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RIVER WATERCRAFT FOR PASSENGER TRANSPORT

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Abstract: *This paper presents the design of a watercraft that will be made under a cross-border project. It shows the detailed construction plans of the hull, the basic requirements that any marine vehicle must meet, the hydrostatic and stability calculations for the watercraft in order to determine how its weight and the shape of the hull can affect its performance and safety; the assessment of the efforts developed within the hull are calculated with SolidWorks.*

Keywords: watercraft, hybrid power generation system

1. Introduction

The ship is a complex elastic system and its structure is subject to stress and which accounts for the choice of constructive solutions [1, 9]. There are many alternatives in the construction of boats, as well as ways to reduce or replace fossil fuels, such as using sails and kites, electric power in ports, biodiesel, wind turbines, photovoltaic solar panels and fuel cells that use hydrogen as fuel. These can be used either exclusively or in combination with conventional power plants based on fossil fuel; they form what is called *hybrid power generation system* on board ships [2, 3]. A model boat that has the following characteristics is put forward: length L = 10 m; width B = 3.1 m; maximum draft: 1.1 m; moment of inertia in relation to the longitudinal axis: I_L= 21.23 m^4; moment of inertia in relation to the transversal axis I_T=245.24 m^4; maximum volume draft of 1.1 * V = 24.5 m^3; block coefficient C_B=0.72; transport capacity = 20 people; area for installation of solar panels on board A_w=30.2 m^2.

Inertia of floating surface about longitudinal axis I_L= 21,23 m^4 ; Inertia of floating surface about transversal axis I_T=245,24 m^4 ;

Based on the plans, the hull was done by using SolidWorks which also helped to evaluate the hull's mass and the position of the gravity center, as shown in figures 1, 2, 3 and 4. Figure 5 shows a side view of the 3D model in SolidWorks in which the simplicity of the concept is to be noted and also the limited requirements of the plate bending. Figure 6 shows an isometric view, and Figure 7 shows a 3D model trimetric view made in SolidWorks; they both represent models of hulls of pleasure boats

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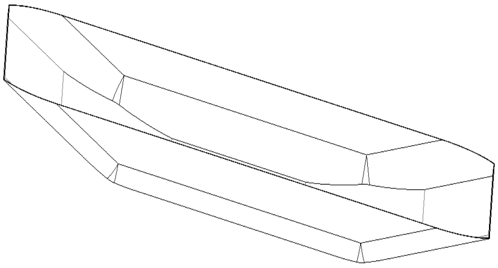

