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Comparative evaluation between E-Glass and hemp fiber composites application in rotorcraft interiors

Claudio Scarponi *, Marco Messano

Sapienza Università di Roma, Dipartimento di Ingegneria Meccanica e Aerospaziale, Via Eudossiana 18, 00184 Rome, Italy

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ABSTRACT

The present paper describes concepts and a preliminary project of a helicopter device, to investigate the use of natural fiber composites for semi-structural applications, such as electronic racks. The aim of the study consists on the evaluation of the substitution of the steel electronic rack, mounted on the helicopter Eurocopter AS 350 Écureuil, with a new version, utilizing hemp fabric/epoxy composite material. This replacement will permit to have an environmental friendly product and lower disposal costs and weight. Lower weight for helicopters and more in general for aircraft means lower fuel consumption, lower pollution and costs. The new rack has been designed using structural static and dynamic analysis through Finite Element Method (FEM). Results are promising from the structural point of view. In fact, a weight reduction of 8.01 kg (55.6%) with respect to steel has been obtained without significantly increasing the production cost. A comparison with glass fabric/epoxy composites is also provided. The results for both the composite materials are very similar, but the advantages for the environment demonstrate that is worthy choosing natural fiber composites configuration.

1. Introduction

In the last decade researchers and engineers have investigated an efficient alternative to the conventional materials used for the manufacture of fiber-reinforced composites. Natural fibers are today widely used in many industrial fields, such as automotive, nautical and civil industry, thanks to some important characteristics, which include:

- Complete biodegradability;
- complete renewability;
- low production cost;
- low carbon footprint;
- high specific mechanical properties;
- good acoustic and thermal properties.

Some examples of hemp applications in the automotive field [1] are the interiors of Lotus Eco Elise [2] and Mercedes-Benz A-Class Coupè [3]. Moreover a recent project of "Sapienza" University of Rome in development phase named "SeaLab" contemplates the use of hemp for the cover of an advanced aquatic drone [4]. In the civil construction industry, hemp is normally used for the production of panels for thermal and acoustic insulation, structural reinforcements and bio-bricks [5].

However, natural fiber composites (NFCs) show some inconvenient, such as low reproducibility, weak fiber–matrix interface and flammability. These problems hinder especially the design of semi-structural parts in natural fiber reinforced composites for the aerospace industry.

No applications of such materials in aeronautics are described in the scientific literature. Research by Scarponi et al. [6] has been recently published concerning the design of a NACA cowling in hemp fabric reinforced epoxy composite, to be installed on an advanced ultra light aircraft. Airworthiness Certification is not required for this typology of aircraft [7]. It is well known that airworthiness certification process is heavy in terms of costs and time; this is the reason why the application of new materials in the field of aircrafts parts production is so complex and difficult.

In the present paper, hemp fibers have been chosen among other available vegetable fibers, such as flax or jute, in consideration of the recent reintroduction of hemp cultivation in some Italian regions (Piedmont [8], Tuscany [9], Umbria [10], Apulia [11]).

The aim of the present paper is to verify the suitability of NFCs to be used for rotorcraft interiors and similar applications in the field of certified aviation. So, the paper describes the preliminary project, developed to replace a helicopter internal rack containing electronic devices for television video streaming. The project is

* Corresponding author.
E-mail address: Claudio.scarponi@uniroma1.it (C. Scarponi).

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applicable to the rotorcrafts Eurocopter AS 350 Écureuil and AS 355 Écureuil II (Fig. 1).

The old rack was manufactured using extruded steel bars with "L" section (30 mm × 30 mm × 3 mm thickness). Each bar was welded to obtain parallelepiped edges. The geometrical sizes are:

- 523 mm on longitudinal aircraft axis (*x*-axis);
- 535 mm on lateral aircraft axis (*y*-axis);
- 900 mm on vertical aircraft axis (*z*-axis).

AISI 4130 steel was used for the entire design. The rack, located in the helicopter crew cabin after the removal of backside passenger seats, weighs 14.4 kg and it is fixed to the floor by an intermediate plate. Four dampers are set up to smooth the vibrations (Fig. 2). Nine electronic devices are fitted to the rack (Table A1, Appendix A), each one of them being joined to it as a cantilever with four screws (ISO M8 A2-70).

