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Methodology for Manufacturing an Optimal Hydrofoil for Windsailing

Abstract

A methodology based on reverse engineering and a digital twin will be presented to optimize the design and manufacture of hydrofoils on special vessels. Windsurfing is a sport that is becoming more and more popular in our county, and it is precisely on this example that the proposed methodology will be applied. In the first phase, using modern laboratory measuring equipment, relevant data on speeds and fluid flow angles will be collected in real conditions when driving by professional driver Enrico Marotti. In the second phase, the tested hydrofoils will be 3D modeled by reverse engineering to create a database. In the third phase of the project, digital twins will be created, with the help of which a new, improved hydrofoil can be defined by applying numerical simulations and optimization techniques. In the fourth phase, the technological process of making an aluminum mold for new, improved hydrofoils will be designed. In the last phase, a prototype of the new hydrofoils will be made using the most modern technologies and materials and the use of numerically controlled machine tools. The prototype will be tested, if necessary optimized and directed into production by local stakeholders from the economy.

Keywords: methodology, reverse engineering, digital twin, hydrofoil, windsurfing

1. Introduction

1.1. The Goal

The goal of the project is the establishment of a methodology that includes testing in real conditions, preparation and creation of a computer model for numerical simulations and optimizations, and ultimately creation of an optimized prototype. The goal is to connect scientists and industry stakeholders, whereby a methodology once successfully established can be easily extended to other engineering problems.

1.2. Work area

The application of advanced numerical procedures to increase competitiveness in sports is becoming increasingly important [1,2]. 3D scanning enables the creation of so-called digital double [3,4] where the existing technical solution can be reconstructed in a virtual environment with a high level of detail. This enables the use of numerical simulations for the analysis of the existing, as well as the research of innovative solutions while reducing the costs of making a large number of prototypes [5,6]. In the end, the obtained solution needs to be made using modern methods of making composite castings [7-9].

The above requires significant interdisciplinary expertise, where in the specific case it is necessary to carry out the measurements necessary for the preparation and validation of numerical procedures [10,11], to determine suitable methods of 3D scanning of large objects and numerical procedures [12,13]. It is also necessary to know industrial procedures for the production of composite products by vacuum infusion or autoclave procedures, all for the purpose of satisfying and achieving the mechanical properties of the material that would satisfy the performance of the hydro wing under the given and previously determined loads. For the purpose of quality control, it is necessary to carry out a series of material tests before production [14] and immediately after production [15,16], and before assembly on the vessel.

The success of the implemented methods can increase economic competitiveness, where there are examples of good practice where a brand that produces surfboards and sportswear has been developed through the active efforts of a former athlete [17].

1.3. Activities

The results of this research included several different economic subjects. In particular, the methodology of creating a virtual double, the establishment of a numerical approach for design improvement, and the use of modern manufacturing procedures that were established as part of this project, can easily be applied to other engineering problems. The mentioned methodologies are already used in the automotive, aviation industry and many others, and their importance is recognized at the international level and leads to significant innovative solutions. In the regional ecosystem, unfortunately, the aforementioned methodologies are not implemented to the extent that they could be implemented due to the limited connection between universities and industrial participants, which is reduced to individual, specific actions. For this reason, the aforementioned cooperation between industrial and scientific stakeholders is a good example. The implementation of the project laid a good foundation that will enable scientists from other fields to establish contact with the economy in order to put their innovations into action.

2. Phase 1. – Data collection

2.1. Development of measuring equipment

As a part the research a system for measuring vessel movement, weather elements and water conditions was developed. By measuring the movement speed, acceleration, angular velocity, inclination and direction of the vessel movement and weather elements in real time, the optimisation process of hydrofoils was accelerated. Measurements were performed with a measuring device attached to the observed vessel, while measurements of weather elements and sea conditions were performed with another device on the accompanying vessel. Wind speed, direction and temperature, environmental temperature, atmospheric pressure, surface water current and wave properties were measured. By combining data from both devices, a database was created on the state of the environment and the vessel movement. Analysis of the database provided the necessary data for the optimisation of the hydrofoil.

2.2. Test pilot Enrico Marotti

Enrico Marotti is a Croatian windsurfer, Fig. 1. He specializes in the slalom discipline in which he became the world windsurfing champion in 2018 and 2021, making him the first athlete from Croatia to win that title. He won the title of athlete of the Primorje-Gorski Kotar County and the City of Opatija several times. Marotti is the first surfer from Croatia who managed to sign a professional contract and is the founder and head of the sailing school Marotti Windsurf Center in Volosko. [18]

Figure 1: Enrico Marotti [19.].