Fig.1. Isometric General Diagram of a Multipurpose River Boat

Fig.2. Side General Diagram of a Multipurpose River Boat

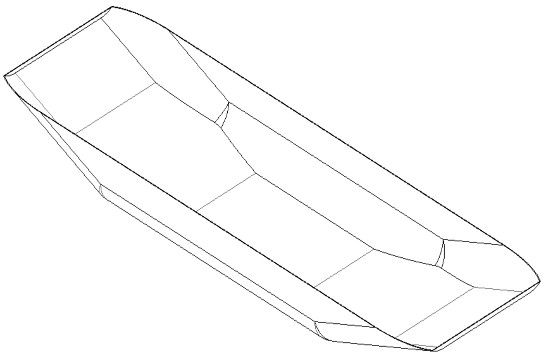

Fig.3. Trimetra General Diagram of a Multipurpose River Boat

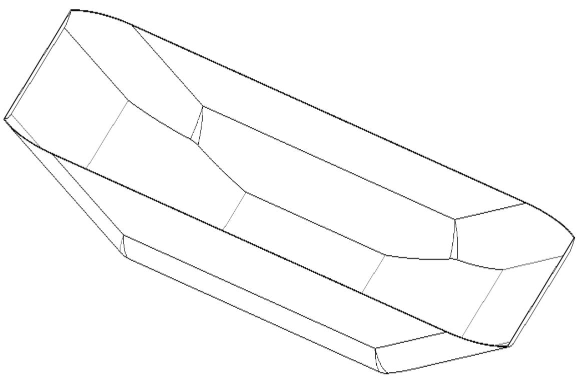

Fig.4. Dimetra General Diagram of a Multipurpose River Boat

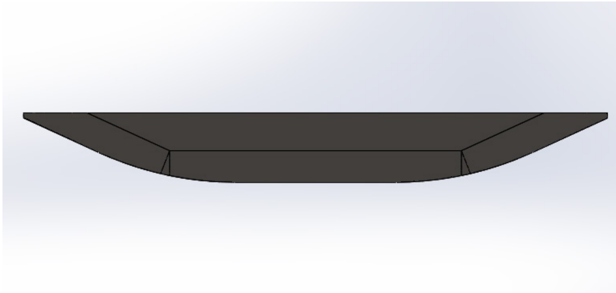

Fig.5. Side View of 3D model made in Solidworks

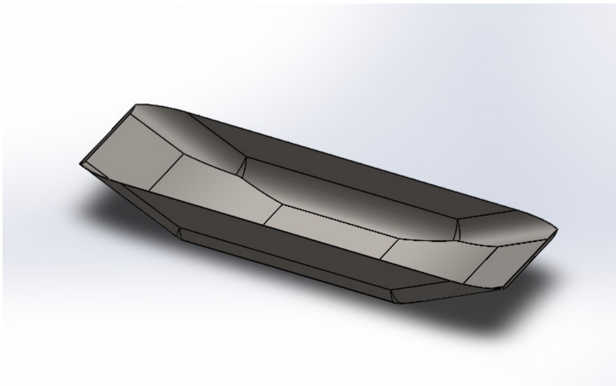

Fig.6. Isometric View of 3D model made in Solidworks

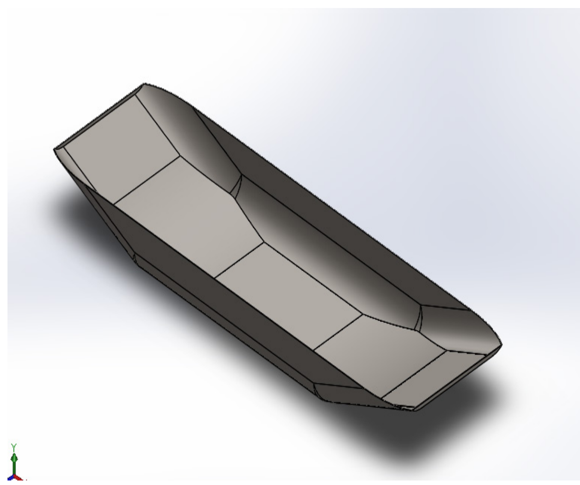

Fig.7. Trimetra View of 3D model made in Solidworks

The approximate calculation of the number of persons who can be accommodated aboard safely is done as follows:
No. of pers. = (L*B)/1.5
where: L-length of watercraft, B- width of watercraft

2. Design Requirements

Taking into consideration the type of watercraft, its speed, useful load, autonomy and operating conditions [4, 5, 6]. The basic requirements that each marine vehicle should comply with are as follows:

1. The craft shall have sufficient buoyancy. This means that the displacement of the craft should be equal to its total weight.
2. The craft shall be economical and easy to build and operate within practical limits.
3. The craft shall be stable enough to avoid capsizing due to waves which are to be regularly encountered during its operation.
4. The craft shall have such a structural integrity so as to prevent any damage to the craft itself or to passengers.
5. The craft shall be able to cut the waves without excessive movements.
6. The craft shall be resistent to fire, explosion, collision and grounding. Both the crew and the passengers shall be provided with sufficient lifesaving equipment.
7. The craft shall be manoeuvrable and have sufficient power to be underway.
8. The craft shall have self-autonomy during its entire voyage.

3. Determining hydrostatic and stability requirements

The hydrostatic (volume) calculations provide information about the hull's shape when vertically positioned while the stability calculations provide additional information that is useful during its recovery when the watercraft has a list. [1].

The hydrostatic calculations determine the hull's shape for any plan of in-line floating. These properties include volume displacement, center of buoyancy, wet surface, metacentric heights and the fine coefficients of the hull. In terms of design, there are two ways to address these calculations [1, 4, 7]:

Method A. First, a waterline (the draft amidships and the trim) is set as well as the calculated properties of the hull, including the displacement and the longitudinal coordinate of the center of the hull (LCB), which will be equal to the weight of the craft and, respectively, the longitudinal coordinate of the center of gravity (LCG). If the designer begins the design process by drawing the waterline on the profile section of the hull, s/he can use draft and trim values (usually a boat is designed to have zero trim or almost zero) in order to calculate the corresponding values of displacement and LCB. The calculated value of displacement shall be equal to the sum of all weights, and LCB position shall match the longitudinal position of all weights of the craft (LCG). If not, then the waterline or the weights shall be modified.

Method B. First, displacement and LCG are known, the properties of the hull have been calculated, including the waterline (draft and trim). This is the opposite of the example calculation of draft and trim. The program shall search the waterline (draft and trim) that fits both the targeted displacement and LCG (LCG shall match LCB position). If the resulting value of the waterline is not appropriate (too high / low or the trim varies considerably in relation to zero value), part of the weights and / or their positions need to be modified or the hull's shape needs to be changed. During the design stages, the designer may find that the longitudinal position of the center of gravity (LCG) does not coincide with the longitudinal position of the center of the hull (LCB) for any trim. This means that the boat will be trimmed either by the head or the stern until the position of the center of hull (LCB) is modified in order to coincide with the LCG position.

