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3D PRINTED SOLAR CATAMARAN MODEL DESIGN AND EMBEDDED SENSING SYSTEM APPLICATION

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ABSTRACT

Technology, energy shortage and maintainability are placed emphasis on global energy policy. Solar energy gives solutions to all around the world. Nowadays, all energy forms are counted as solar origin. In the long term, unmanned and remotely controlled ships will be significant on marine applications. For this reason, remote controlled, solar powered, model catamaran design and embedded sensing system have become important aspect for on board maritime applications.

In this paper, remote controlled model catamaran was designed and printed with additive manufacturing technology. Various type sensor modules were installed on the catamaran. Weather prediction is the most important aspect in maritime transportation. Thereby, aim of the study was determined as predicting weather conditions of the environment such as temperature, absolute pressure, humidity of the air. Furthermore, voltage and current of the ship motors were measured, sensor data were saved, and measurements were demonstrated with graphical charts.

Ultimately, model ship design can constitute basis following patent studies with its intermediate and final outputs. On the other hand, 3D printed catamaran model saves energy by using renewable energy and creates nearly zero emission.

Keywords: Remote Control. Additive Manufacturing. Catamaran. 3D Printing. Solar Energy. Sensing System.

1.INTRODUCTON

Ship models have been started nearly five thousand years and it is possible that some may yet be discovered perhaps in Crete, or on one of the Aegean Islands, or in some other place of Eastern Mediterranean region where the earliest civilizations were mostly lived. By the year 2000 BC, the Egyptians were used for practical purposes and practical use of model ships and boats maybe considered to have begun on the banks of the River Nile [1].

Ships models were produced for practical purposes in the dockyards of almost every maritime nation. These ships have been manufactured for several centuries by sailors wishing to obtain divine protection, aesthetic reasons, also toys of the children. Active or retired sailors were made models which are closely related with the sea that is shown in Figure 1 [2]. Beginning of the 20th Century, amateur ship model kits became available companies in United Kingdom and United States. Early 20th century models comprised a combination of wooden hulls and cast lead for anchors, deadeyes, and rigging blocks. These materials gradually gave way to plastic precast sets [3].

Figure 1: Model passenger ship.

Model boats are produced with wood, pottery, stone, metal, ivory and plastic. According to American Society of Mechanical Engineers, favourite materials for 3-D printing are defined as sintered powdered metal, metals, carbon fiber, composites, carbon nanotubes and graphene embedded in plastics, nitinol, water-absorbing plastic, stem cells, conductive carbomorph, paper, concrete, food, yarn [4]. 3D printing thermoplastic materials used in fused deposition modeling (FDM) include, acrylonitrile butadiene styrene (ABS); acryloni-trile styrene acrylate (ASA); nylon-12; polycarbonate (PC); polyphenylsulfone (PPSF/PPSU); polyetherimide (PEI or ULTEM); polylactic acid (PLA); thermoplastic polyurethane (TPU). Material [5] and also polyvinyl alcohol (PVA) used as water-soluble support material [6]. 3D printing technology ensures that topological objects, which cannot be produced by normal production methods, are more accessible than ever [7]. In recent years, many studies have been carried out on 3D printer technology and manufactured products. For example, Aydın et al. [8], produced a vertical type extruder design and prototype capable of producing filament from granular plastic raw material for 3D printers. Tensile test specimens were printed, and tensile tests were carried out using PLA (Polylactic acid) commercial filament via designed extruder. In addition, total electrical energy consumed per hour, raw material processing capacity and energy consumed per material were measured.

Nowadays, model boats are manufactured by thermoplastic materials with the spreading of three-dimensional (3D) printing. 3D printing technology is an additive manufacturing process which product are built on a layer-by- layer with series of cross-sectional slices. 3-D printers generally use thermoplastic filament and powder. Materials that are printed are produced with the help of 3-D CAD software to determine exactly how each layer is to be constructed [9].

