5th International Conference
″Computational Mechanics and Virtual Engineering ″
COMEC 2013
24- 25 October 2013, Braşov, Romania

THE STRENGTH OF SIMPLE BELT GUIDE UNDER TENSION

Vasile CIOFOAIA
[1] Transilvania University of Brasov, ROMANIA, ciofoaiav@unitbv.ro

Abstract: *We present the development of a safety system (the safety belt) that satisfies not only resistance, but also cost and durability criteria. We used in order to develop this system both experimental and numerical approaches. In this paper, we present the stress and deformation analysis of the safety belt simple belt guide. The analysis of the stress state is realized by using both the finite element method (FEM) both in linear and non-linear states and the tensile breaking and the photoelastic method. Both numerical and photoelastic methods of analysis determine the danger zones for the safety belt guide. The validation of the obtained results was done by the traction load trial in similar conditions to real world safety belt guide usage, by using 10 randomly selected samples from a 100 lot. The breaking belt guide is applied on every studied piece, with special attention being taken to the tension concentration zone both experimentally and with the finite element and photoelasticity methods. The results thus obtained can be used to optimize the shape of the safety belt guide and the manufacturing technology.*
Keywords: *safety belt guide, finite element, photoelasticity, stress, deformation.*

1. INTRODUCTION

A reduction in the number of motor vehicle accidents and their consequences requires multiple medical, legal, economical and technical approaches. New features are required in order to design safer vehicles. One set of such features is represented by the active safety systems that reduce the probability that an accident may happen. Such systems are represented by the electronic distribution system for the breaking force and the anti-lock wheel system during breaking (ABS). Another set of such safety features is represented by the passive safety systems for which the goal is to reduce the number of human casualties once an accident occurs. Such features are represented by the safety zones, the safety belt [4] and the airbags. Safety systems have been created in order to absorb the kinetic energy of the passengers, without causing them severe injuries. The three point safety belt initially introduced in 1950, prevents passengers being effected outside of the vehicle at the time of the impact, thus preventing them hitting the wheel or other parts of the vehicle. In 1973 a safety system based on airbag was introduced. Over the course of the years, the safety belt and the airbag were perfected by introducing additional systems. Such an additional system is the pre-tensioning system that eliminates the safety belt delay at the time of an impact. Further research pointed out that different features of the passengers, such as position, weight, and age can determine the probability of a severe injury as well as the impact of situational factors (the direction of collision, the type of road, and the presence of an airbag system), demographic factors, and constructs (criteria) elicited from subjects regarding safety belt use [2]. Furthermore, it was noted that the speed of the vehicle and the forces applied to the safety system can lead to severe injury and even casualties. The effectiveness of safety belt usage in reducing mortality and morbidity among traffic crash victims has been well established. In the paper [5] it is presented by state an estimation of the population safety effect belt usage rate on traffic fatality rates in the presence of known confounders such as alcohol use and young drivers. Current research is focusing on the development of systems that determine the airbag deployment time, features such as reversible pretension systems but also simulations for the impact of the auto vehicle to determine, verify and control the resistance of the safety belt components. High durability and lower cost are also criteria that lead the development of the safety belt. This paper presents the analysis of the resistance and behavior conditions that the simple belt guide needs to meet. From the production lot that contains 100 pieces, a random sample of 10 safety belt guide is selected. The areas where tension is concentrated is then numerically and experimentally described, while subjected to increasing forces.

2. Analisys of the tension and deformation state

The safety belt system consists of the belt and the buckle pre-tensioner. The limiter and the simple belt guide are illustrated in Figure 1. The polyamide belt has a length of approximately 2.5 m and a width of approximately 25 mm. The belt is rigidly connected to the chassis at the downside of the B-pillar, goes over the pelvis to the buckle, cross-diagonally over the chest and is through the simple belt guide connected to the load limiter, in which the unused belt length is winded around a cylinder. The buckle pre-tensioner consists of the buckle and the pre-tensioner. The buckle has to ensure that the chest section of the belt is cross-diagonally aligned over the chest and that the lap section of the belt is more or less horizontally aligned over the pelvis. The pyrotechnical pre-tensioner removes slack in the belt system by abruptly tightening the belt.

