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# STRUCTURAL EVALUATION OF ERGOMETRIC EQUIPMENT AVAILABLE BY THE PROJECT OPEN-AIR ACADEMIES IN PUBLIC SQUARES

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*Abstract. Currently in Brazil an alternative of stimulation of the sports practice without cost denominated "Open-air academies" was created. Various gymnastics equipment was installed in Belo Horizonte in public spaces, which should be duly evaluated and certified. The objective of this work was to verify the mechanical and structural design of these gymnastic equipment, using the finite element method. For this, software simulations were carried out, allowing to evaluate the structural effectiveness of some of the gymnastics equipment that are part of the " Open-air academies" program, in such a way that the safety and well-being of the users are guaranteed.*

*Keywords: Gymnastics equipment, Structural analysis, Finite element method, Simulation, Safety.*

## 1. INTRODUCTION

According to the World Health Organization (2011), sedentarism is known as the disease of the century along with stress and a depression. Defined as an absence or diminution of physical activity, it is associated with the daily behavior of modern life. People who have a caloric expenditure of less than 2,200 calories per week are considered sedentary or have a sedentary lifestyle (OMS, 2011; Benedetti, 2004, Mocellin, 2016). According to a survey conducted by the Ministry of Sports (Brasil, 2016), the sedentary lifestyle reaches 45.9% of the Brazilian population, which means that about 67 million people did not perform physical activity.

Man's health and quality of life can be preserved and improved by regular physical activity. Sedentary lifestyle is an undesirable condition and poses a health risk (OMS, 2011, Verissimo, 2011). In order to reduce the rate of sedentarism, an alternative of public activity at no cost through the so-called "open-air academies" was created in Brazil (Fig. 1). The academies aim to promote the health of the population and stimulate sports practice (Veríssimo, 2011).

Figure 1. Open-air academies.

Therefore, it is necessary to carry out a dimensional analysis that proves the structural efficiency of the equipment. This work aims to perform an evaluation of the mechanical and structural design of one of the gym equipment of the Open-air academies project, to verify the safety and well being of users.

For this, a finite element model was constructed to perform the computational simulation for structural analysis of the geometry of one of the ergometric devices. This analysis was done comparing different types of material to the structure to verify the safety factor resulting in the dimensioning of the equipment components.

## 2. METODOLOGY

The equipment called the triple walking simulator was chosen to perform structural verification (Figure 2).



Figure 2: The triple walking simulator.

The steps for the development of the project are:
- Construct a finite element model using Hypermesh software, the geometry of the apparatus to be analyzed and its boundary conditions.
- Perform the computational simulation for static analysis of the submitted efforts.
- Perform the computational simulation for modal analysis of the structure.
- Compare the tensile response for two different materials for manufacturing the equipment, being Steel SAE 1020 and Steel SAE 1030.
- Check the safety factor for the dimensioning of the equipment components.

A geometric model of the equipment structure was constructed and all boundary conditions were applied to the model (Fig. 3a). The loads in the Z direction were applied in the value of 650 N in each pedal and were applied to an angular variation of 30º at -30º.

The mesh construction was performed using the two-dimensional shell element with dimension of 6 mm, three-dimensional penta element and rigid elements of one dimension (Fig. 03b). The penta element was used only in the weld regions for a better representation thereof and to avoid a build up of tension. Already the rigid elements were used in the screws, axes and places where it was necessary to use a rigid element. The remainder of the mesh was constructed using the shell element.
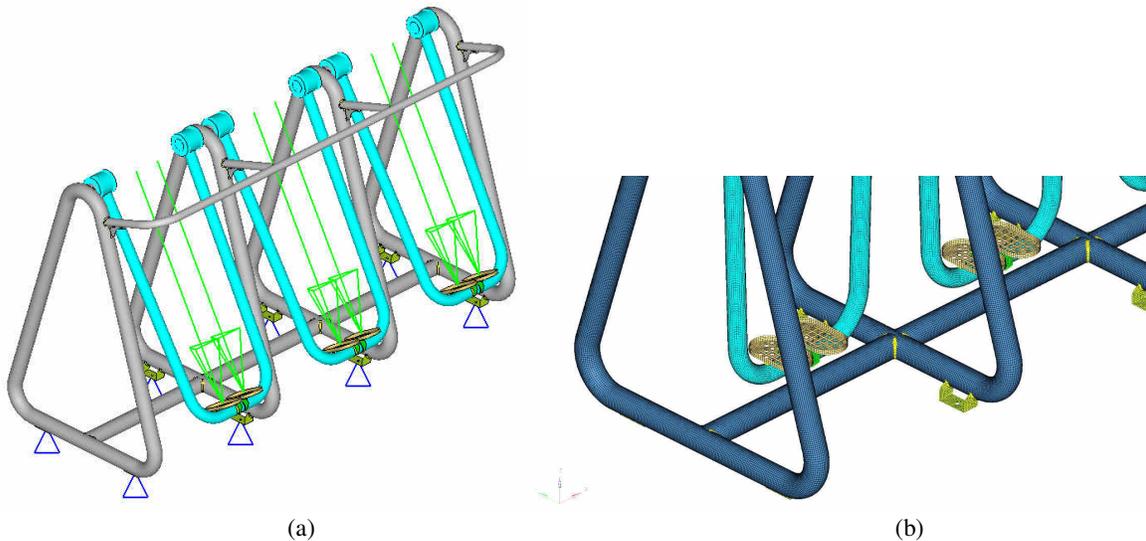
(a)                                                                                   (b)