Marine vehicles should have many components to observe activities near their environment and weather [10]. Therefore, weather monitoring and its forecasting has become important part of marine applications. Measuring the weather using conventional methods require skilled personnel for operation and maintenance which increases the life cycle cost [11]. Thus, aim of the study is determined as predicting weather conditions of the marine environment such as temperature, absolute pressure, humidity of the air and solar energy power. In that manner, 3D Printed, remotely controlled solar catamaran is designed to fulfil these requirements. Furthermore, the maritime sector needs marine vehicles in difficult weather conditions and in places where people have difficulty in accessing.

2.MODEL SOLAR SHIP DESIGN

The design of the ship was decided to be multi-hulled watercraft as known “catamaran” due to high stability with wide beam comparing with mono-hull boats. Catamarans typically have less hull volume, shallower draft and less propulsive power requirement than mono-hulls of comparable length. Besides that, catamaran deck is suitable for locating weather station components with its wide beam.

Remote controlled, model solar ship design process started with surface modelling on Rhinoceros CAD software as shown Figure 2. Surface model is transferred to Solidworks CAD software and catamaran models converted to solid model and saved as stereolithography (.stl) format that is suitable for 3-D printing.

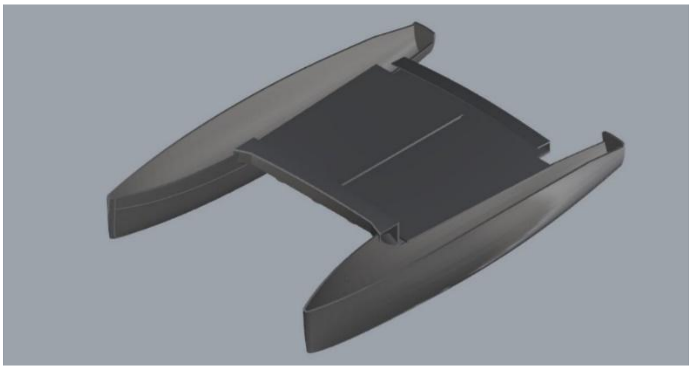

Figure 2: Catamaran hull design

Geometry with .stl format is modified and repaired by Netfabb additive manufacturing and design software. Later, 3-D Print geometry is opened with Simplify 3D printing software. Geometry of remote controlled, model solar catamaran's hull is shown in Figure 3.

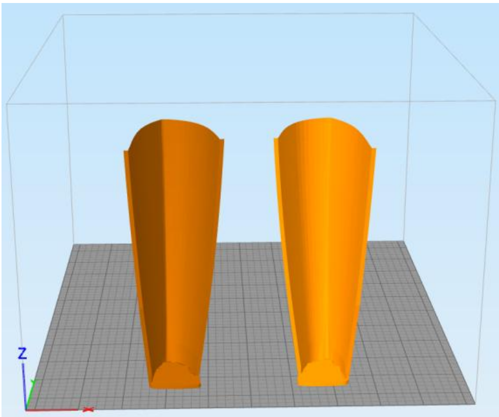

Figure 3: Remote controlled, model solar catamaran's hull on Simplify 3D software

3. MODEL SHIP HULL MANUFACTURING WITH 3D PRINTER

3D printing can be described as additive manufacturing (AM). In the International Organization for Standardization (ISO)/American Society for Testing and Materials (ASTM) 52900:2015 standard, AM is defined as the "Process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies" [5].

Manufacturing process was performed by Leapfrog Creatr HS 3-D printer (Figure 4) with FDM via thermoplastic ABS thermoplastic filament. ABS filament and build platform were heated up 250 ^{0}C and 50^{0}C, respectively during printing process.

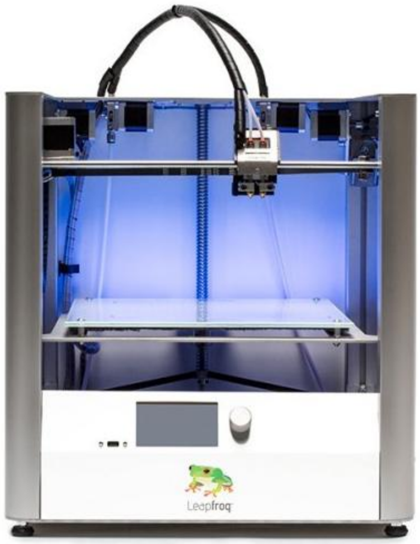

Figure 4: Leapfrog Creatr HS 3-D overview.