2.3. Conclusion of the conducted testing

The goal of testing within Phase 1 was to gain an insight into the state of the market, that is, to examine the performance of competitive hydro wings available on the market and to determine room for improvement and optimization. The current best wing with which the world speed record was broken was singled out and was chosen as a benchmark for further modifications and optimizations.

3. Phase 2. – Application of reverse engineering

3.1. 3D scaning

The selected foil was scanned at the Center for Advanced Computing and Modeling of the University of Rijeka using a modern 3D scanner, Figure 2. The editable digitalized computer model was obtained.

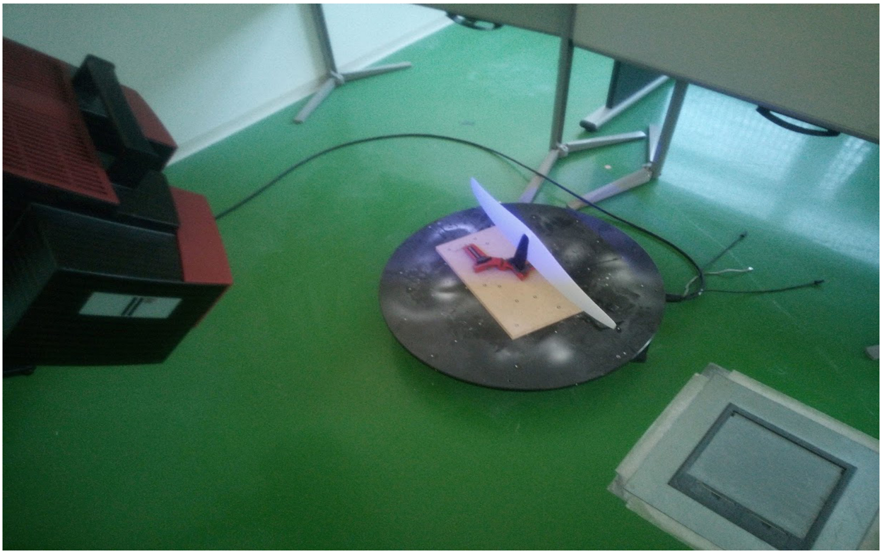

Figure 2: 3D scanning procedure of the hydro wing

3.2. Creating a 3D model of prototype "0"

The generated digital model was geometrically modified based on the measurement results and feedback from the test pilot. The new form of the zero prototype, Figure 3, represents the basis for the creation of a digital twin, which will be used for production and further testing and development.

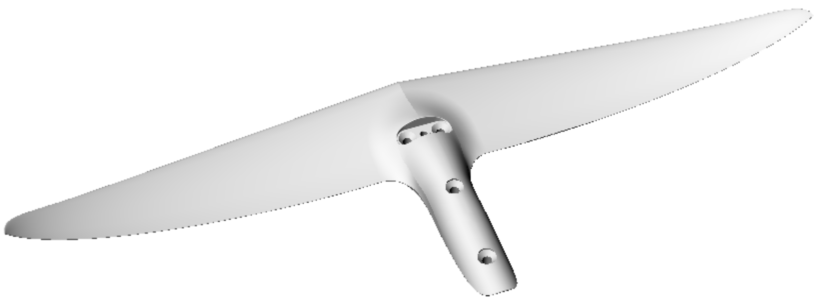

Figure 3: Prototype "0" hydro wing

4. Phase 3. – Creating a digital twin

A digital twin is a virtual model of a product or even an entire system. It is based on a simulation and a virtual model of the object itself connected with information from the real world. In this way, the virtual model represents the most similar copy of the realized solution in reality. By using simulation, the virtual model is brought to life with data from the real world and enables a deep understanding and optimization of all changes before the actual implementation, Figure 4. Such development of prototypes becomes incomparably faster and more economical [20].

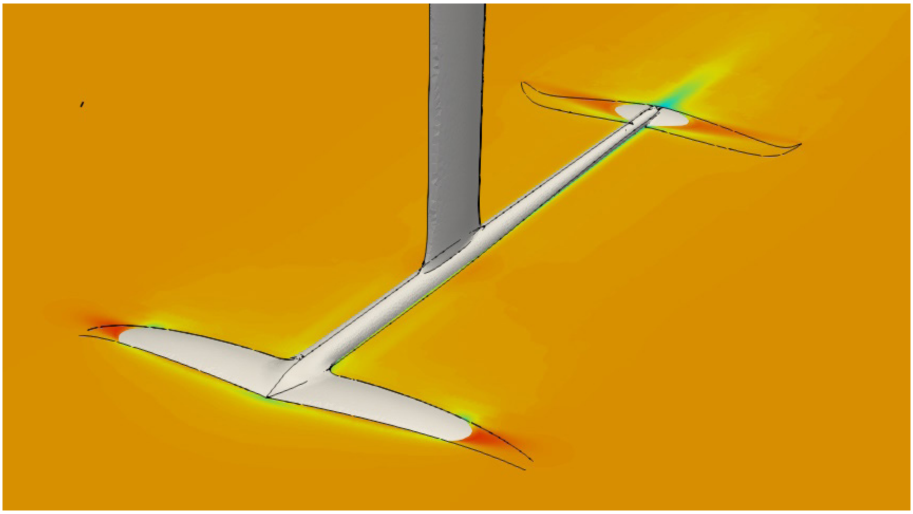

Figure 4: Digital twin of prototype "0" hydro foil

5. Phase 4. - Making molds and prototype "0"

For the creation of the zero prototype, a 3D model of the mold, Figure 5, was established as the basis for generating the NC code for numerical production.

