Composites Part B 91 (2016) 18–26

Contents lists available at ScienceDirect

Composites Part B

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

Design and manufacturing of automobile hood using natural composite structure

Changduk Kong [a], Haseung Lee [a], Hyunbum Park [b, *]

[a] Department of Aerospace Engineering, Chosun University, 375 Seosukdong, Donggu, 502-759, Gwangju, Republic of Korea
[b] Department of Defense & Science Technology-Aeronautics, Howon University, 64 Howondae 3gil, Impi, 573-718, Gunsan, Republic of Korea

ARTICLE INFO

Article history:
Received 31 January 2015
Received in revised form
2 October 2015
Accepted 26 December 2015
Available online 3 February 2016

Keywords:
B. Mechanical properties
B. Strength
C. Finite element analysis (FEA)

ABSTRACT

Recently, there has been a growing interest in the use of naturally sourced fibers for use in composites design and manufacture. In this work, a structural design on automobile hood using natural flax fiber composite was performed. The structural design results of flax/vinyl ester composite hood were compared with the design results of metal hood structure. Through the structural analyses using commercial FEM software, it is confirmed that the designed automobile hood using natural composite is reasonable for structural safety, stability and weight. Through the structural test, it is confirmed that the designed hood structure is acceptable for structural safety and stability.

1. Introduction

Recently due to increasing interest in eco-friendly materials, studies on fiber obtained from nature have been actively performed to the area of composite. Although the natural fiber has less strength than the high strength fiber such as the carbon fiber, it has similar strength to glass fiber. Accordingly, it can be applied as very advantageous composite when an appropriate resin has been selected.

In this study, the design of eco-friendly structure using natural fiber was performed after investigation on mechanical properties of natural composite. The selected target structure is hood for automobile.

Among the previous studies, A. Masoumi et al. performed the study on comparison of steel aluminum and composite bonnet in terms of pedestrian head impact. This paper focused on the investigation of heat injury criterion. In this paper a new finite element model has been developed which is capable to simulate head impact phenomenon between head form impactors and glass composite bonnet [1].

Jung H. S. et al. performed the study on computer-aided system for bonnet tool design using relation rules. This paper illustrates the development of a tool design aided system for bonnet [2].

Mohammad Hassan Shojaeefard et al. studied pedestrian safety investigation of the new inner structure of the hood to mitigate the impact injury of the head. In this paper, a new finite element model has been developed to simulate the collision between head form impactors and five different hoods [3].

Daeyoung Kwak et al. performed the study on optimal design of composite hood with reinforcing ribs through stiffness analysis. In this study, a one-piece glass composite hood with reinforcing ribs was optimally designed and manufactured [4].

The General Motors (GM) and Ford introduced carbon composite bonnet to the Reinforced Plastics Journal [5,6].

Marco Valente et al. performed the study on metal matrix composites for automotive application. This paper focused on the investigation of mechanical tests and fractographic analysis of MMC specimens [7].

Georgios Koronis et al. performed the study on automotive applications of green composite. This study provides a bibliographic review in the broad field of green composites seeking-out for materials with a potential to be applied in the near future on automotive body panels [8].

Many research works of hood design using metal or glass composite were performed in an early stage of research. However, little research work has been carried out to apply natural composite for structural design. And also, previous studies did not consider the research of low cost manufacturing process.

In the previous study, the mechanical properties of several natural fibers are reviewed and compared to select a proper natural fiber for the target structure [9–11]. Finally the flax is selected as a

* Corresponding author.
E-mail address: swordship@daum.net (H. Park).

http://dx.doi.org/10.1016/j.compositesb.2015.12.033
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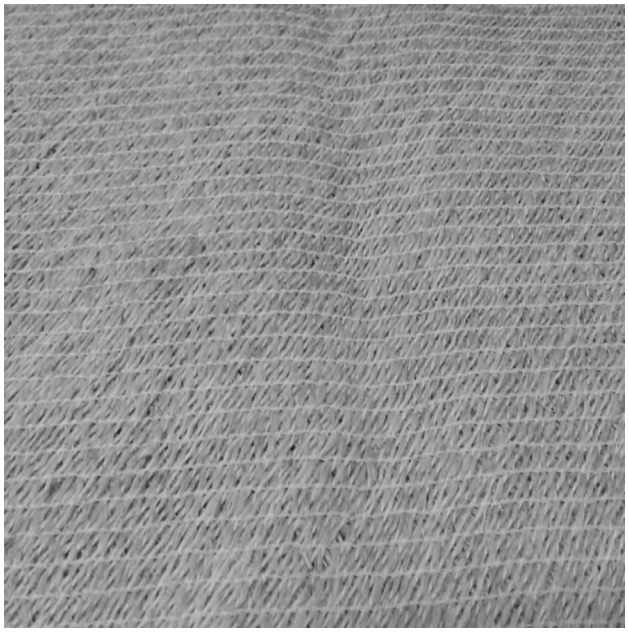

Fig. 1. Weaving configuration of flax composite 2D fabric.

