Horizontal-Axis Wind Turbine Blades Mold Manufacture by Using Cutting Processes

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Abstract **– The current paper presents the designing and technological manufacturing process of the 2.5kW horizontal - axis wind turbine (HAWT) blades mold. The stages of the process from the 3D modelling to the manufactured parts are presented. Firstly, a CAD model of the blade is realized using airfoil cross-sections and with Mold tools from Solidworks the model of the semi-molds are defined. After then for the technological process a CAM simulation is done. The semi-molds are manufactured by using the cutting process using a CNC machine. The infrastructure that NRDI COMOTI has at its disposal was implied in order to obtain the blades mold.**

Index Terms **– HAWT, mold, technological design, manufacturing, blades.**

I. Introduction

In terms of functionality, a wind turbine blade can be divided into two areas of interest, as shown in Fig. 1 . The first area regards the aerodynamic characteristics of the blade – aerodynamic area, whereas the second one refers to the blade's resistance – structural area [1].

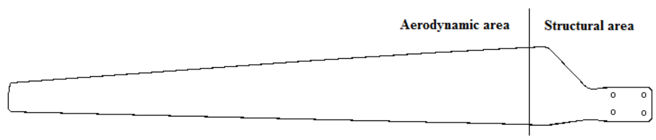
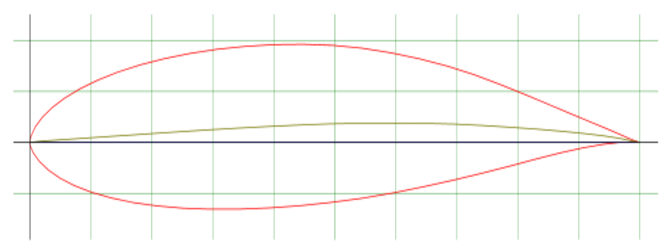


Figure 1. HAWT blade's areas.

The main objective when designing an aerodynamic area is based on the transformation of wind kinetic energy into lift, which is used to generate torque [2]. On the other hand, the structural area is designed to resist high values of bending torque, which reach a peak value at the hub, where the blade is linked to the central shaft [3].

The designing process for wind turbine blades implies the selection of a series of airfoils with specified geometry parameters, meaning a selected type for the airfoil, the chord length, the twisting angle and the position for the airfoil's centers in each radial section [4]. According to the given requirements, one can choose the optimal configuration for airfoils from an open access data base, which includes various standardized aerodynamic airfoils.

These aerodynamic airfoils generally have a chord length equal with the unit and are available in cartesian coordinates x and y. For example, in Fig. 2 airfoils S822 and S823 are presented, which are generally used in the development of wind turbines. These particular two airfoils are suited for small turbines that generate between 2 and 20kW power output. For small blades, the tip-region airfoil is S822 and for the root-region airfoil S823 is used [5].



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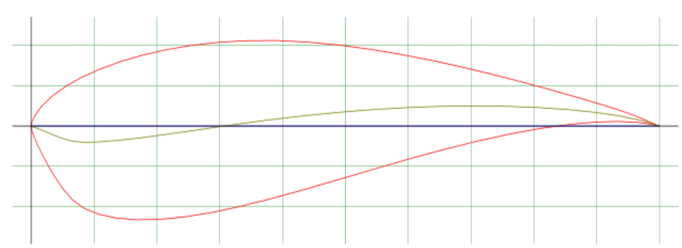

b)

Figure 2. Aerodynamic airfoils NREL: a) S822; b) S823

In order to obtain better aerodynamic performances and to reduce stresses in the structural area, but also to improve the life span of the wind turbine's blades, the optimization process can be done in 2D on the aerodynamic profiles [6]. After

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importing the coordinates for every airfoil, the designers use standard procedures to define and smoothen the composing surfaces of the wind turbine's blade.

In the wind blade manufacturing from composite materials it is necessary to have a mold [7]. For high precision and satisfying surface roughness this mold can be realized by using the cutting process [8]. The cutting process implies the removal of the manufacturing addition from the surfaces of the rough pieces, that were obtained through casting, stamping, forging or lamination. The size of the manufacturing addition depends on the method used for creating the semi-finished shape, the configuration and complexity of the part, material type and also the production character (small or large series).