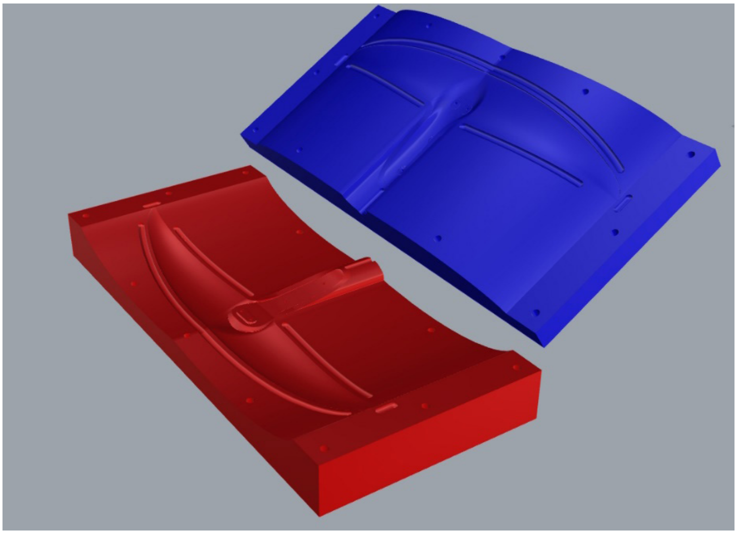

Figure 5: 3D model of the mold

In the next step, the mold was made from an aluminum block by NC milling, after milling, surface preparation and installation of the carbon structure for the first zero prototype was performed, Figure 6. The production of the zero prototype itself was carried out by applying previously, in laboratory conditions, impregnated carbon fibers in epoxy resin. The laminate is vacuum-bagged and heat-treated in accordance with a confidential procedure, Figure 7.

Figure 6: Aluminum mold

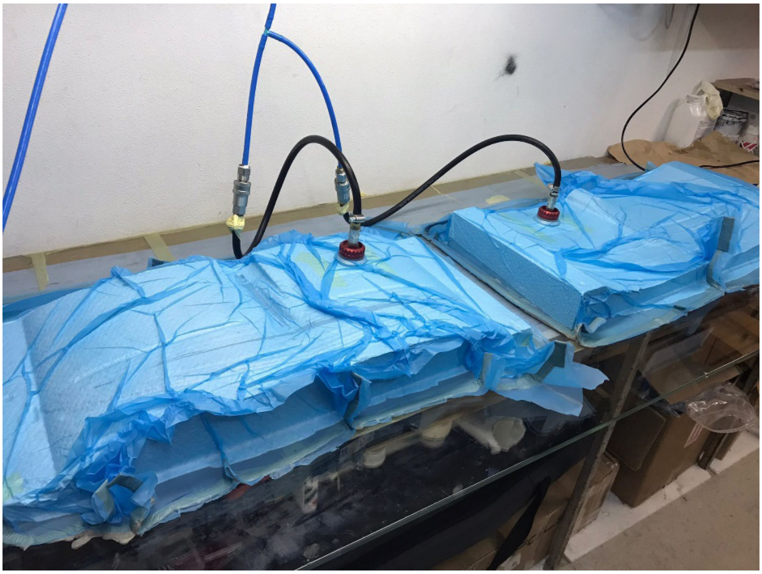

Figure 7: Vacuum bagging procedure

At the end of the process, the first "0" prototype, Figure 8, comes out of the mold, which needs to be trimmed around the perimeter. The same procedure was repeated several times, changing the laminate plan, that is, the mechanical properties of the hydro wing in order to determine by testing which mechanical property contributes the most to the performance of the hydro foil.

Figure 8: odljevak prvog prototipa „0" hidro krila

6. Conclusions

In this paper, the methodology for making hydro wings for windsurfing is presented. The methodology itself, in the several stages presented, included market research, creation of a digital twin as a basis for optimization processes, preparation of production of the zero prototype, and final creation of the same. Examining and testing prototypes with data collection will enable an iterative process that will converge to the optimal solution.

7. Acknowledgements

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