COMPARISON OF THE USE OF TWO STRUCTURAL PROFILES IN THE RACING WHEELCHAIR DESIGN

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Abstract. *The structure of racing wheelchairs has undergone several changes since the introduction of the modality in the paralympic games. These changes have brought about extraordinary improvements in athletes' performance. Thus, the objective of this work was to evaluate the mechanical resistance of a new structural profile that can be applied in a race wheelchair. Two models of racing wheelchair with the same dimensions, but different structural profiles were designed. In one model, commercial commom structural profiles were used and in the other model an approximately triangular shaped profile was used. The models were computationally analyzed by the finite element method (FEM). The results of the analyzes showed that the triangular profile are better than commercial profiles in mechanical resistance and weight saving. Thus, the use of the new profile in the design of race wheelchairs is suggested, since it allows gain in performance, due to the decrease of weight.*

Keywords: *Racing Wheelchairs, Finit Elements, Paralympics, Structure*

1. INTRODUCTION

Since the introduction of the wheelchair race in the Paralympics, there have been drastic changes in the designs of these equipment. These changes have brought about extraordinary improvements in athlete performance (MASSE *et al.*, 1992).

In the 1980s there were extraordinary improvements in the racing wheelchair records, which can be attributed in part to the development of better racing wheelchairs. Among these improvements can be mentioned changes in the structure that gave lower mass and improvement in the aerodynamics of the chairs (MASSE *et al.*, 1992).

According to Katariina (2008), the racing wheelchairs are fairly lightweight, and made of a monostructure usually in aluminum. Figure 1 shows an example of a currently used racing wheelchair.

According to Fuss (2009) one of the parameters that most influence the time of arrival in a race is the weight of the wheelchair.

According to Fuss (2009), although wheelchair racing is an athletic exercise, it can be compared to cycling when related to the design of the equipment. However, in addition, in wheelchair races the rolling frictional force can be reduced by reducing the weight of the equipment.

In this sense Fuss (2009), analyzed the influence of weight on the speed of the race wheelchair. This work was performed for 100 m races. In their studies, speed improvement and time gain with weight reduction were modeled mathematically and the results validated through practical experiments.

The three key parameters that affect the time of arrival are the weight of the wheelchair, the drag coefficient and the rolling resistance. However, of these parameters, what influences most in this time is the weight (FUSS, 2009). The results of the studies by Fuss (2009), showed that the influence of the weight can be up to 5.5 times greater than the influence of the aerodynamic drag coefficient is 4 times greater than the influence of the rolling resistance.

The results and conclusions presented by Fuss (2009) show that it is advantageous to reduce the weight of the wheelchair. Since in a 100 m run the 10 kgf reduction in weight can result in a time gain of 1 to 2.3%.

Thus, due to the importance of the mass decrease in the structure of the racing wheelchair, the objective of the present work is to evaluate the use of a structural profile based on a "triangular" format, in comparison to the profiles currently available in the market to verify Its mechanical resistance and the decrease of mass in relation to the profiles commonly used in the manufacture of these equipments.

Figure 1: Racing wheelchair. Font: (DRAFT, 2015)

2. COMPUTATIONAL PROCEDURE

Aiming to understand the behavior of a structure with commercial profiles and another one with the new "triangular" profiles, two models of wheelchair structure were developed. The models were designed using as a basis measures found in the user manual and catalog of parts of two commercially-known racing wheelchairs. In the commercial profiles model structural profiles were used available in manufacturer's catalogs, such as the examples shown in Figure 2.

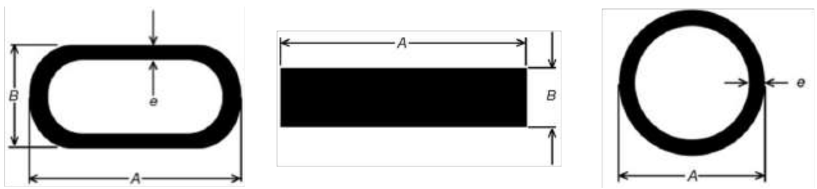


Figure 2: Structural profiles used in the model with comercial profiles. Font: (ALCOA, 2015)

In the other model the same dimensions of the chassis were maintained. However, where round tubes and gloves would be used, the new "triangular" profiles were inserted (Figure 3).

