

Horizontal-Axis Wind Turbine Blades Manufacture with Composite Materials

I O Bucur^{1,2}, I Malael², S Breban³

²Romanian Research and Development Institute for Gas Turbine – COMOTI, Iuliu Maniu Boulevard, No. 220D, 061126, Bucharest, Romania

³S.C. BMEnergy SRL, Cluj-Napoca, Romania

E-mail: ioana.bucur@comoti.ro

Abstract. The aim of this paper is to contribute to the wind turbine manufacturing industry through investigating the technological manufacturing process of a 2.5kW horizontal axis wind turbine's (HAWT) blades. Composite materials, such as fiberglass and carbon fiber are engaged in the manufacturing process, due to their mechanical properties. The material selection process is discussed, motivating the choices based on several criteria, such as weight and tensile strength. The adopted technologies for the manufacturing process include layup method at ambient temperature and vacuum. Regarding the used moulds, these were previously manufactured using the infrastructure that NRDI COMOTI has at its disposal. Layups of fiberglass and carbon fiber are disposed in the aluminium alloy moulds. In the end, a layup of peel ply is placed upon the outer surface of the composite and the vacuum bag is applied and sealed. The outcome of this research consists of two parts. Firstly, the presented methodology, techniques and materials selection criteria represent a reliable source of information for future scientific papers on the matter. Secondly, the manufactured blades, after post-processing techniques, can be tested in relevant conditions in the aerodynamic tunnel and further studies can be conducted with the obtained results.

1. Introduction

In the context of sustainable development, most countries prefer to reduce fossil fuels dependency in favour of renewable energies. In order to do so, wind farms should be extended, as well as the popularity of wind turbines for domestic applications increased. In the last decades, wind energy developed considerably and nowadays is considered one of the most reliable sources of renewable energy both from the environmental and economical point of view [1]. Wind turbines can be divided into two main categories, namely vertical axis wind turbines (VAWT) and horizontal axis wind turbines (HAWT). The latter type presents better efficiency, generating greater quantities of energy, but such systems need to be installed in remote areas, as they can generate disturbing levels of noise [2]. In this paper the manufacturing process of the wind turbine blades for a 2.5kW HAWT is described, approaching subjects such as material selection or adopted technologies. This research is relevant for future manufacturing studies and its output, namely the blades, can be further used for aerodynamic or structural studies.

¹ To whom any correspondence should be addressed.

The materials used for the manufacturing of wind turbines have a strong impact on its performances and lifespan. Composite materials are preferred especially for the blades, as studies confirmed that such materials can improve the lifetime of the turbine as well as its performances [3]. Fiberglass and carbon fiber are composite materials widely used for the manufacturing of wind turbine blades, due to their characteristics, such as high strength to weight ratio, tensile strength, long durability, low maintenance costs [4]. One of the biggest drawbacks when employing fiberglass and carbon fiber in the production of wind turbine blades is represented by the material waste once the wind turbine exceeded its lifetime [5]. Fortunately, the need of such materials in the industry of renewable energy encouraged the development of solutions for the recycling of the blades, once their endurance surpassed its limit. For the recycling of reinforcement fibres such solutions include mechanical [6], thermal and chemical recycling, as described in [7]. Composite materials from wind turbine blades at the end of their lifecycle can be reused for different applications, for example in additive manufacturing [8] or even housing projects as proposed in [9]. Taking into consideration the number of studies that provide numerous solutions for the recycling of wind turbine blades [10] manufactured using fiberglass and carbon fiber, composite materials represent a reliable solution for the maximization of the benefits presented by wind power.

Popular technologies for the manufacturing of wind turbine blades include the layup method, resin infusion, filament winding or prepreg technology. The layup manufacturing technique implies the use of composite material layups and resin for the reinforcement of the composite fibers. The resin is applied on the fiber foil with tools such as hand rollers or paint brushes in order to force the resin through the fiber's thickness [11]. Resin infusion technology includes two methods: vacuum infusion process and resin transfer moulding. When such technologies are used, the fibers are placed and sealed in moulds, then resin is introduced into the closed cavity under pressure. The main difference between the named methods is represented by the pressure, for the resin transfer moulding the resin is injected in the cavity under a pressure higher than the atmospheric one, while as for the vacuum infusion process the pressure is lower than the atmospheric one [12]. In an attempt to reduce manufacturing costs several other technologies have been exploited by developed companies, including filament winding and prepreg technology. The latter one utilizes pre-impregnated composite fibers in order to obtain finite products [13].