4. Archimedes' Principles and the Forces of Gravity

Two forces are exherted upon the river boat in its state of rest:

- force of gravity:

$$\overrightarrow{F_g} = -g\Delta\vec{k}; \quad (1)$$

- hydrostatic force:

$$\overrightarrow{F_p} = \rho g V\vec{k} = \gamma V\vec{k}. \quad (2)$$

In equations (1) and (2) the following notations have been made :
g[m/s^2] – gravitational acceleration ; V[m^3] - volume of the ship's hull ; Δ [t] – ship's weight (displacement); ρ [t/m^3] – water density; γ [kN/m^3] – specific weight of water.

In order to keep the ship in equilibrium , it is necessary that the torque of the two forces be null:

1. The force of gravity is equal to the force of buoyancy $\Delta = \gamma V$;
2. The two forces act in the same medium : $x_B = x_G$, $y_B = y_G$.

The density of fresh water is ρ=1 t/m^3, and the density of the salt water ranges from 1.005 t/m^3 and 1.088 t/m^3, depending on the area and season.

5. Assessment of Efforts Developed in the Hull that Have Been Calculated Using Solidworks

We shall study the mechanical behavior of the ship's hull using SOLIDWORKS under the action of an onboard mass distributed on deck boat and under the action of the buoyant force distributed on the ship's hull as well as the selection window of the material the watercraft is made of - Fig 8, 9, 10, 11, 12, 13, 14, 15, 16.