(a) Minor profile (b) Major profile

Figure 3: Tubular profiles in "triangular" format.

After the finalization of the modeling the structural static analysis was carried out by the finite element method (FEM) aiming to investigate the mechanical strength of the structures. ANSYS software was used in the analysis. The material assigned to the structure for analysis was 6061 aluminum alloy with T6 type tempering. This alloy is characterized by high mechanical strength, good corrosion resistance and good formability. Its mechanical properties are: modulus of elasticity 71 GPa, coefficient of poisson 0.33, yield strenght 280 MPa.

In the FEM tests, a vertical load of 1800 N was defined, essentially, on the two tubes that support the load of the athlete in the seat. Figure 4 shows the two tubes where the force was applied.

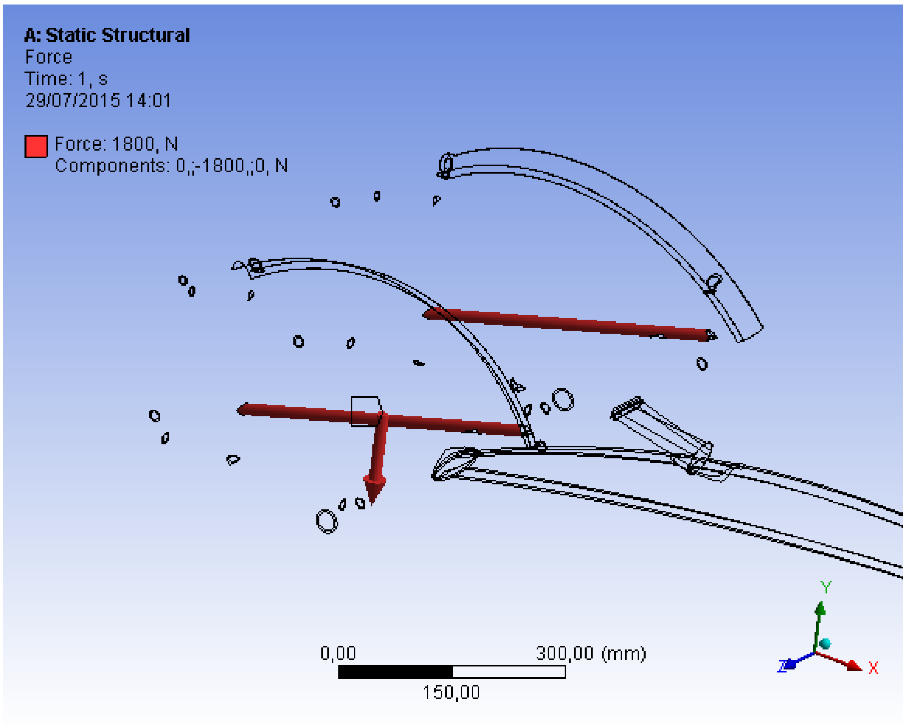


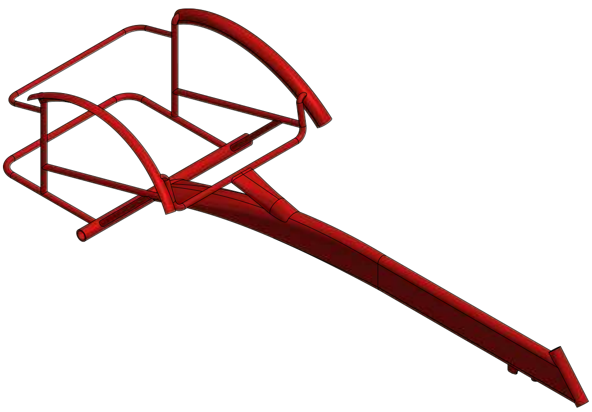
Figure 4: Identification and location of loads applied on the chassis.