In the following sections the manufacturing process of the wind turbine blades for a 2.5kW HAWT will be described, including the selected materials for such an application, that involve fiberglass and carbon fiber, as well as the adopted technologies, that consist of lay-up method and vacuum.

2. Methodology

In this section the procedures leading to the manufacturing process are discussed, as well as the manufacturing process itself.

Firstly, the CAD model of the blade was designed employing the Solidworks software and two airfoil families, S821 and S823. The 3D CAD model of the blade is illustrated in figure 1.

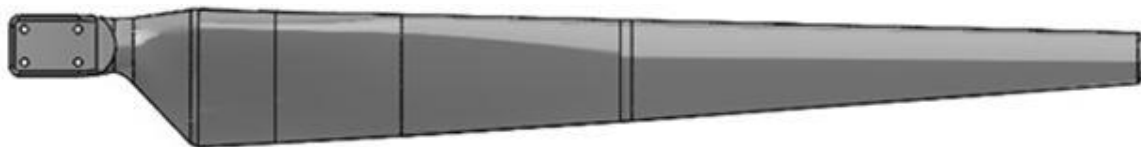


Figure 1. 3D CAD model for the 2.5kW HAWT blade [14].

The selected materials for the manufacturing of the presented blade comprise of a configuration that incorporates both fiberglass and carbon fiber. The main factors that were taken into consideration when establishing such a configuration include the mechanical properties of the selected composites, such as good flexural strength or tensile strength. Carbon fibers ensure a high stiffness level, which

prevents the deforming of the blade at strong impacts that can occur during its lifecycle [15]. Furthermore, the selected composites present a low density, implying that the resulted blades are light-weighted, allowing them to also function and generate power even in low wind regimes. Previously to the manufacturing of the blades, two moulds were fabricated using NRDI COMOTI's infrastructure. The material used for the manufacturing of the moulds was an aluminium alloy, namely alloy EN AW 2017A. In paper [14] the complete fabrication process of the moulds is described, presenting its design, a CAM simulation of the manufacturing process and in the end the process itself that implies the use of a CNC machine for the cutting process. The moulds are represented in figure 2.



Figure 2. Moulds used for the manufacturing of the blades.

The manufacturing of the blade is an iterative process, which consists of disposing layups of fiberglass and carbon fiber in the aluminium alloy moulds. The placing of the layups of composite fibers is done at an ambient temperature and afterwards a vacuum bag is applied and sealed for the reinforcement process.

The first stage in the manufacturing process is represented by the preparing of the moulds, which are degreased using acetone. Then, a clearing agent is applied in order to facilitate the separation of the structure from the mould after the polymerization.

The fiber layups are cut as shown in figure 3, using a template. After the mould is ready, the composite fiber layups can be disposed, as illustrated in figure 4.



Figure 3. Cutting process of the layups.



Figure 4. Disposing the first fiberglass layup.

A mix consisting of resin and a hardener is made in a recipient and then spread along the surface of the fiber using a paint brush or roller. A schematic representation of the hand layup method is portrayed in figure 5.

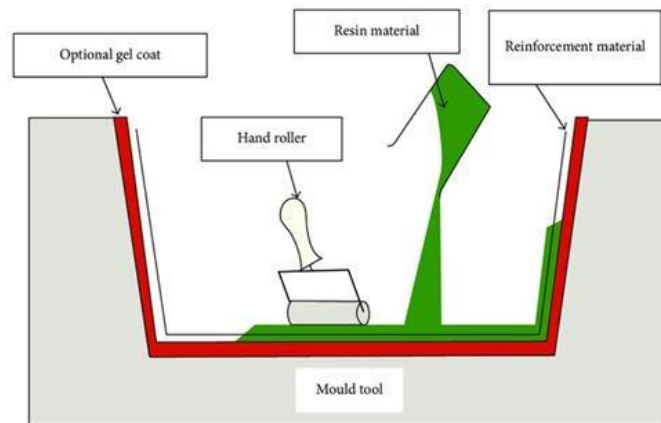


Figure 5. Schematic representation of the hand layup process [16].

