Composites Part B 81 (2015) 53–63

Contents lists available at ScienceDirect

Composites Part B

journal homepage: www.elsevier.com/locate/compositesb

Hemp fiber composites for the design of a Naca cowling for ultra-light aviation

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ARTICLE INFO

Article history:
Received 4 December 2014
Received in revised form
16 May 2015
Accepted 1 June 2015
Available online 13 July 2015

Keywords:
A. Polymer-matrix composites (PMCs)
B. Computational modeling
E. Manual lay-up
D. Electron microscopy
C. Finite element analysis (FEA)

ABSTRACT

The present study focuses on the design of a Naca cowling of an acrobatic ultra-light airplane, where the traditional woven glass/epoxy laminate utilized for the production has been replaced by woven hemp reinforced epoxy composite. Specialized software (Fluent and ANSYS) was used for configuration, design and analysis. The results showed comparable mechanical performance, about same weight, but easier disposal and better eco-friendly characteristics as compared to their synthetic counterpart. The engine cover, produced by the use of hemp/epoxy composites, demonstrates the effective possibility to produce semi-structural aeronautical components using natural fiber composites in substitution of glass ones.

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1. Introduction

Nowadays, fiber reinforced polymeric composites are used for a variety of semi-structural and structural applications because of their high specific strength and modulus compared to metals. Initially developed for the aerospace industry, high-performance composites are now found in applications from automotive parts to circuit boards, and from building materials to naval constructions and sporting goods [1].

Most composites currently available are made using non-degradable polymeric resins, such as epoxy, vinylester and phenolic, and high-strength fibers, such as carbon, aramid, and glass. Many of these polymers and fibers are derived from petroleum, a non renewable resource. With increasing number of applications and mass volume uses, disposal of composites after their intended life is becoming critical, as well as expensive. Most composites still end up in landfills, while some are incinerated after use, although there are some efforts to recycle and/or reuse them. Both these disposal alternatives are expensive and wasteful, and can contribute to pollution.

Recent concerns about the preservation of environment and recycling have led to renewed interest for eco-friendly materials as, for instance, composites based on natural fibers. The application of such composites is rapidly increasing, especially for problems related to waste disposal and recycling of synthetic fiber reinforced composites. These issues justify the search for more environmentally compatible alternatives.

Long plant-based fibers such as abaca, bamboo, flax, henequen, hemp, jute, kenaf, pineapple, ramie, sisal, etc., with good mechanical properties are being evaluated as low-cost alternative reinforcements to commonly used glass fibers in composites based on thermosetting [2–8], thermoplastic [9–13], and most recently also on biodegradable polymer matrices [14,15].

These fibers, obtained from the plant stems or leaves, on a per weight basis, show moduli and strengths comparable or even higher than E-glass ones [16,17]. Despite the advantages, the use of natural fiber reinforced composites has been restricted due to their high moisture absorption tendency, poor wettability, and low thermal stability during processing and poor adhesion with the synthetic counterparts [18,19]. Another drawback is that, unlike synthetic fibers, natural fibers are perceived to have significantly greater variability in their mechanical properties as a consequence of the conditions experienced in the field and the potential damage arising from the extraction processes. During last years, many of these issues have been addressed and partially solved, especially for what concerns the compatibility between polymers and natural fibers [20,21]. Until this moment in time,

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http://dx.doi.org/10.1016/j.compositesb.2015.06.001
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Fig. 1. Hemp specimens for bending tests.

natural fiber composites have found applications as non structural materials, especially in the packaging, transportation and building industries.

No application of natural fiber composites has been attempted so far in aeronautical constructions. This can be ascribed to both the heavy in-service stresses (thermal, mechanical and acoustic fatigue) and the need for materials with reliable mechanical performances. A further obstacle is represented by the material certification processes which are time consuming and expensive.

In an effort to broaden the applications of natural fiber composites, this paper investigated the possibility of replacing glass fibers with hemp ones for the manufacture of a Naca cowling of an ultra-light aircraft, a possibility which was suggested in previous studies [22]. Ultra-light Aviation was selected in that it is not subject to compulsory certification and it is a growing sector with more than 8000 aircrafts only in Italy. As a raw material, hemp fiber is one of the strongest and stiffest available natural fibers with high aspect ratio and cellulose content and therefore has great potential for use in composite materials [23,24]. In this case, high aspect ratio fibers were used with filaments of average length, before thread making, of 60 mm and average diameters in the range of 25–30 microns.