Table 1
Mechanical properties of natural fibers.

Fiber type	Density [g/cm^3]	Stiffness [GPa]	Strength [MPa]
Hemp	1.5–1.6	30–60	300–800
Flax	1.5–1.6	50–70	500–900
Jute	1.3–1.5	20–55	200–500
Sisal	1.2–1.4	9–22	100–800
Cotton	1.5–1.6	6–10	300–600
Soft wood	1.2–1.4	10–50	100–170

Table 2
Mechanical properties of thermosetting resin.

Property	Poly esters	Vinyl esters	Epoxies	Phenolics
Tensile strength (MPa)	34–105	73–81	55–130	50–60
Tensile modulus (GPa)	2.1–3.5	3–3.5	2.7–4.1	4–7
Flexural strength (MPa)	70–110	130–140	110–150	80–135
Flexural modulus (GPa)	2–4	3	3–4	2–4
Specific gravity	1.1–1.4	1.1–1.3	1.2–1.3	1.2–1.3
Cure shrinkage (%)	5–12	5–10	1–5	2–4

natural fiber due to higher strength and better mechanical behaviors than other natural fibers, and the vinyl ester is selected as a resin due to lower cost, easier procurement and better treatment for the resin injection. For easy and fast production of the complicated configuration structure, the vacuum assisted resin transfer molding (VARTM) manufacturing method is selected. The flax/vinyl ester composite specimens are manufactured and tested to find the mechanical properties. After investigation on mechanical properties of flax/vinyl ester composite, the hood design of eco-friendly structure using flax/vinyl ester was performed.

2. Selection of flax fiber and vinyl ester resin

For the eco-friendly structure design, properties of various natural fibers are compared. Firstly, the fiber contents shows that 71% in flax, 65% in jute, 72% in hemp and 69% in sisal. Through comparison of mechanical strength and stiffness, it is found that the flax fiber has the best properties. And also, the fiber surface is more uniform than another natural fiber. Fig. 1 shows the weaving configuration of the flax 2D fabric for specimen manufacturing. Mechanical properties of representative natural fibers are presented at Table 1 [12]. Therefore the flax is selected as a natural fiber to be applied to the eco-friendly structure. Moreover, the flax fiber has better vibration absorption behavior, cheaper and easier procurement than other natural fibers. The flax fiber is widely produced in Europe currently, for instance, France occupies 80% of its supply. Recently the use of flax fiber increases for aircraft door, automobile interior, tennis racket, bicycle frame, table, building structure and mobile phone case, etc [12].

The resin for natural fiber composite is mainly divided into thermoplastic resin, thermosetting resin and bio resin. Representative thermoplastic resins are polyethylene, polypropylene and polyamide, and the representative thermosetting resins are epoxy, vinyl ester, phenolic, etc.

In order to select a proper resin for this study, mechanical properties of polyester, vinyl ester, epoxy and phenolic resin are investigated shown as Table 2 [12]. Although the phenolic resin has excellent flame resistance, it has a flaw of manufacturing process difficulty. The epoxy resin is widely used for carbon or glass fiber composite as well as for natural fiber composite, but a disadvantage is relatively high price. In this study, the vinyl ester is firstly selected due to cheap price even though somewhat low mechanical properties compared to epoxy.

3. Resin transfer molding manufacturing method

Recently, the resin transfer molding process method is emphasized for curing large complicated shape composite structures. The

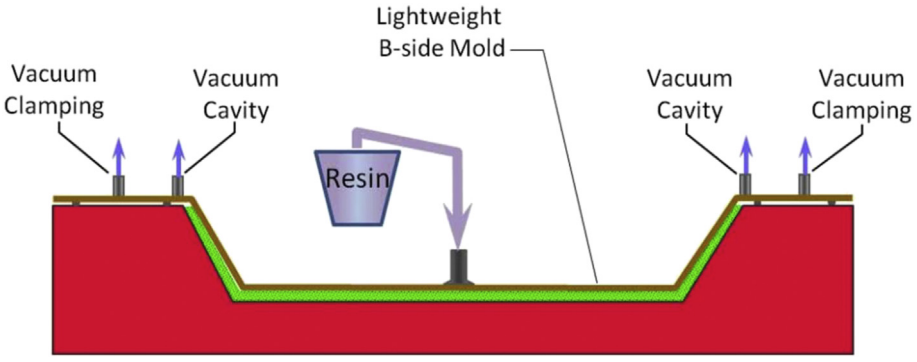

Fig. 2. Schematic diagram of VARTM Process.