3. RESULTS AND DISCUSSION

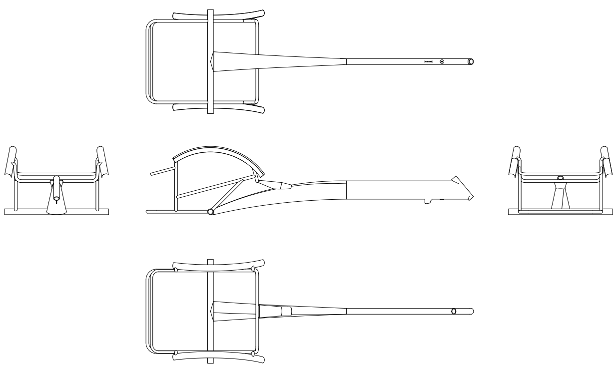
3.1 Geometric Model with Commercial Profiles

The model shown in Figure 5, is commercially known as U-frame. It is the most common model in high-performance competitions, and is suitable for athletes who "sit" on their own legs in the racing wheelchair. Typically, these chairs have straps or a metal plate under the seat to support the knees and the lower portion of the legs.

This model was designed using commercial aluminum profiles.



(a) Perspective



(b) Orthogonal projections

Figure 5: Geometric Model with commercial profiles

Figure 6 shows the structure of the racing wheelchair shown previous. In this case it is possible to notice that the frame is mounted with the accessories (wheels, steering device, axles, etc).

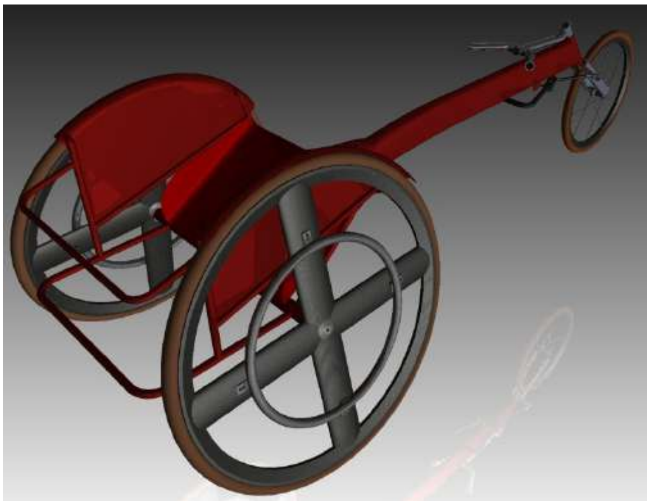
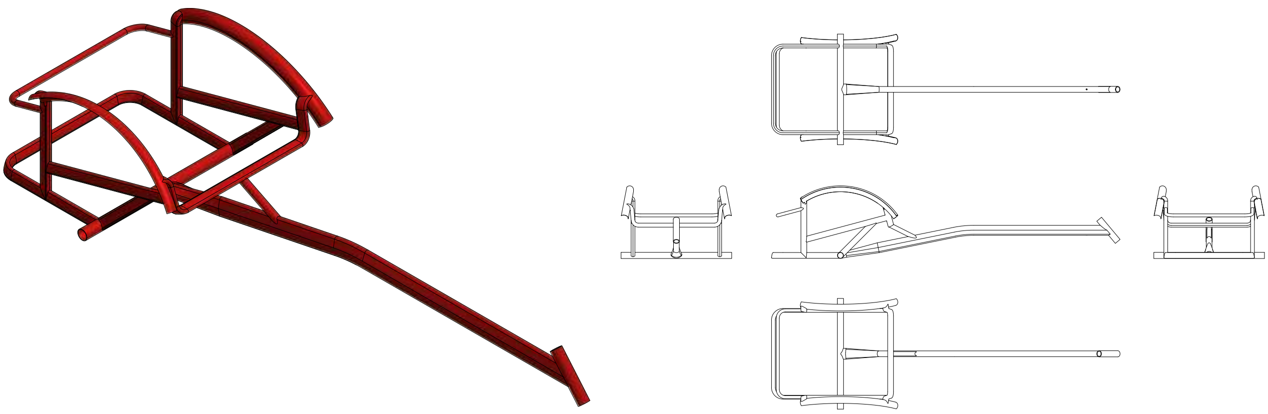


Figure 6: Athletics racing wheelchair.