The disposal of the composite fibers was done alternating one layup of fiberglass with one layup of carbon fiber. In order to ensure stiffness after the fourth layup a carbon rod was inserted, as shown in figure 6.



Figure 6. The insertion of the carbon rod.

On the rod, two more layups were fixed, a fiberglass layup followed by a carbon one. In the end, carbon strips were placed along the model in order to reinforce the airfoil, as illustrated in figure 7.

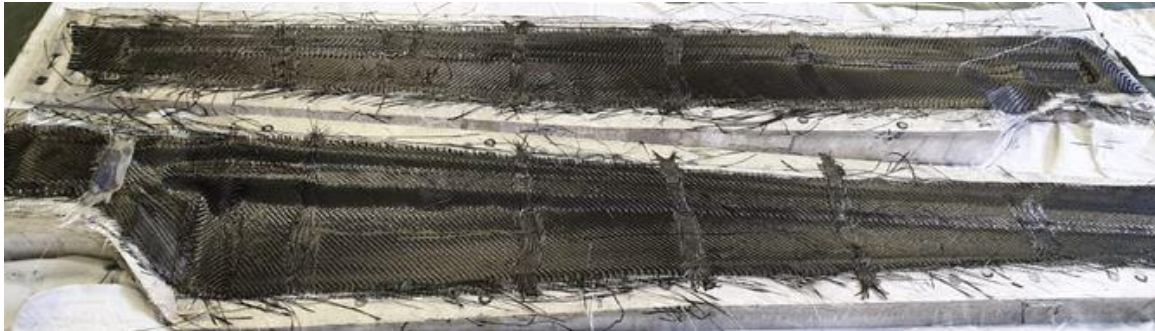


Figure 7. Model after the placement of the layups and strips.

The next step involved fixing the gripping area, where the blade would be combined with the generator flange. To do so, in the gripping zone a wooden structure was placed and on it were disposed the last two composite layups (one fiberglass and one carbon fiber). This step is represented in figure 8.



Figure 8. Fixed gripping area with the wooden structure.

The final step consists of applying a coat of peel ply in order to avoid the situation in which the vacuum bag remains glued to the airfoil. In figures 9 and 10 the layup structure with the vacuum bag applied is represented, respectively the vacuum process.



Figure 9. Vacuum bag sealing process.

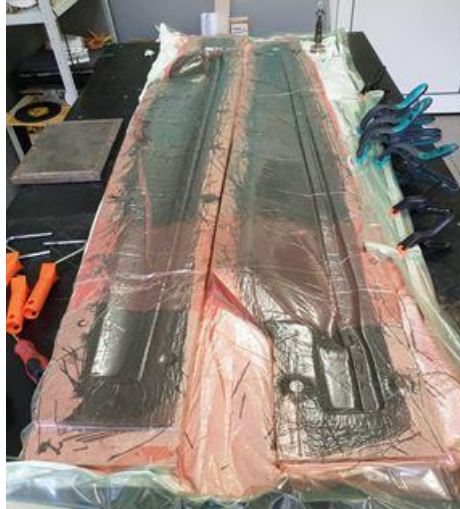


Figure 10. Vacuum process.

3. Results

The polymerization process at ambient temperature lasted for a period between 48 and 72 hours. Afterwards the airfoils were extracted from the moulds (figure 11) and post-processing techniques were applied in furtherance to obtain the finite product, as represented in figure 12.



Figure 11. Manufacturing blade prior to post-processing techniques.



Figure 12. Manufactured blade after post-processing procedures.

Results of the present work consist of three HAWT blades, as the one illustrated in figure 12. The blades were painted and balanced in preparation for future testing in the wind tunnel.

