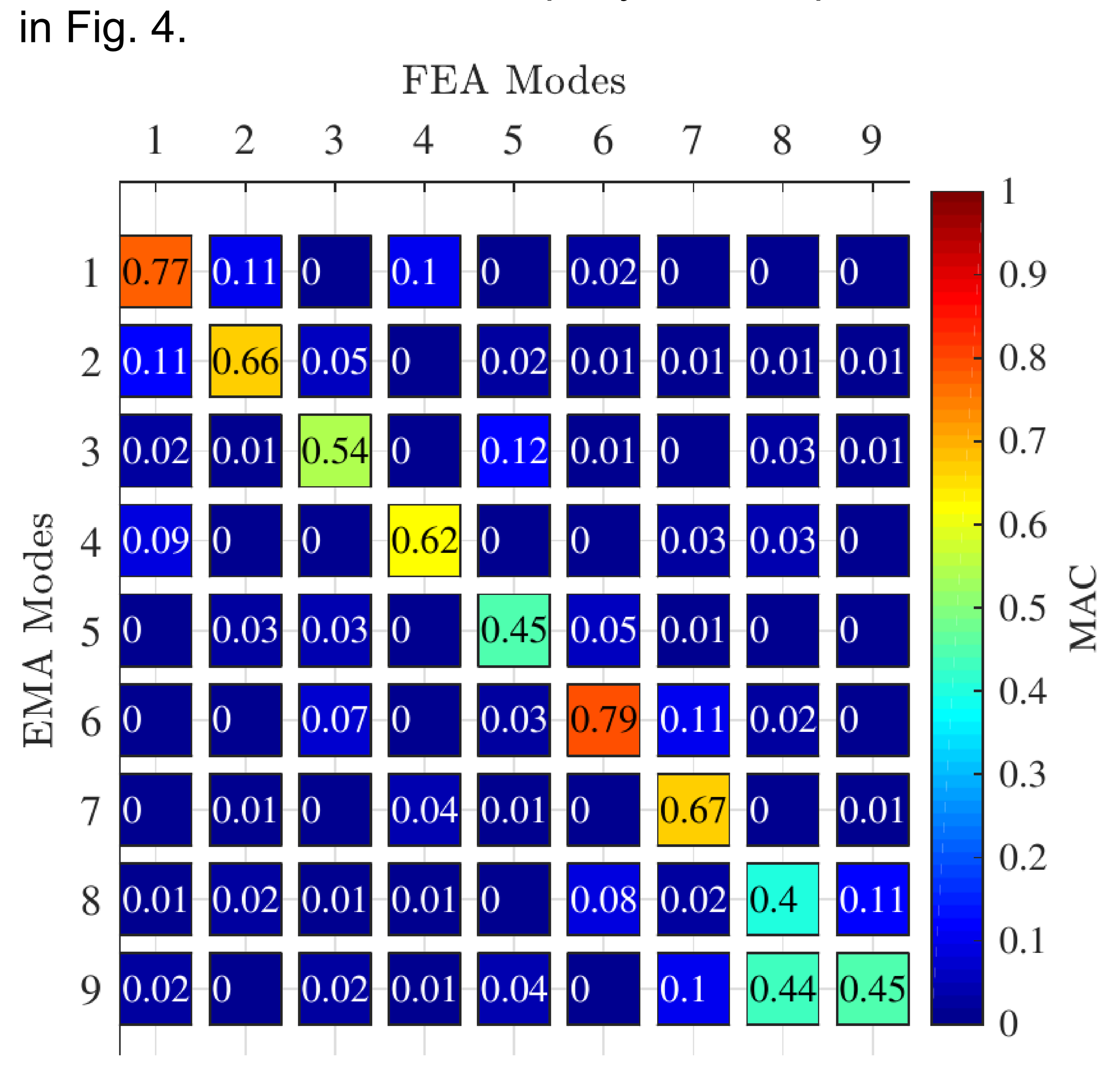
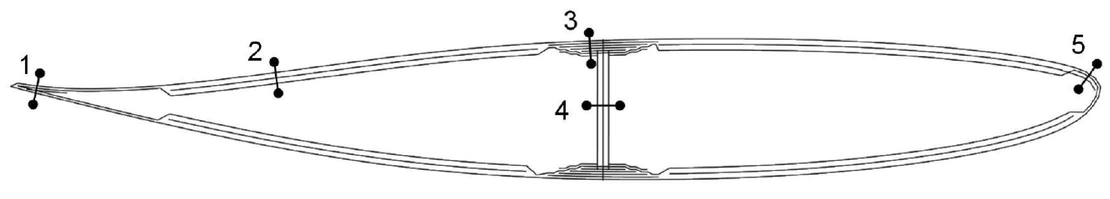


Fig 4: Modal Assurance Criterion for FEA and Experimental Modal Analysis validation of the Reference Carbon Composite Door

References:
[1] B. Madsen, "Guidelines for mechanical design with biocomposites: properties, weight and cost," Vol. 37, 2007.
[2] Technical Datasheet, FLAXPREG BL150, SAS LINEO, 08/2016
[3] K. Strohrmann, S. Schmeer, G.Fortin, H. Hamada, M. Hajek, Crashworthiness Characteristics of Carbon-Flax Composite Tubes for Aerospace Applications, ECCM18 , Athens, Greece, 24-28th June 2018
[4] J. Rouchon, Certification of Large Airplane Composite Structures, Recent Progress and new Trends in Compliance Philosophy, ICAS-90-1.8.1, pp 1439-1447, 1990
[5] K. Strohrmann, J. Blaut, C. Panescu, H.-J. Endres, R. Svidler, M. Hajek, "Impact Damage Behavior and Non-Destructive Inspection Methods of Thin Hybrid Carbon-Flax Laminates" DLRK 2017, Munich, 2017
[6] R. Rinberg, R. Svidler, M. Klaerner, L. Kroll, K. Strohrmann, M. Hajek, H.J. Endres, Anwendungspotenzial von naturbasierten hybriden Leichtbaustrukturen in der Luftfahrt, DLRK 2016, Braunschweig, 2016



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