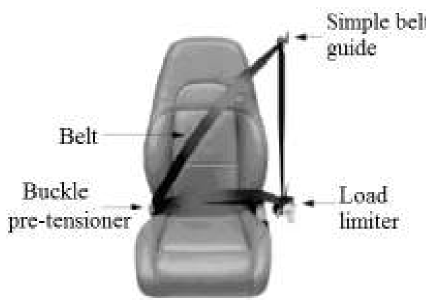

Figure 1 Three-point belt system [5]

The simple belt guide attached to the B-pillar. It has to properly align the belt over the chest and to allow a more or less free flow of the belt through the loop. For a proper belt alignment for small and tall occupants, the simple belt guide is height adjustable. The load limiter limits the force applied to the occupant by the belt. The rotation of the cylinder around which the unused belt is winded, is locked when its angular velocity exceeds a certain threshold, typically due to the abrupt tightening of the belt. From that point of time, the force in the section of the belt connected to the load limiter is limited by the deformation of certain load limiter components. The design of the belt system often focus on the (adaptation) of these deformation characteristics.

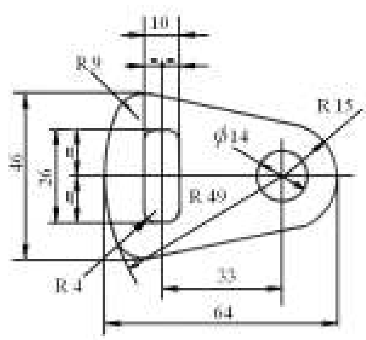

Figure 2 Simple belt guide

Figure 2 Finite element model - limitations

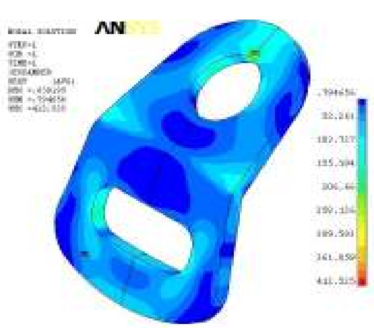

Figure 3 Equivalent Von Mises tension for the step 1, corresponding to a 750N force.

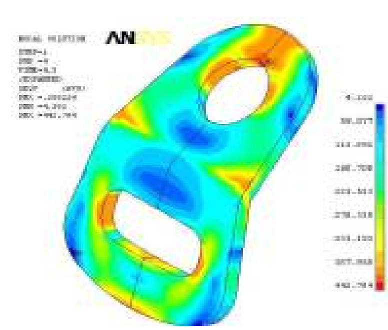

Figure 4 Equivalent Von Mises tension for step 4, corresponding to a 3375 N force.

In order to analyze the simple belt guide, shown in figure 1, both the linearity and nonlinearity of the contact details were considered (bolţ-simple belt guide contact), as well as the elasto-plastic material details. Thus, the material was considered an elasto-plastic bi-linear kinematic Von-Mises material with the following characteristics: $E = 2 \cdot 10^5\,MPa$, $E_t = 2000\,MPa$, $\sigma_c = 400\,MPa$. The elements used were Solid 95, Target170, Conta 174 and the total number of these was aproximatively 2700 with 13500 nodes. Due to the symmetry of the model, only half was used (Figure 2). The analysis was realized in a 7 step process, and the force used was simulated through a uniformly distributed pressure for the entire model having a resultant 15000N. Thus, for the half model analysis, the maximal force used was 7500N. The figures 3-10 present the equivalent tensions for the V resistence theory corresponding to the loading steps 1-7. Figures 4-5 present the equivalent Von Mises loading states for steps 1, 4 and 7 and figure 6 presents the displacement resulting at maximal load.

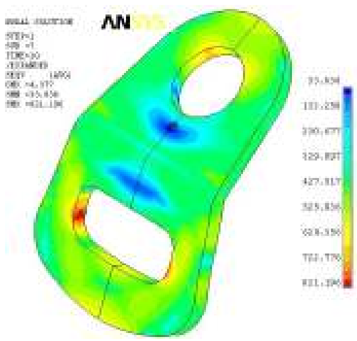

Figure 5 Von Mises equivalent tension for step 7 corresponding to a 7500N force.