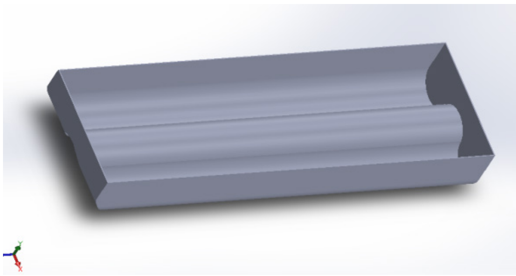

Fig. 8. Simplified model made in Solidworks SHELL function

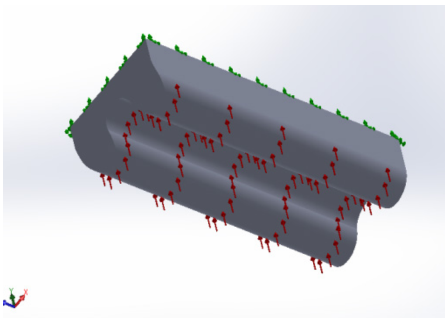

Fig.9. Adding buoyant forces and pressures on the hull

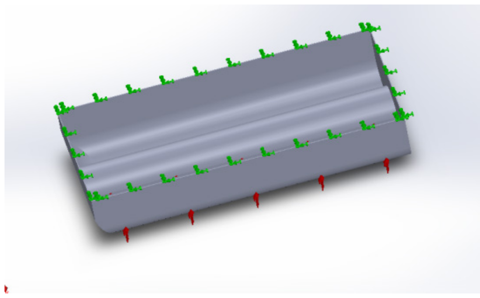

Fig.10. Isometric image of stress the watercraft is subject to

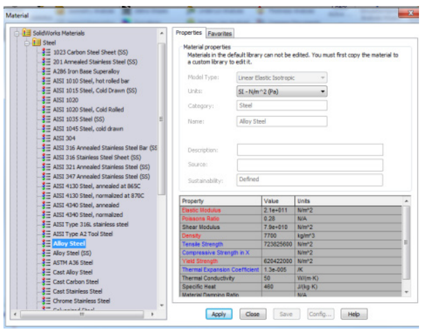

Fig.11. The selection window of the material the watercraft is made of

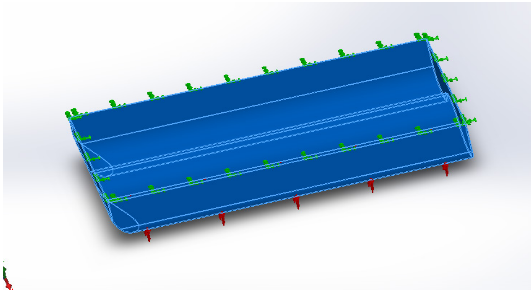

Fig.12. Digitization of ship's hull

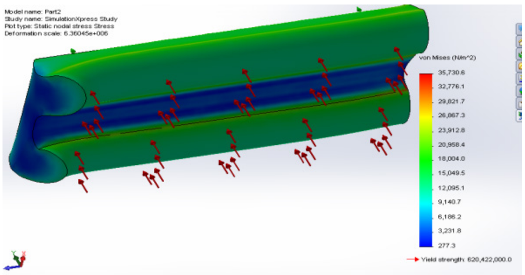

Fig.13. Digitization of Von Mises stress

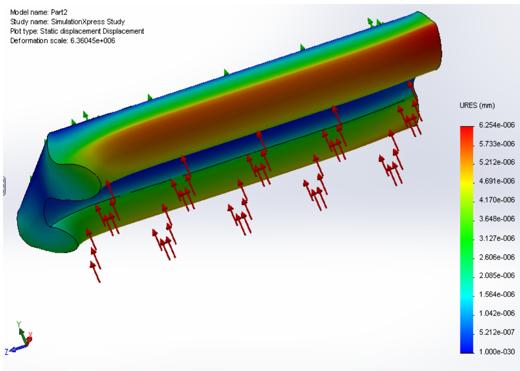

Fig.14. Representation of results regarding deformation

The above figures show the simplified calculation method and the resulting values of efforts and displacements. They help to discover the areas subject to stress that will need extra attention in the design stage and in operation. The load that had been distributed on the main deck achieved a clear picture of its efforts in case of uniform loading of the ship.

6. Conclusions

This watercraft is built for recreational purposes. Its electrical energy storage system contains: 2 - 4 batteries connected in various series/parallel circuit diagrams, each having a voltage of 12 V and a

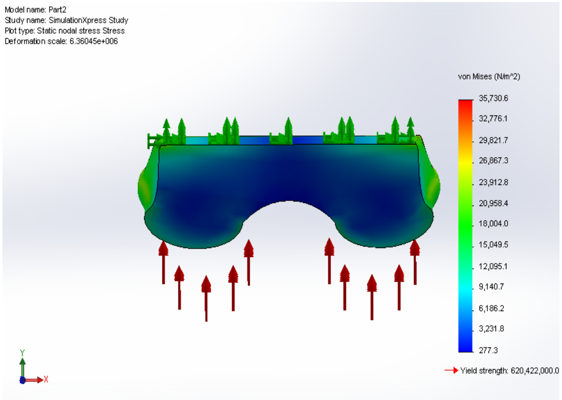

Fig.15. Bow view of exaggerated deformations

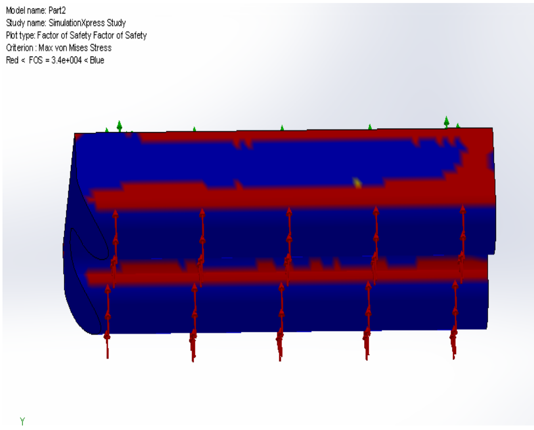

Fig.16. Presentation of areas of low safety coefficient (red)

capacity of 75 Ah (the energy storage system was purchased by INCDIE ICPE-CA). The electric propulsion system consists of an alternating current electric actuator (brasless), body movement transmission, propeller , electric power drive propeller (electronic inverter, variator of speed, powered by the electric battery pack) . The propulsion system, including the propulsion propeller and the gear housing were developed as collaborative work of ICPE- SA and UPB.[8]

- Voltage of electric engine: 24 V
- Maximum power of electric engine: approx. 2 KW
- Maximum absorbed current: approx. 90 A

The conversion system of solar energy into electric power has three photovoltaic panels (USP 150 type) connected in parallel with the terminal voltage: 24 VDC and maximum power: 450W.

- The outgoing photovoltaic panels are connected to an electronic controller in order to stabilize at a voltage of 24 V, required for battery charging and on-board electrical utilities (conversion system of solar energy into electric power was built by INCDIE ICPE-CA, and its primary energy source - the photovoltaic panels being purchased).
- The characteristics of a USP 150 type photovoltaic panel are: maximum power (W): 150; short circuit current (A): 4.98; open circuit voltage (V) : 42; I at Pmax (A): 4.39 ; U at Pmax (V): 34.2; length (mm): 1600; width (mm): 800; area (m2): 1.28; Unom (V) = 24V.

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