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The Mechanical Behavior Of A Nylon Seat Belt Exposed To Cyclical Loads: A Numerical Approach

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ABSTRACT
This work aims to study the mechanical behavior of a nylon seat belt when it is exposed to cyclical loads through the Finite Element Methods. This work used as base the brazilian regulamentoy standard ABNT NBR 7337:2011 to create the virtual model of the seat belt, with the following dimensions: 1.20mm thick, 48mm width and 250mm length. The next step was to import this CAD model to ANSYS 14.5 software, to create the correct material model for this case and apply the correct boundary conditions in order to analyze its behavior under a load that varies from 0 to 2000 N at a 10 Hz frequency. The final step was to analyze this numerical results that referring to this component under these conditions.
Keywords – ANSYS Workbench 14.5, fatigue, FEM, polymers, seat belt

I. INTRODUCTION

With the accessibility to the automotive vehicles and consequently the increase of sells, the regulatory agencies constantly look for actions to increase the safety of passengers of these vehicles in order to reduce efficiently the consequences of severe accidents. Among the various components that a vehicle has in order to guarantee the safety of the passengers the seat belt is a basic safety item and its use is obligatory, as prescribed at the BTC (Brazilian Traffic Code).

The vehicular seat belt is probably the most common safety item used around the world when we think about passengers vehicles. Its use is obligatory as its prescribed at the Article 65 of the BTC, and its non-use is treated as a serious offense against the Brazilian Traffic Code. Some of the benefits of its utilization was said by Marcus Romaro (2005): this item keeps the occupants at the same point, do not allow them to be thrown in case of a collision, absorbs part of the impact’s energy and distribute the remain energy by the strongest points of the human body, minimizes the chance of a second collision (when the occupants collide with the vehicle interior), reduces the chance of occurring a conscience loss and guarantee a correct and stable position to drive.

The fatigue failure occurs when the material is subjected to a dynamic load during a period and it fails under an inferior stress than its yield strength (Evandro, 2011). Therefore, understanding the mechanical behavior of the seat belt when its subjected to cyclic loads, allow us to predict risks situations and the need of and eventual intervention allowing the preventive substitution of this component. The finite element methods is inserted at this analysis due it’s advanced analytical capacity and due its relative short response time, when its compared to the fatigue experiments.

Because its material is a polymer and its behavior depend of more variables than metals, as for example the load frequency (Evandro, 2011), the actual scenario faces a lack of studies around this issue.

I. METODOLOGY

Model criation

To analyze the seat belt thread, first it was necessary to generate its model at a CAD software. The model was created through the SolidWorks software with 1.20 mm thick, 48 mm wide and 250 mm long. The next step was to generate the finite element mesh for this model. This mesh was created as it is shown at Figure 1, with 134389 nodes and 24000 elements.

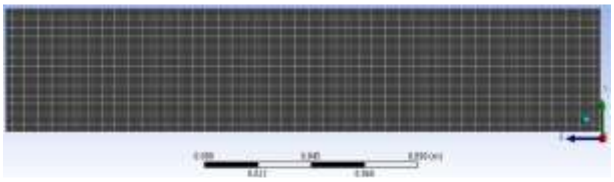

Fig. 1: Mesh used for this analyzis, with 134389 nodes and 24000 elements

As Geisiel (2014), the materials used to manufacture the seatbelts usually are made using synthetic fibers and must have good absorption and dissipation of energy capacity, in order to guarantee a uniform pressure applied to the passengers. In this study, the nylon was chosen to model the seat belt, as the Altair HyperWorks reference model (2012). The values of density, modulus of elasticity and the Poisson coefficient of the material used are shown at Figure 2 below.

Density	1360 kg/m^3
Young's modulus	7,2 GPa
Poisson coefficient	0.4

Fig. 2: Nylon properties

In addition to the mechanical properties shown above, it was introduced at the ANSYS software the stress-strain nylon curve, that can be seen at Figure 3 shown below.

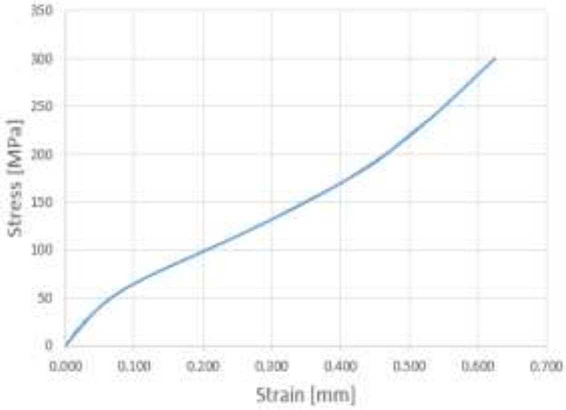

Fig. 3: Nylon Stress-Strain curve

It was also required the addition of the nylon SN curve, in order to model the material to the fatigue study. The curve used was presented by Averett (2004) and can be seen at the Figure 4 below.