Cooling fans was disabled for whole process to prevent warping of printed material. Technical specifications of the 3D printer are shown in Table 1.

Table 1: Technical specifications of Leapfrog Creatr HS

Specification	Metric
Build Size Single Extruder (DWH)	280 x 270 x 180 mm
Build Size Dual Extruder (DWH)	280 x 240 x 180 mm
Build Volume	13.6 L
Heated Bed	Max. 90 ℃
Hot End	Max. 275 ℃
Number of Extruders	2
Extruder Size	0.35 mm
Filament Size	1.75 mm
Layer Thickness	0.02 – 0.35 mm
Max. Print Speed	18000 mm/min. or 300mm/sec.
Max. Travel Speed	24000 mm/min. or 400mm/sec.
Supported Materials	ABS, PLA, PVA, Nylon

Catamaran hull was divided into four sections. Each section was printed separately due to printable area dimensions. 3D Printed Catamaran dimensions is given in Table 2 and side view is shown in Figure 5.

Table 2: Model catamaran dimensions.

Parameter	Dimensions
Length (mm)	450
Height (mm)	200
Width (mm)	330

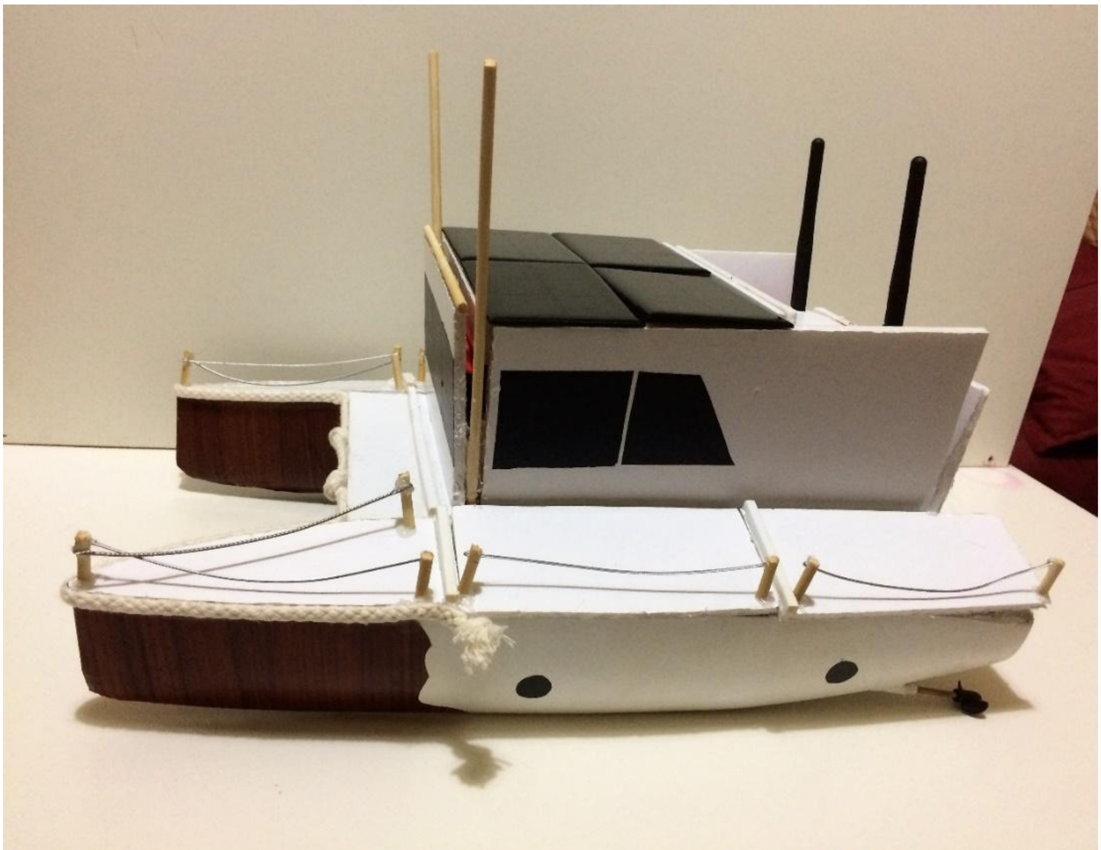

Figure 5: Model catamaran.