Due to the absence of a database on mechanical properties of natural fiber composites, some mechanical properties of the woven hemp/epoxy composite materials were determined to provide accurate inputs for component modeling. Based on these properties, geometric constraints and load requirements, the Naca cowling of the MAG 1 advanced ULM was modeled using finite element analysis (FEA).

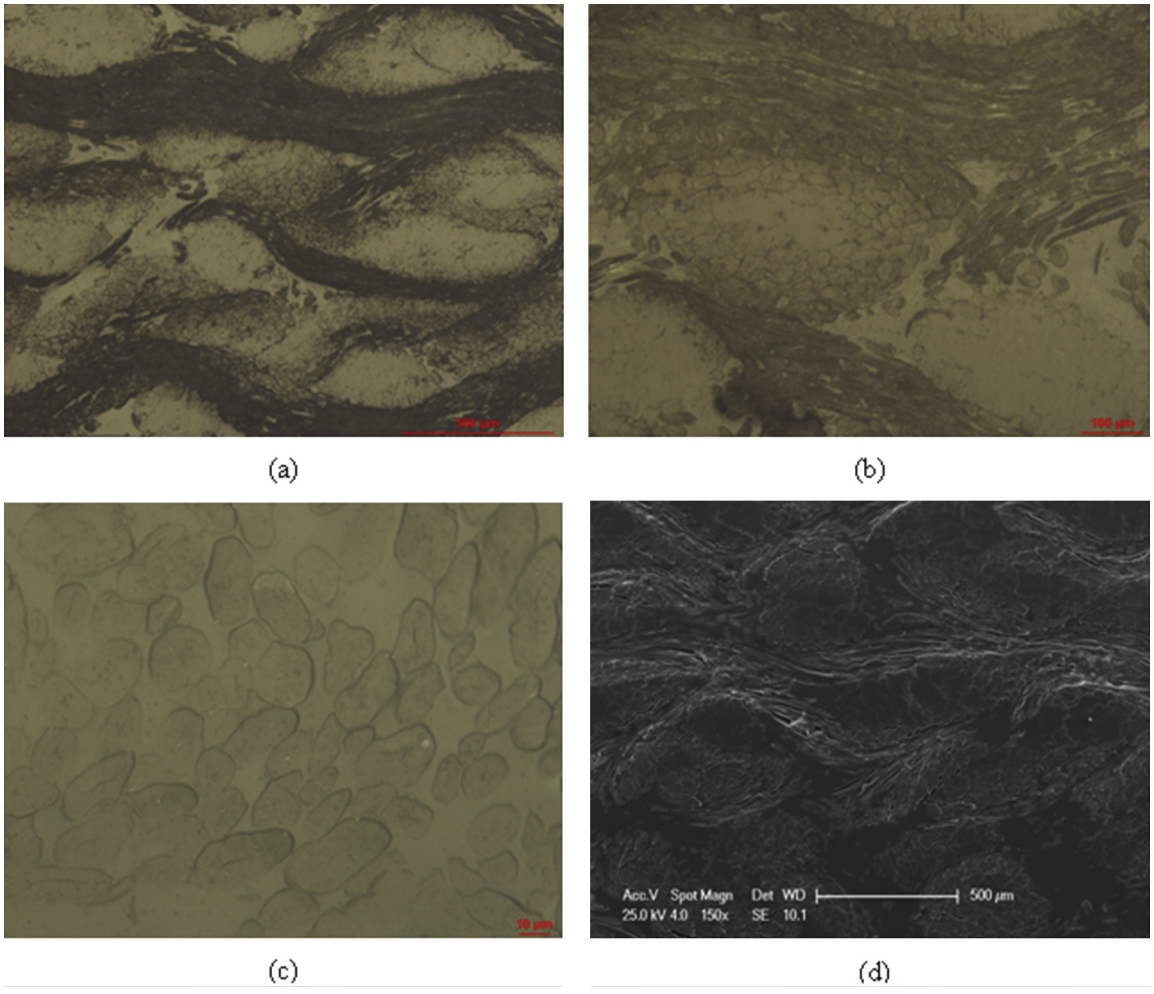

Fig. 2. Optical microscopy (a–c) and SEM images (d) of hemp/epoxy composites in the as-manufactured state.

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