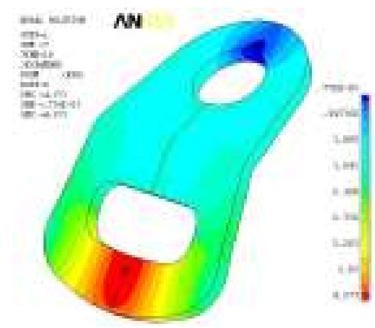

Figure 6 Resultant displacements at maximal load.

The numerical experiment analysis concluded that the tension and deformation state is met mostly in the areas where contact between bolt and the simple belt guide and belt occur. An Araldit model was made with similar dimensions. The experiments were performed on a device in which the bolt and belt (band) were made out of rubber. The sample was fixed in the superior part and loaded by subjecting it to various weights. Thus it was noted that the tension state is similar to the one obtained though a numerical experiment. These results confirm the breaking of the loaded test pieces by a a traction load device. The guiding of the simple belt guid was loaded through the safety belt guide under traction by the lower fixing device . In the superior part of the simple belt guide a metallically bolt was fixed. The loading was progressive with a very small speed until the breaking of the 10 randomly selected samples.

Figure 7 The photoelastic model

a. b. c. d.

Figure 8 A few of the simple belt guides loaded by traction

The isochromatic fringes allow us to obtain the values of the principal stresses difference on the model by using the well known relation $\sigma_1 - \sigma_2 = N(\lambda / C)e$ where is light wave used.This can only be done once the values of the fringe order N have been completely determined. The values of the fringe order N are determined either by the compensation technique or, whenever possible, by starting from a non stressed region on the model were N=0. The fringe orders can then be easily deduced for the other fringes. The ratio $f=\lambda/C$ called the fringe constant depends on the light wave used and the model material. The isochromatic and the isoclinic fringes are comparable to the photoelastic fringes obtained on a regular polariscope. Several solutions are available to obtain this value easily.
Figure 8 presents a few samples displaying the way the simple belt guide breaks when subjected to traction loading. Thus, the experimental results confirm the breaking areas previously determined for traction loading.

3. CONCLUSION

In this paper we determine the danger areas for the simple belt guide when subjected to traction loading, by using both experimental (tension test and photoelastic method) and finite element methods. Following the analysis of the simple belt guide deformation, the following conclusions emerge:

- the finite element method and the photoelastic test determine easily the zone of the fracture;
- the fracture occurred at force values higher than those recommended by the international regulations;
- the dimensions of the pieces have been corrected based on the numerical data;
- the manufacturing process was subsequently modified and the sharp edges were redesigned;
- the photoelastic fringes obtained experimentally with a plan polarized light are used to determine the values of the principal stresses difference over the whole model.
- simulation of stresses developed on a simple belt guide gives relatively good agreements with the experimental ones.
- the experimental and numerical results were used to correct the shape of the piece and were used for homologation.
- the experimental and numerical results for the simple belt guide experiments contribute to the increase in human safety in collision motor vehicle accidents.

REFERENCES

[1] Barton E. D., Airbag safety: deployment in an automobile crash with a fall from height. The Journal of Emergency Medicine, Vol13, No 4, pp 481-4841, 1995.
[2] Calisir F., Letho M.R., Young drivers' decision making and safety belt use. Accident Analysis and Prevention 34 (2002) 793–805.
[3] Ciofoaia V., Botis M.Fl., Dogaru Fl., Curtu I., Methoda elementelor finite. Editura Informarket Brasov, 2001.
[4] Dee Th.S., Reconsidering the effects of seat belt laws and their enforcement status. Accid. Anal. and Pm., Vol. 30, No. 1, pp. l-10, 1998 Published by Elsevier Science Ltd
[5] Derrig R.A., Segui-Gomez Maria ., Abtahi A., Ling-Ling Liu. The effect of population safety usage rates on motor vehicle-related fatalies. Accident Analysis and Prevention 34 (2002) 101–110.
[6] Hesseling R., Active Restraint Systems. Feedback Control of Occupant Motion. Technische Universiteit Eidhoven, 2004.
[7] Szava I., Ciofoaia V., Curtu I., Metode experimentale in dinamica structurilor mecanice. Editura Universitatii Transilvania din Brasov, 2000.