The manufacturing addition is removed as splinters. This addition should be as small as possible in order not to waste metal resources and in order to reduce the consumption of cutting tools.

II. Methodology

In the current paper the designing process and technological manufacturing process of the semi-mold for the blade of a HAWT of 2.5 kW were realized.

The mold design implies taking decisions regarding: the operating mode, the power mode, opening, alignment etc. The active part is integrated in the mold and consists of two main elements. One of them is the core, which is the fixed part and represents the interior surface of the piece and has a negative tilt. The other one is the cavity, the mobile part, which consists of the exterior surface of the piece and has a positive tilt.

In order to realize the mold, a first step is represented by the CAD model of the turbine's blade (Fig. 3), which is done by importing the curves that define the aerodynamic airfoils. In Tab. I the main characteristics for the blade are given for each section of interest, as well as the type of airfoil used.

TABLE I. Blade Characteristics

Section No.	Radius [m]	Chord [m]	Airfoil Type	Twist Angle [º]
S1	0.28	0.183	S823	16
S2	0.29	0.188	S823	16
S3	0.39	0.178	S823	14
S4	0.55	0.162	S822	11
S5	0.84	0.133	S822	2
S6	0.855	0.132	S822	2
S7	1.5	0.067	S822	-2

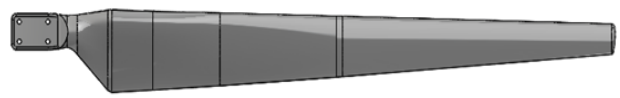
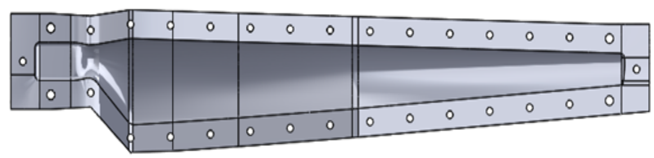


Figure 3. 3D CAD model of the blade

The designed mold is composed of two semi-molds, one for the suction side and one for the pressure side, as illustrated in Fig. 4.



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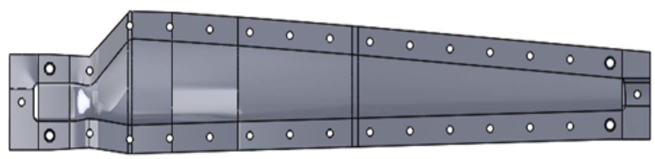

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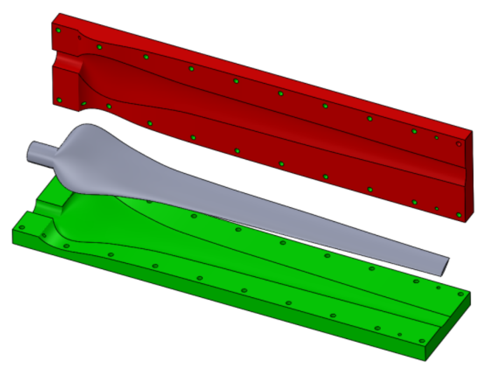


c)

Figure 4. Mold model: a) semi-mold for the suction surface; b) semi-mold for the pressure surface; c) blade's molds

The semi-molds will be manufactured from two aluminium alloy boards by using the cutting process, using the infrastructure that NRDI COMOTI has at its disposal.

The steps for the technological process are described and presented in a logical order in Fig. 5. First of all, the 2D design is realized using the cartesian coordinates of the airfoils (S822 for the root-region and S823 for the tip-region as specified before). Then, the next logical step is to generate the 3D model, which is saved as parasolid.x_t format. Before the direct manufacturing of the semi-molds, the process is simulated using a CAM software in order to ensure that the finite products meet the design conditions. The use of such a software reduces costs, as one can simulate the manufacturing process as many times as necessary until the wanted configuration is obtained, without using any material resources. In the end, the mold is manufactured using a CNC machine.