3. IMPLEMENTATION OF REMOTE CONTROL AND ON-BOARD SENSING SYSTEM

In the frame of the project, an embedded sensing system was established into the catamaran for the purpose which can be used as on board weather station. Further parts of catamaran are solar panels, remote control modules, sensors, batteries, DC motors and shafts, micro controller board, wireless transceiver communication modules and joystick shield modules. Extensive presentation is shown Table 3 below:

Table 3: Model catamaran equipment.

Equipment	Specifications	Pieces
Micro controller Board	Arduino UNO R3 Development Board	4
Wireless Transceiver Communication Module	NRF24L01 Wireless Transceiver Module with SMA Antenna	4
Joystick Shield Module	Funduino Joystick Shield Module for Arduino	1
Sensor Shield	Arduino Sensor Shield v5.0	1
Motor	TAMIYA Mabuchi RS-240DC Motor	2
Propellers	30 mm dia. FPP Propeller	2
Shafts	RABOESCH 300-04 Stainless Steel Shaft	2

Table 3(Cont.): Model catamaran equipment.

Equipment	Specifications	Pieces
Solar Cells	1.5V 500mA 110x66mm Solar Cell	4
Batteries	4.8 Volt 1300mA Rechargeable Battery	12
Motor Driver	L298N Dual Motor Controller Module	2
Voltage Regulator	LM2596S DC-DC Step-down Module (Max. 3A)	1
Display	N5110 LCD Display	1
Temperature and Humidity Sensor	DHT11 Range: 20-80% RH / 0-50°C	1
Pressure Sensor	BMP180 Range: 300-1100 hPa	1
Current Sensor	ACS712 Range: 0-5A	1

Remote control system was designed with embedded micro controllers, wireless transceiver modules, motor drivers, DC motor, joystick driving module. Schematic view of remote-control system is shown in Figure 6. Propulsion system which is remotely controlled consist of two reversible DC motor, shaft, couplings and propellers. Wireless communication and remote-control algorithm were coded in Arduino IDE Software with C++ programming language.

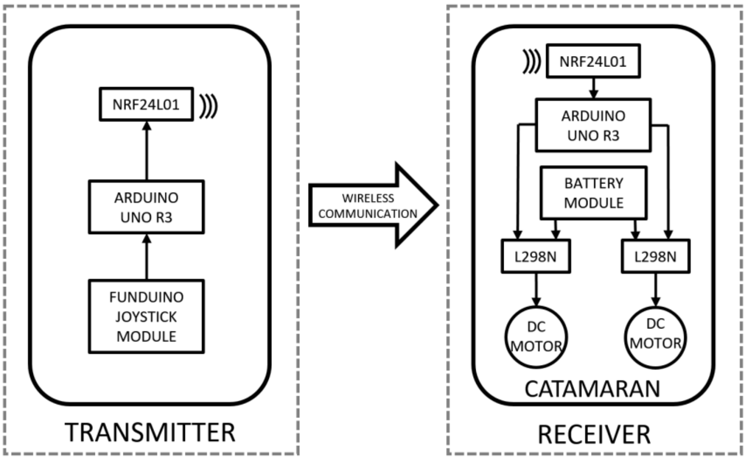

Figure 6: Catamaran remote control system diagram.

Temperature, absolute pressure, humidity of the air, and solar energy power were measured by catamaran sensor system which was used as weather station. Besides that, electrical parameters as well as voltage and current of the ship motors were measured, measurements were stored in SD card module. DHT 11 temperature and humidity sensor was used to determine ambient temperature and relative humidity of catamaran's surroundings. Absolute pressure was measured with BMP 180 sensor. Furthermore, DC motor and solar panel voltage-current data were monitored with voltage and ACS712 current sensor. Sensor values were displayed with Nokia 5110 LCD module in discrete time intervals. Catamaran remote control system is demonstrated in Figure 7.