2. The new design

The new rack is designed as a box (Fig. 3) with the same geometrical size. It requires open surfaces on forward and rear edges. The electronic devices are fitted on the box front, each one being connected to the structure through 4 screws. The forward hole is required to ensure device ventilation and cable setting up. On the bottom there are 4 aluminum alloy (Al 7075 – T6) triangular elements, where the rack is fitted to the dumpers.

3. Materials

With the exception of the triangular elements, the rack is entirely conceived to be realized using composite materials, more in particular NFCs and glass fiber composites, as a matter of comparison. In Fig. 4 is represented the hemp plain weave fabric manufactured in Italy (Linificio – Canapificio Nazionale S.p.a.); the cost is only 8 €/m^2 [12] for a small quantity (10 kg). Some physical and mechanical properties are described in Table A2, Appendix A.

The matrix is the bi-component epoxy resin Hexion L-285 (hardener H-285), widely used in aeronautics, such as gliders and small airplanes [13]. It shows very good features as mechanical and thermal properties and a wide operating temperature range (Table A2).

The fiberglass material selected to be considered for the design is an E-Glass balanced woven roving, embedded with the epoxy resin SP System Ampreg 26, described in Table A3 in Appendix A. The experimental data and the parameters to be used in the code are reported in Ref. [6].

3.1. Stacking sequence

The final configuration is a quasi-isotropic, 8 plies symmetric laminate, in consideration of the fact that no prevalent directional load is present for the structure. The following notation has been utilized for the description of the sequence:

- 0° for a ply with 0°/90° fibers.
- 45° for a ply rotated by 45° (±45).

The lamination sequence is $[0/45/0/45]_{sym}$.

The configuration of the fiberglass stacking sequence is a 4 plies $[0/45]_{sym}$ symmetric laminate. The features of the composite laminates [6] are reported in Table A4, Appendix A. The laminates considered have different thickness. The rationale for this choice is that the fiberglass presents better mechanic properties than hemp laminate, so that a minor thickness still ensures strength to external loads, though with different (lower) safety margins, as it will be shown in the results analysis.

3.2. Fabrication process

The new rack is conceived as an assembly of four parts:

- Two lateral parts.
- One base (at the bottom).
- One cover (on the top).

Each segment is built as a plate having all outer edges 90°, bent for 20 mm; such a solution allows easing the final assembly of the structure. The complete description of the fabrication process is out of the limit of the present paper, so only the fabrication concept can be considered here. For instance, any single part can be fabricated in an easy way, such as vacuum bag technique and curing process in furnace. In case of this choice, the sequence could be shortly described by the following steps:

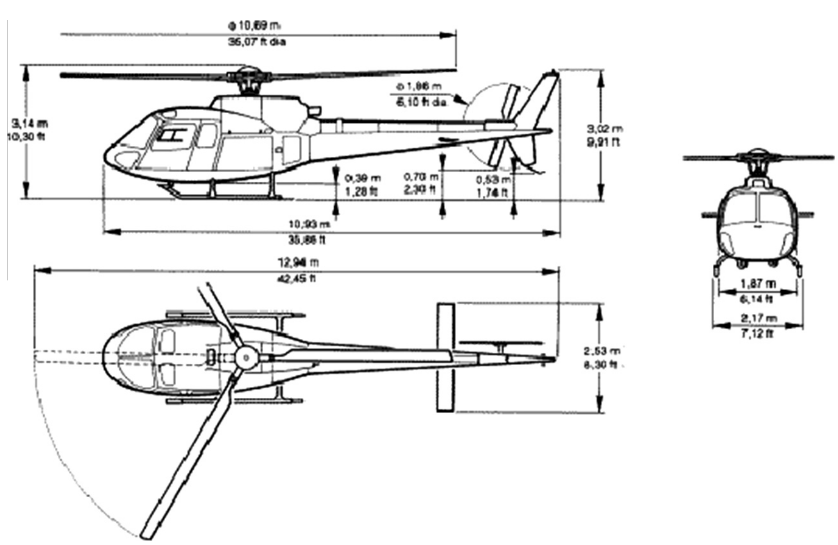

Fig. 1. Eurocopter AS 350 Écureuil view with dimensions.