ROV Design for Pluvial Applications

Diseño ROV para aplicaciones pluviales

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Abstract

Brazil is a country where disaster levels increase each year due to changing climatic conditions, principally in the south east region. Disorganized occupation in urban areas, with inadequate structures increases the probability of these disasters. This work sought to study environments with high levels of floods and river overflow by using a robot, which could monitor the soil of possibly polluted rivers, as well as sediments and detritus. This work shows a proposal for a mechanical structure that will be used as a prototype for future developments. Two different alloys of materials and dimensions were tested for the same structure; the first one is "2024-T4" aluminum, and second one is "ASI 316" steel. The best results in terms of safety factor (SF) were obtained with the aluminum alloy with 4.64 SF. The structure shows mechanical characteristics that allow the usability for the proposed application; Solid Works was used for tests and designs.

Key words: ROVFLUV, Applied Robotics, Mechanical Design, Environmental Protection, Structure Analysis

Resumen

Brasil es un país donde los niveles de desastres aumentan cada año debido a las condiciones climáticas cambiantes, principalmente en la región sur oriental. La ocupación desorganizada en áreas urbanas, con estructuras inadecuadas aumenta la probabilidad de estos desastres. Este trabajo pretende estudiar los entornos con altos niveles de inundaciones y desbordamiento de ríos mediante el uso de un robot, que pueda monitorear los suelos de ríos posiblemente contaminados, así como sedimentos y detrito. Aquí se muestra una propuesta para una estructura mecánica que se utilizará como prototipo para desarrollos futuros. Se probaron dos diferentes materiales de aleaciones y diferentes dimensiones para la misma estructura; el primero fue aluminio "2024-T4", y el segundo fue acero "ASI 316". Los mejores resultados en términos de factor de seguridad (SF, por su sigla en inglés) se obtuvieron con la aleación de aluminio con 4.64 SF. La estructura muestra características mecánicas que permiten su utilización para la aplicación propuesta; Solid Works se utilizó para las pruebas y los diseños.

Palabras claves: ROVFLUV, Robótica aplicada, Diseño mecánico, Protección ambiental, Análisis estructural

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Introduction

Floods represent a big problem in the Brazilian south and south-east regions. Due to unplanned occupation of river lands, the Brazilian populations must endure floods and mudslides [1, 2]. Furthermore, human, environmental, and material damage changes the region's vulnerability.

The level of soil on river beds is a variable that can be used to measure the degree of danger areas near rivers, given that this is dependent on the amount of water that the bed has in a specified interval of time.

The autonomous vehicle [3-7], object of this project, consists of a system that provides monitoring of river beds compare to [8, 9], through the detection of significant changes in ground levels, as done in [8, 10, 11]; also, with data transmission over wireless networks. Based on the technology of embedded systems, the autonomous vehicle will also get information related to physical and chemical conditions of the water (temperature, density, salinity, pH, and other variables) [12, 13]. The vehicle will also have the functionality of remote handling when the system detects any abnormalities or changes in the environment and the solution depends on human intervention [9]. Therefore, a communication interface is established based on wireless networks (IEEE 802.11), optical networks and/or sensor network (IEEE 802.15.4E) and mesh networks. This interface will provide greater flexibility to the autonomous vehicle, facilitating its configuration and operation in areas of difficult access [12, 14].

Future modifications will be included (the projection of a decision center, oriented environmental monitoring), which will add value to the project to process the information perceived by the autonomous vehicle and use of disaster prevention.

This work will be present a proposal for a mechanical structure that will be used as a prototype for future developments.

Materials and Methods

For the present application, Solid-Works software was used, along with analysis tools through finite elements. Two materials were tested: 2024-T4 (ASME) aluminum alloy and L316 alloy steel (AISI). Further, we used two structures of different dimensions to validate different behaviors.

Material Properties

The first material used was the aluminum alloy known as aeronautical construction material (2024-T4), whose composition includes: Al: 90.7%, Cr: 0.1%, Cu: 4.9%, Fe: 0.5%, Mg: 1.8%, Mn: 0.9%, Si: 0.5%, Ti: 0.15%, Zn: 0.25%. Aluminum alloys are well known in different applications for their properties for machinability and surface finish, with high strength and adequate workability. They are used in structural applications, like, aircraft fittings, fuse parts, hydraulic valve bodies, piston rectifier parts, worm gears, fastening devices; in this application aluminum was used because the environment where the robot will operate presents high pressure and corrosion conditions due to the depth and chemical components of the water.