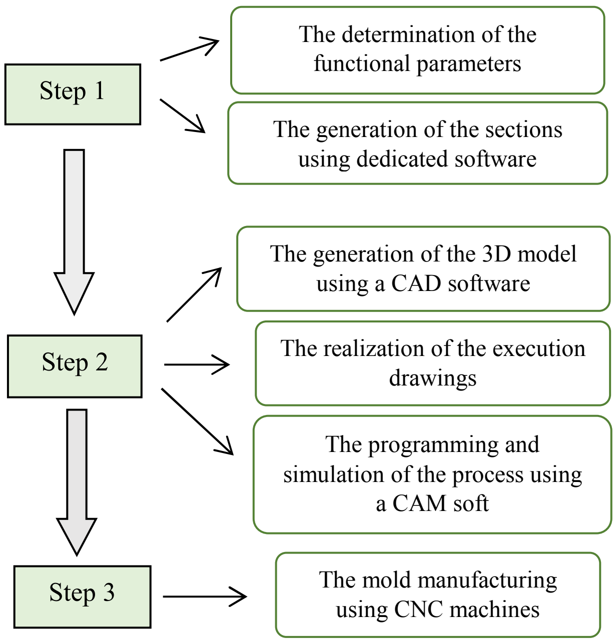


Figure 5. Designing methodology for the semi-molds

III. RESULTS

The material that was selected for the manufacturing of the mold was aluminum alloy 2017, alloy EN AW 2017A, that belongs to the 2xxx class and incorporates aluminum, copper, magnesium and silicon. Two thick boards with the characteristics presented in Tab. II were processed, using CNC machines, in order to obtain the semi-molds.

TABLE II. ALUMINUM ALLOY BOARDS CHARACTERISTICS

	Thickness [mm]	Length [mm]	Width [mm]
Board 1	80	1600	300
Board 2	60	1600	300

In order to design and manufacture the molds for the blades, CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) techniques were implied. The designing process starts with the blade's design, which was realized using the SolidWorks software. After determining the functional parameters and creating the sections using a specialized software, the next logical step was to realize the 3D model in SolidWorks. In fig. 6 one can observe the generated template.

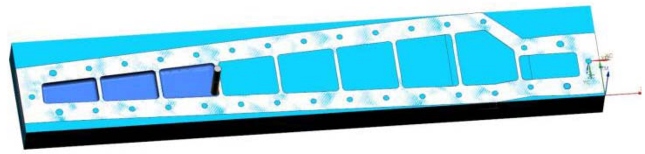
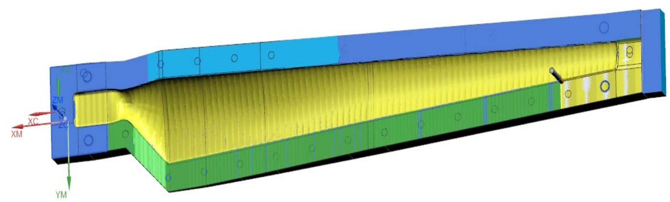


Figure 6. Generated template

In the next phase, a manufacturing technological simulation was realized using a CAM software (Fig. 7). The use of such software is preferred because it provides a manufacturing plan that is realized indirectly.



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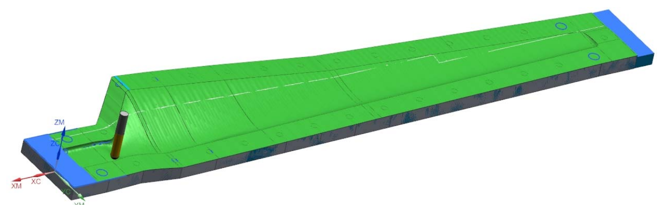


b)

Figure 7. CAM simulation of the manufacturing process: a) pressure surface; b) suction surface

Due to the surface roughness imposed by the design, different types of cutters were used for certain areas. The smallest cutter was the 3 mm spherical head. Figure 8 shows the areas where several mills have been changed.