3.2 Geometric Model with Triangular Profiles

The model shown in Figure 7 shows the same length, width and height measurements used in the previous model. However, it was designed with triangular profiles in 80% of its structure, the main tube being configured with the larger triangular profile and the remainder with the smaller one.



(a) Perspective (b) Orthogonal projections

Figure 7: Geometric Model with Triangular Profiles

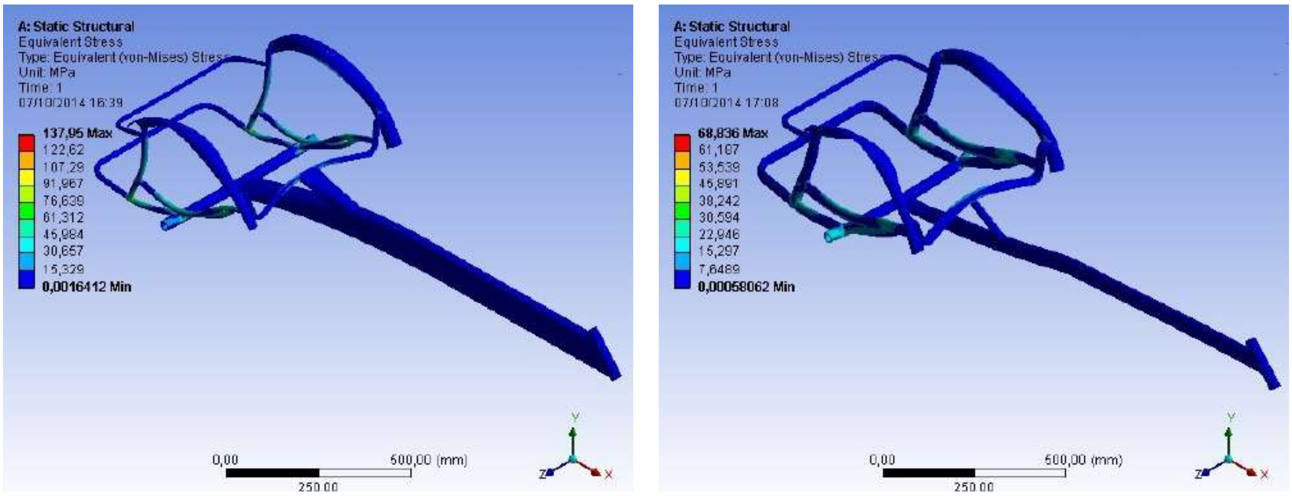
3.3 Numerical Modeling of the Racing Wheelchairs

Figure 8 shows the distribution of equivalent von-Mises stress in the two models of projected frames. In Figure 8a it is possible to observe the distribution of tension in the frame with commercial profiles. Figure 8b shows the distribution in the frame with triangular profiles.

The maximum equivalent von-Mises stress reached 137.95 MPa in the structure shows in Fig. 8a, and 68.836 MPa in the Fig. 8b. Thus, considering that the maximum stress at which any of the structures could be reached is equal to the material flow limit (280 MPa); The two models meet the mechanical strength requirement. However, the version with triangular profiles is twice as resistant as the model with commercial profiles. Therefore, the structure can be optimized aiming at reducing its weight for maximum performance.

Among other information, it is worth mentioning the mass of each one of the models. For example, the version with commercial profiles presented theoretical mass close to 4.50 kg, while the other model resulted in 3.46 kg of theoretical mass. This information is important because the weight of the wheelchair also significantly influences the performance of the athlete.

Since the model with triangular profiles is more robust, it presented a greater mechanical resistance and smaller weight in relation to the model with commercial profiles, it becomes interesting to invest in the manufacture of sports wheelchairs with structural profiles in this format.