The second material used was 316-L stainless steel; the characteristics for this material include good cold formability and high strain hardening capacity. Generally, it is not magnetic, but may have small amounts of ferrite; thereby, presenting mild magnetism. When cold-deformed, it becomes partially martensitic and lightly magnetic. It is very ductile. Machinability is considered bad except for steels and resulfurized CORFaC. Corrosion resistance: shows high resistance means in acetic acid, sulfuric 1% picric, nitric, oleic acid, formic acid, boric acid, benzoic acid and chromic at 20 °C. Good resistance means in concentrated acetic acid at 70 °C, citric acid, 10% oxalic acid, phosphoric acid at 100 °C, 5% sulfuric acid at 20 °C. Saline solutions: chlorides of magnesium, calcium, zinc, potassium permanganate, potassium sulfate at 20 °C, nitrate, cyanide and copper acetate. Applications in sea water: good resistance at 20 °C. Water: good resistance at any temperature.

Structure

For the structure, a tubular profile was used with two different diameters, which will from now on be known as minor-car (MC) and normal-car (NC). The MC has an external diameter of 0.03 m and internal wall of 0.005 m; the NC has an external diameter of 0.05 m and internal wall of 0.01 m.

For NC, the principal volumetric properties for both materials were obtained, shown on Table 1.

Also, for MC, the principal volumetric properties for both materials were obtained, shown on Table 2.
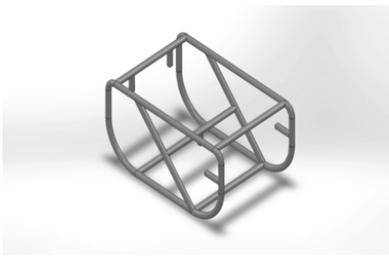
Table 1. NC in Aluminum and Steel alloy
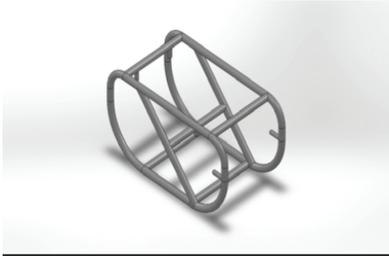
Material	Type of design	Focus / Framework
Aluminum 2024-T4		Mass: 38.1723 kg Volume: 0.0137311 m³ Density: 2780 kg/ m³ Weight: 374.089 N
Stainless Steel 316-L		Mass: 109.848 kg Volume: 0.0137311 m³ Density: 8000 kg/ m³ Weight: 1076.52 N
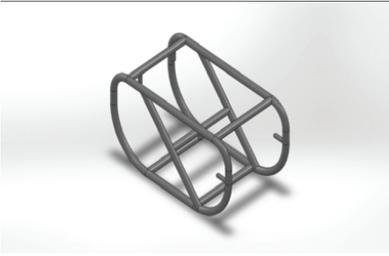
Table 2. MC in Aluminum and Steel alloy

Material	Type of design	Focus / Framework
Aluminum 2024-T4		Mass: 9.52268 kg Volum: 0.00342542 m³ Density: 2780 kg/ m³ Weight: 93.3223 N
Stainless Steel 316-L		Mass: 27.4034 kg Volume: 0.00342542 m³ Density: 8000 kg/ m³ Weight: 268.553 N

Forces Applied

Both of structures were tested with the same applied forces (78.5 N + 38.5 N); forces represent the maximum forces due to the four thrusters propulsion, and the second force is relative to the force that a generator will add to the structure. And pressures (2.354.400 N/m^2) come from the maximum application of the robot in the extreme river depth observed, which is 240 m. The structure was also fixed on two components representing the ground connection between the car and the soil of the water.

Results

This work tested four models (two for each material NC and MC); each model with the same conditions represents different behaviors, as expected. Results for aluminum in NC and MC are presented for both of the structures; furthermore, the results obtained for the steel alloy will be presented.

Both structures were tested and analyzed in two ways, tensile analysis (Tables 3 and 4) and safety factor analysis (Tables 5 and 6). They were obtained from Von Misses theorem; these results were calculated with Solid Works tools through finite element analysis.