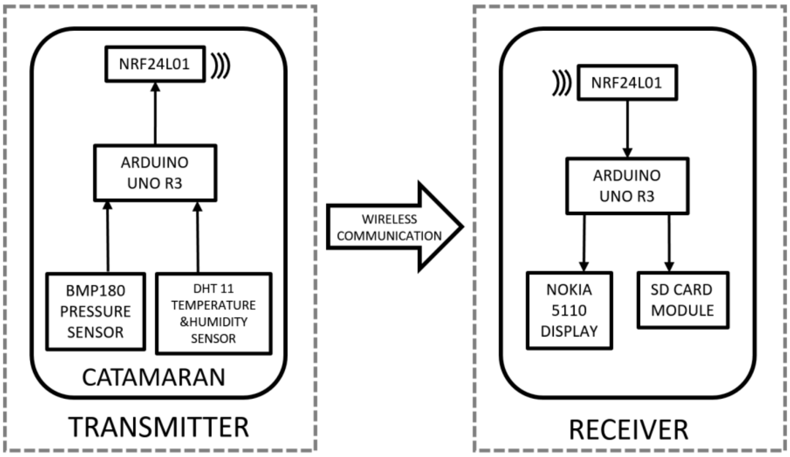

Figure 7: Catamaran remote control system diagram.

5. RESULTS and DISCUSSIONS

Temperature, relative humidity, absolute pressure of environment was measured by implemented weather station system on model catamaran ship. Besides that, voltage/current values of DC motors and solar panels are obtained by sensors. Saved data was displayed by LCD module as shown in Figure 8.

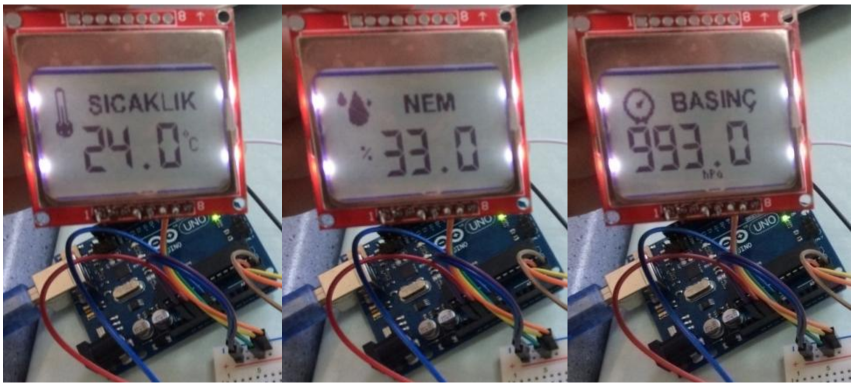

Figure 8: Weather station monitoring on LCD display.

Four pieces of generic solar cell panels are mounted on top of the catamaran. 1.5V and 480 mA solar panels are connected serially. According to measurements, 6V of voltage and 2.88W of power is achieved in total which is enough to support the batteries on board.

During the day, ambient measurements which were collected by weather station are demonstrated hourly in 4-hour time in Figures 9,10,11.