4. Conclusions

In this paper the manufacturing process of the blades for a 2.5kW HAWT using composite materials was described. The selected materials for this application were fiberglass and carbon fiber and two previously manufactured aluminium alloy moulds were employed in the fabrication process. The adopted technologies comprise of the hand layup method and vacuum infusion process. In the end, this paper provides insightful information for future research papers on the matter, regarding manufacturing technologies.

Furthermore, the resulted blades will be tested in relevant conditions in the aerodynamic tunnel. The assembled experimental model is represented in figure 13.



Figure 12. Experimental model realised with the manufactured blades.

5. References

- [1] Leung D Y C and Yang Y 2012, Wind energy development and its environmental impact: A review, *Renewable and Sustainable Energy Reviews* **16** 1031-1039
- [2] Saad M M M and Asmuin N 2014, Comparison of Horizontal Axis Wind Turbines and Vertical Axis Wind Turbines, *IOSR Journal of Engineering* **4** 27-30
- [3] Mishnaevsky Jr. L 2012, Composite materials for wind energy applications: micromechanical modelling and future directions, *Computational Mechanics* **50** 195-207
- [4] Rajesh V, Rao P M V and Sateesh N 2017, Investigation of Carbon Composites Subjected to Different Environmental Conditions, *Materials Today: Proceedings* **4** 3416-3421
- [5] Kalagi G R, Patil R and Nayak N 2018, Experimental Study on Mechanical Properties of Natural Fiber Reinforced Polymer Composite Materials for Wind Turbine Blades, *Materials Today: Proceedings* **5** 2588-2596
- [6] Yazdanbakhsh A, Banc L C, Rieder K A, Tian Y and Chen C 2018, Concrete with discrete slender elements from mechanically recycled wind turbine blades, *Resources, Conservation and Recycling* **128** 11-21
- [7] Yang Y, Boom R, Irion B, Heerden D J, Kuiper P and Wit H 2012, Recycling of composite materials, *Chemical Engineering and Processing: Process Intensification* **51** 53-68
- [8] Rahimizadeh A, Kalman J, Fayazbakhsh K and Lessard L 2019, Recycling of fiberglass wind turbine blades into reinforced filaments for use in Additive Manufacturing, *Composite Part B: Engineering* **175** 107101

- [9] Bank L C, Arias F R, Yazdanbakhsh A, Gentry T R, Al-Haddad T, Chen J F and Morrow R 2018, Concepts for Reusing Composite Materials from Decommissioned Wind Turbine Blades in Affordable Housing, *Recycling* **3**
- [10] Jensen J P and Skelton K 2018, Wind turbine blade recycling: Experiences, challenges and possibilities in a circular economy, *Renewable and Sustainable Energy Reviews* **97** 165-176
- [11] Cairns D S and Skramstad J D 2000, Evaluation of Hand Lay-Up and Resin Transfer Molding in Composite Wind Turbine Blade Manufacturing, *Sandia Report – Sandia National Laboratories*
- [12] Pierce R S and G F Brian 2017, Simulating Resin Infusion through Textile Reinforcement Materials for the Manufacture of Complex Composite Structures, *Engineering* **3** 596-607
- [13] Mishnaevsky Jr. L, Branner K, Petersen H N, Beauson J, McGugan M and Sorensen B F 2017, Materials for Wind Turbine Blades: An Overview, *Materials* **10** 1285
- [14] Malael I, Bucur I O and Breban S 2019, Horizontal-Axis Wind Turbine Blades Mold Manufacture by Using Cutting Processes, *2019 International Conference on ENERGY and ENVIRONMENT (CIEM)* 34-38
- [15] Okayasu M and Tsuchiya Y 2019, Mechanical and fatigue properties of long carbon fiber reinforced plastics at low temperature, *Journal of Science: Advanced Materials and Devices* **4** 577-583
- [16] Udipi S R and Rodrigues L L R 2016, Detecting Safety Zone Drill Process Parameters for Uncoated HSS Twist Drill in Machining GFRP Composite by Integrating Wear Rate and Wear Transition Mapping, *Indian Journal of Materials and Science*

Acknowledgments

This work was carried out within POC - Competitiveness Operational Program, supported by the EU and Romanian Minister of Research and Innovation funds, project number POC 9/01.09.2016, MySmis 105890, ID P_40_309.