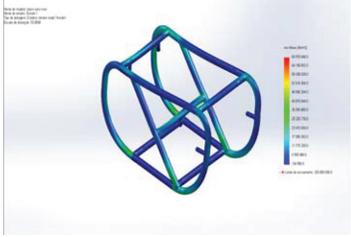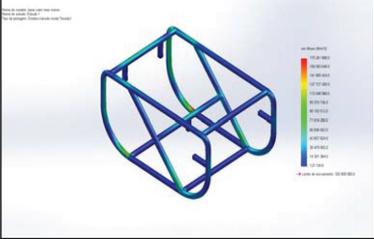Table 3. Tensile analysis in Aluminum alloy

Material	Type of design	Focus / Framework
Aluminum 2024-T4 Normal Car		Min: 134906 Max: 6.99768 $*10^7$
Aluminum 2024-T4 Minor Car		Min: 123135 Max: 1.70262 $*10^8$

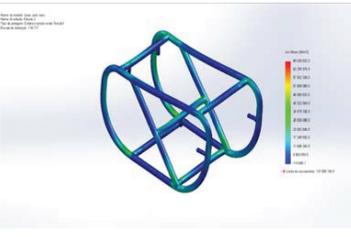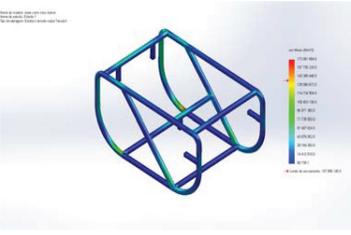Table 4. Tensile analysis in Stainless Steel alloy

Material	Type of design	Focus / Framework
Stainless Steel 316-L Normal Car		Min: 119845 Max: 6.90388 $* 10^7$
Stainless Steel 316-L Minor Car		Min: 80739.1 Max: 1.72062 $* 10^8$

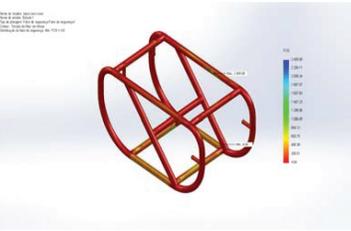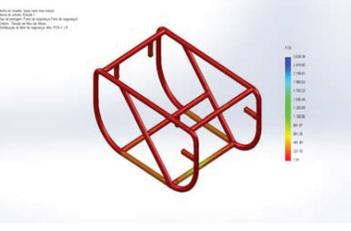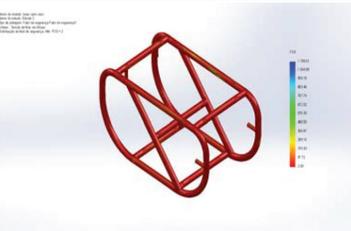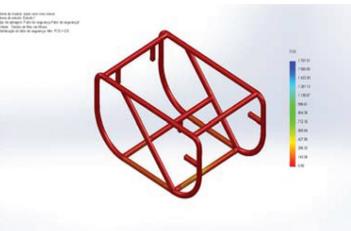Table 5. Safety factor analysis in Aluminum alloy

Material	Safety Factor Analysis	Min and Max values
Aluminum 2024-T4 Normal Car		Min: 4.64 Max: 2409.08
Aluminum 2024-T4 Minor Car		Min: 1.90 Max: 2639.39

Table 6. Safety factor analysis in Stainless Steel alloy

Material	Safety Factor Analysis	Min and Max values
Stainless Steel 316-L Normal Car		Min: 1.99 Max: 1150.61
Stainless Steel 316-L Minor Car		Min: 0.80 Max: 1707.91

Conclusion

The results were analyzed in terms of minimum tension (MT) and safety factor (SF); the best result was obtained with the aluminum alloy with 134.906 of MT and 4.64 in SF, which refer to the NC structure. This represents that the structure has mechanical characteristics that allow its use for the proposed application.

It was very important for this study to apply the Solid Works environment for design and test analysis; its properties facilitated the process and its changes, which will improve the structure for the final purpose.

Future works will improve in the structure of new equipment and components, so, the models will have to be re-validated for new configurations or changes that could arise.

Acknowledgements

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