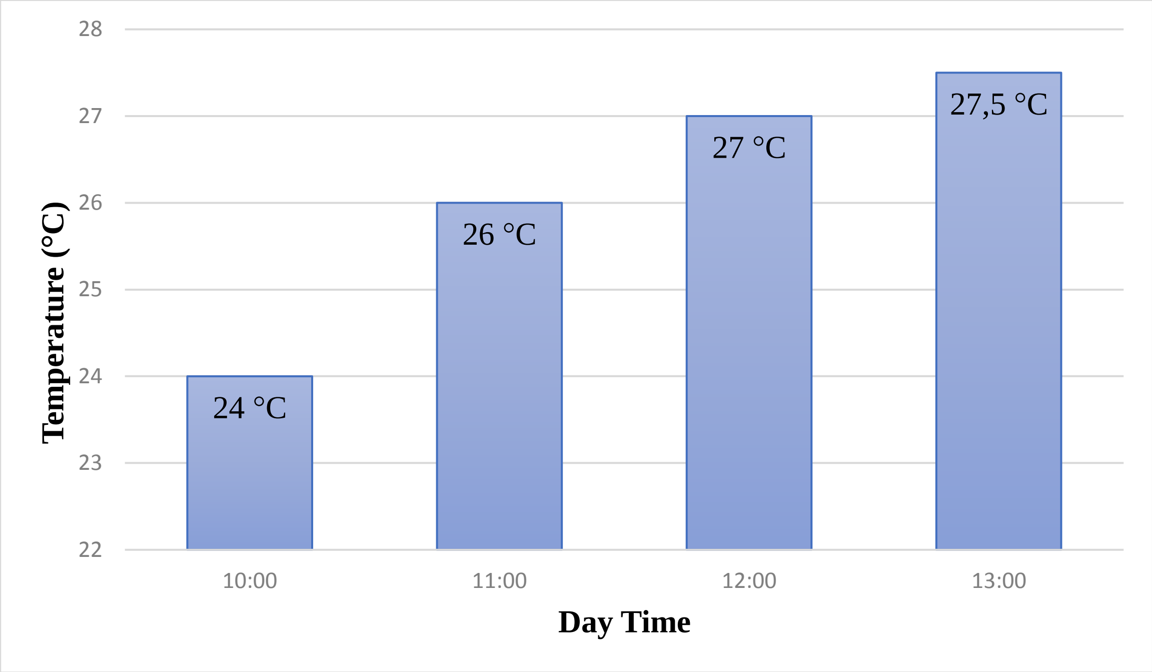

Figure 9: Temperature measurement of weather station.

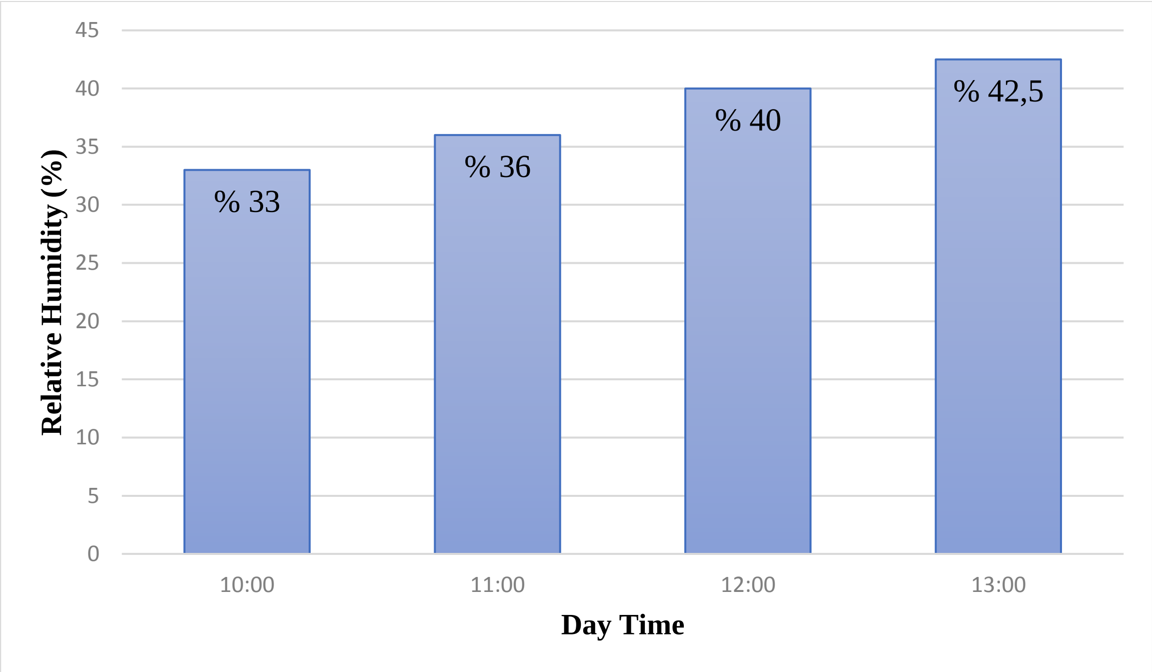

Figure 10: Relative humidity measurement of weather station.