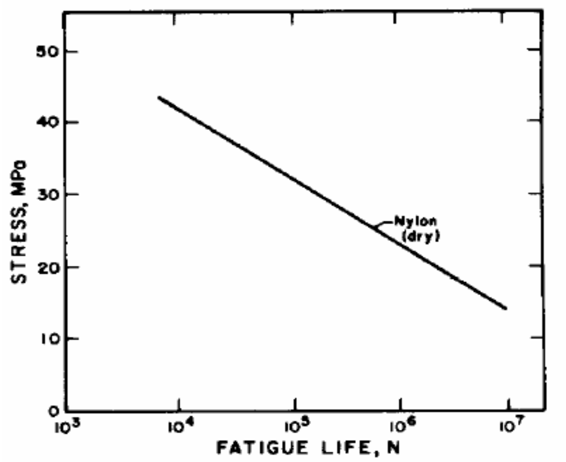

Fig. 4: Nylon SN curve [7]

II. BOUNDARY CONDITIONS

Figure 5 below shows the boundary conditions applied at this analysis. The six degree of freedom of the model were constrained at one end of the seat belt thread in order to constrain its translation and rotation movements at the X, Y and Z axis. At the opposite end, was applied a cyclical force varying from 0 to 2000 N. This load case were defined by numerical approximation in order to define the seat belt's usual conditions.

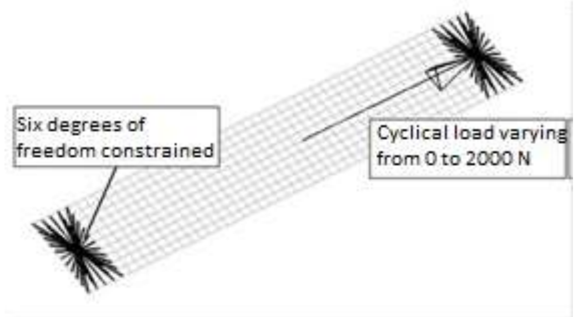

Fig. 5: Boundary conditions. Adapted from [5]

Besides the defined applied loads, the Goodman criterion were chosen to analyze the model at specified conditions, as (1) show us.

$$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{\sigma_R} = \frac{1}{FS}$$

Where σ_a is the alternating stress, σ_m is the medium stress, S_e is the material's fatigue yield strength, σ_r is the ultimate stress and FS is the safety factor.

III. RESULTS

According to the described methodology, the following results were obtained through the analysis. The alternating stress calculated at these conditions reached extremely high levels.

The Figure 6 below shows the estimated results relative to the components life, according to the load case discussed before. We can notice that the estimated life to the tension condition between 0 and 2000 N at 10 Hz is on the order of 9,07 x 10^6 loading cycles. At Figure 7 the detailed area that presents the highest fluctuations oscillations at the results is shown.

Fig. 6: Estimated component's life

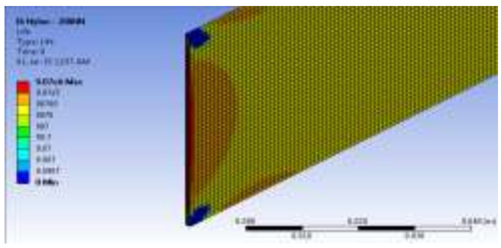

Fig. 7: Detailed view of model's most relevant oscillations of it's estimated life

At Figure 8 showed below the maximum and minimum safety coefficients determined to this analysis are shown, with the maximum value equals to 1.3322 and the minimum determined as 0.23537.

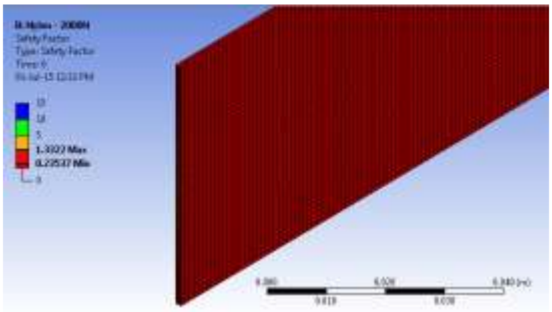

Fig. 8: Determined safety factors

IV. CONCLUSION

The main goal of this work was to determine, through the Finite Element Method, the mechanical behavior of the nylon seat belt, when it is under a cyclic tension load of magnitude of 2000 N at a application frequency of 10 Hz.

Although the mechanical behavior of the seat belt was in accordance with the expected results, experimental tests are recommended in order to obtain the validation of the numerical model presented.

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