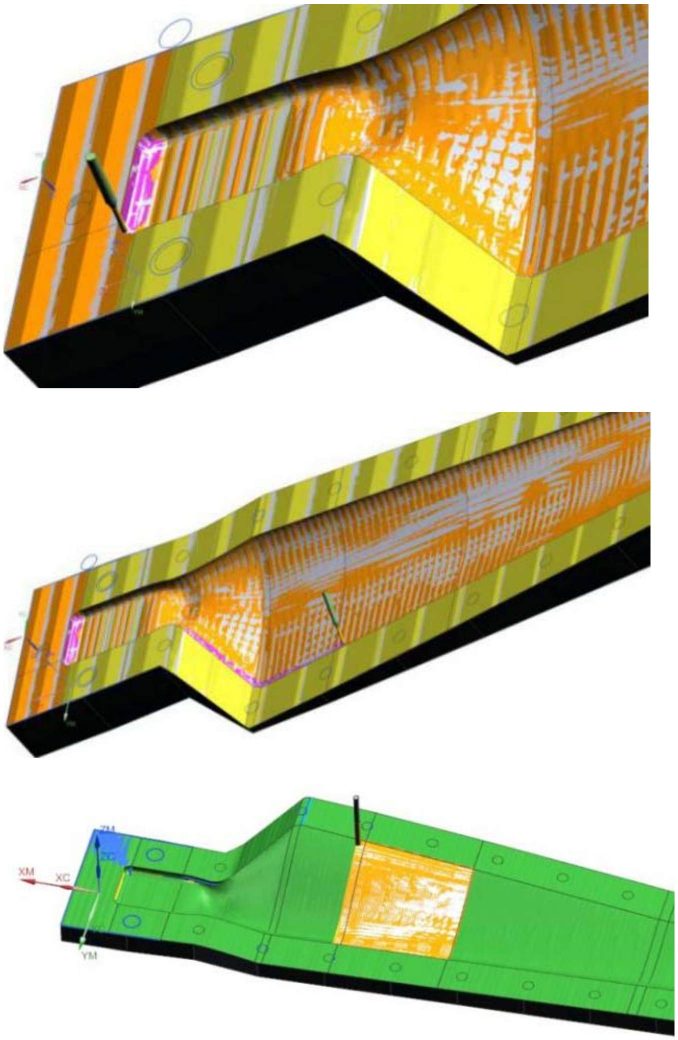


Figure 8. Mold regions where 3mm mill tool was used

In Fig. 9 the semi-mold is presented in the manufacturing phase on the CNC and in the stage with 2mm additional material in Fig. 10.

a)

b)

Figure 9. Manufacturing process: a) Mold on CNC machine; b) The manufacturing process

Figure 10. Mold prepared for finishing stage

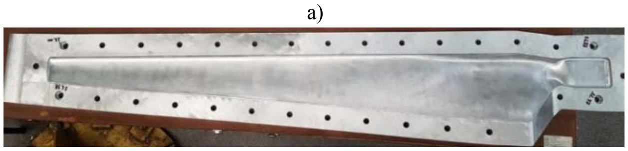
The technological process started with manufacturing the semi-mold for the pressure surface, starting with the ribs on the back. In order to proceed, 20mm mills were used at the beginning, followed by 12.8mm mills and in the end 3mm mills.

Due to the fact that the two semi-molds have a length of 1600 mm and the smoothing of the surfaces needs to be done with a 0.05 mm tolerance, the splintering process lasted for a full month. The semi-molds were realized through splintering using the infrastructure that INCDT COMOTI has at its disposal. Some details of the CNC Engelhardt Serie 8800 machine used are presented in Tab. III.

TABLE III. CNC MACHINE CHARACTERISTICS
5-AXIS MILLING MACHINE FOREST - LINE

Machine table	2000x1300 mm
X axis	2000 mm
Y axis	1500 mm
Z axis	1000 mm
C	±170
A	±110

a)



b)

Figure 11. Finished parts: a) Pressure side semi-mold; b) Suction side semi-mold.

IV. CONCLUSIONS

In the current scientific paper the designing process and technological manufacturing process of the semi-molds for the blade of a horizontal-axis wind turbine of 2,5 kW were finished.

The manufacturing technique used in order to design the molds for the turbine's blades relied on the use of CAD and CAM software. The correct implementation in CAD and CAM ensures perfect aerodynamic areas further in the process and contributes to the overall efficiency.

The proposed methodology for the manufacturing process is based on the simulation of the technological process, before implying the CNC machine for the actual manufacturing process. This approach is an economical solution and presents various advantages, making the proposed paper a reliable source for future scientific papers on the matter.

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