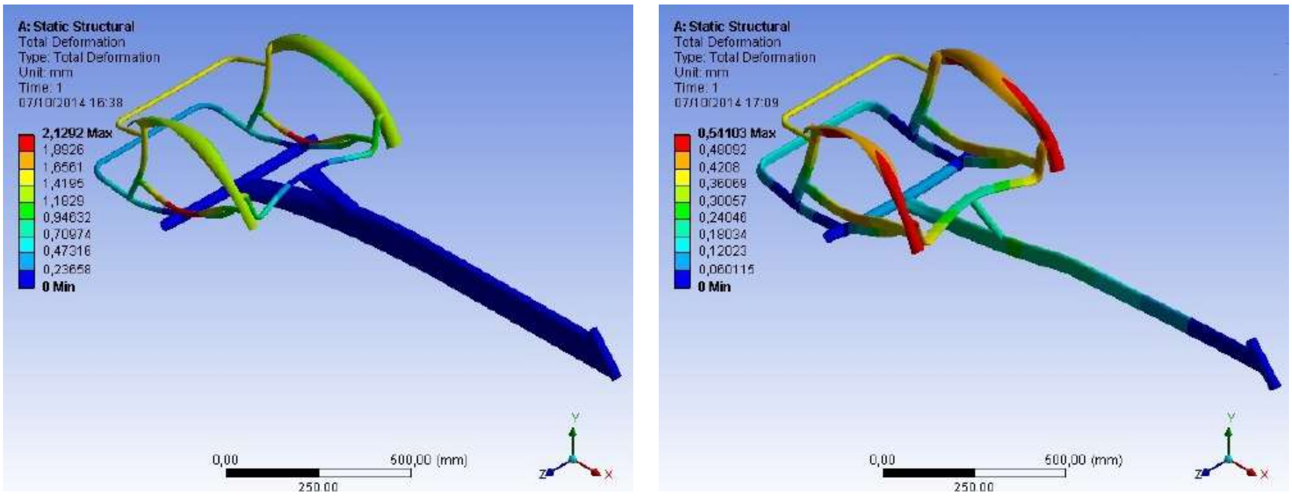


(a) Commercial profiles (b) Triangular profiles

Figure 8: Illustration of the result obtained with the von-Mises equivalent stress.

Figure 9 shows the results of the structural millimetric displacement. In Figure 9a it is possible to observe the displacements in the frame of the version with commercial profiles. While Figure 9b shows the displacement in the frame with triangular profiles.

The maximum displacement in the case of the commercial profile was 2.1292 mm, and in the race wheelchair with triangular profile was 0.54103 mm. It is found that the deformation in the current racing wheelchair structure is approximately 4 times greater than the deformation in the new structure. This implies a greater rigidity in the new structure, which can help in the performance of the athlete on the wheelchair race.



(a) Commercial profiles (b) Triangular profiles

Figure 9: Illustration of the result obtained with the deformation in the chair structures racing wheels.

It is worth mentioning that the visual scale of the displacement presented in the figures, in the case of tensions as well as the displacements, is increased for a better understanding and visualization of the results found.

4. CONCLUSIONS

From the analysis of the results obtained through the computational simulation using the finite element method (FEM), it can be observed that the new "triangular" structural profile presented superior mechanical resistance in relation to the commercial structural profiles. In addition, it presented lower weight in relation to the model with commercial profiles. The gain in resistance aligned with the chair's weight reduction can bring enormous advantages in improving athletes' performance. Thus, the authors suggest that the new profiles be used in the construction of racing wheelchairs in view of the advantage they presented.

5. REFERENCES

ALCOA, 2015. Perfis Standard.

DRAFT, W. Top End OSR: Racing chairs. 2015. Available in: http://www.draftwheelchairs.com/shop/products/racing-wheelchairs/racing-chairs/topend- osr.html. Accessed in: July 30, 2015.

FUSS, .K. **Influence of mass on the speed of wheelchair racing**. Sports Engineering, 2009. Vol. 12, No. 1, pp. 41-53.

KATARIINA, J. **Kinematic differences between three wheelchair racers (t54) in sprint start**. University of Jyvaskyla, 2008.

MASSE, L., Lamontagne, M. and Oriain, M. **Biomechanical analysis of wheelchair propulsion for various seating positions**. Journal of rehabilitation research and development, 1992. Vol. 29, No. 3, pp. 12-28.

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7. RESPONSIBILITY NOTICE

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