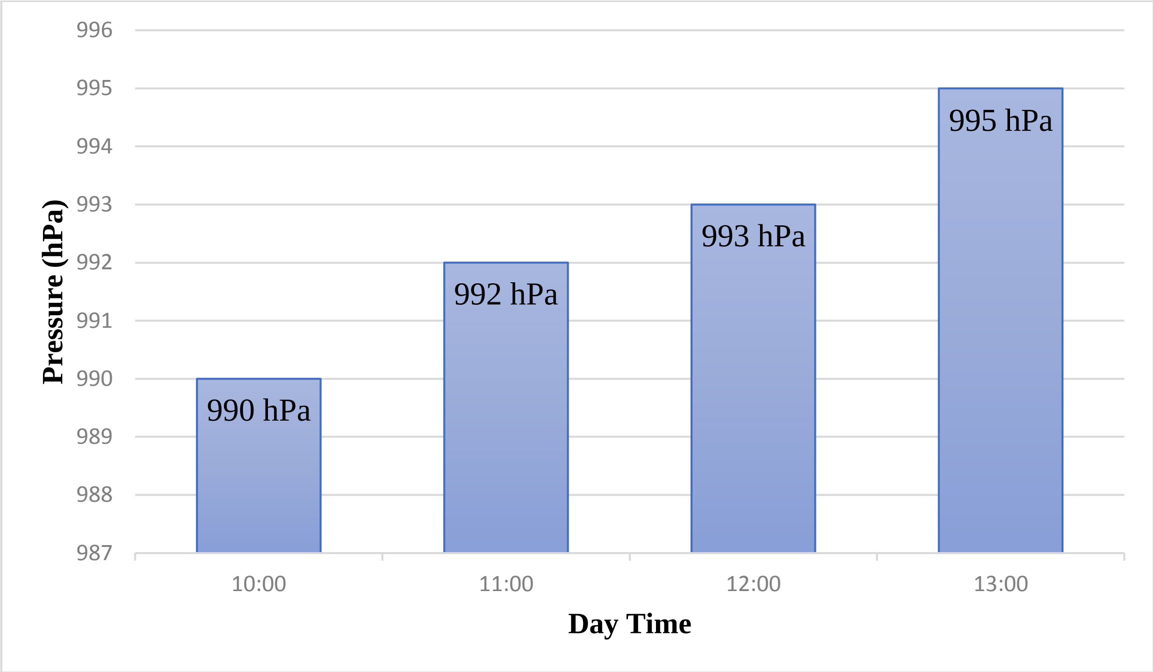

Figure 11: Pressure measurement of weather station.

3D Printed model catamaran water tests were applied in a closed dock which is shown in Figure 12.

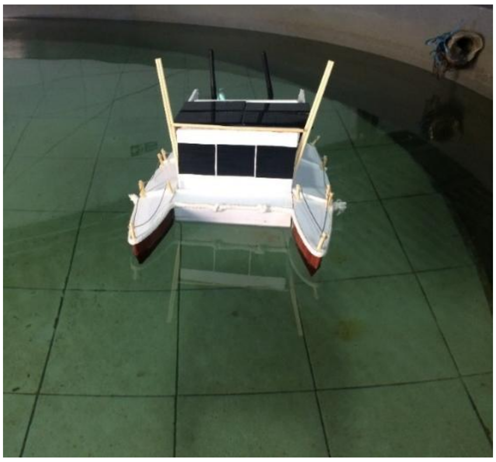

Figure 12: Water tests of model catamaran.

6. CONCLUSION

This paper is focused on developing an unmanned, remotely controllable and eco-friendly catamaran model ship. Through renewable energy resource of the sun, model catamaran creates zero emission. In the realization of this study, the use of 3-D printing technology has increased the speed and efficiency of design and manufacturing process. It provides advantages such as easy machining, low cost, strength, short production time compared to conventional model building methods.

Thanks to the sensors and data collection tools applied on the boat, it is possible to monitor, store and evaluate meteorological data which is crucial for marine applications. Besides of these capabilities, the designed wireless remote control and data transferring system allows to operate in hazardous conditions such as radioactive, chemical and extreme weather.

As a future work, it is planned to implement wider sensor range, different type of sensors for further measurement applications. Through the outputs and idea of this study, it is expected that usage of renewable energy, remote control and sensor systems will take place much more in the marine systems.

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