Figure 3: (a) Geometric model of the equipment structure. (b) The mesh for the Finite Element Model

## 3. RESULTS AND DISCUSSION

For the simulation, it can be observed in Fig. 4a that the major deformations occurred in the external pedals, having a maximum deformation of 13,915 mm. The maximum tension that occurs in the bearings has a maximum value of 260,794 MPa (Fig. 4b).



(a)                                                                                   (b)
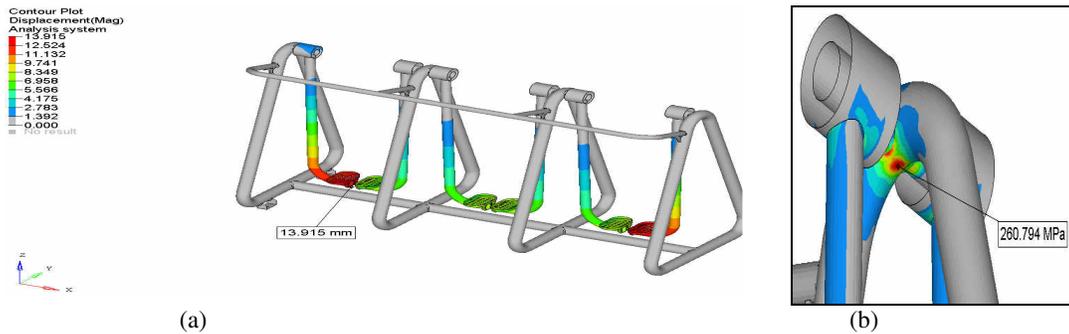
Figure 4: Static simulation. (a) Tension in structure; (b) Bearing tension.

The value of the estimated yield stress of some steels can be found in the literature. The materials SAE-1010, SAE-1020 and SAE-1030 have the yield limit of 300 MPa, 350 MPa and 440 MPa respectively (Chiaverini, 2008).

The safety factor estimated for the project is given by the ratio between the yield stress and the maximum tension that can be generated at a certain point of the equipment during its use (Norton, 2013). Thus, the maximum tension obtained in the simulation was used to obtain the value of the safety factors for the steels used in this analysis (Table 1).

Table 1. Experimental results for flexural properties of CFRC-4HS and CFRC-TWILL composites.
Span/depth ratio = 35:1. Average results of 7 specimens.

| Material | Yield stress (MPa) | Safety factor |
|---|---|---|
| SAE-1010 | 300 | 1.15 |
| SAE-1020 | 350 | 1.34 |
| SAE-1030 | 440 | 1.69 |

However, following the ABNT NBR 8800: 2008 standard, for steel structure and mixed steel structure projects, the equipment must have a safety factor (FS) of at least 1.67. It can be observed that all the steels present in table 1 have the yield limit above the maximum tension of 260.8 MPa, obtained in the static analysis. However, SAE-1010 and SAE-1020 steels have a safety factor below the value of 1.67 that is provided in the ABNT NBR 8800: 2008 standard.

## 4. CONCLUSIONS

The results obtained showed that the triple walk simulator will not fail mechanically, since the maximum tension suffered by the equipment is lower than the yield stress of the analysed steels. However, its safety factor is below 1.67 (provided by ABNT NBR 8800: 2008), for SAE-1010 and SAE-1020 materials. It is recommended to use SAE 1030 steel to ensure greater safety to users.

It would be of great interest to carry out future studies for the analysis of fatigue resistance and dynamic analysis to ensure greater safety for users of the equipment that constitutes the Open-air academies project.

The analysis done in this work was purely structural, and it is not possible to state whether the equipment compromises the physical and physiological integrity of the user from the physiotherapeutic point of view. In the performed analyzes a maximum displacement of 13.9 mm was found in the external pedals, a situation that could or could not constitute a risk situation for the execution of a physiological movement. It would be of great interest to carry out evaluations of health professionals in order to ensure that issues such as these do not cause harm to the health of the user.

## 5. ACKNOWLEDGEMENTS

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