

FINITE ELEMENT ANALYSIS OF A LATCH PLATE AS COMPONENT OF THE SEAT BELT BUCKLE ASSEMBLY

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Abstract: *The seat belt system is one of most important elements of the safety equipment in a vehicle. This paper presents the modeling, analysis and evaluation techniques for a Seat Belt Buckle Assembly strength. In order to perform this analysis and evaluate the strength, we examine the effectiveness of a latch plate as component of the seat belt buckle assembly, using the finite element analysis method.*

Key words: *seat belt system, seat belt buckle assembly, FEA*

1. INTRODUCTION AND CONTEXT

In the last years, there has been rapid and extensive progress in automotive technologies, particularly in devices that provide increased protection for the occupants of the vehicle in case of crash.

Vehicle crashworthiness and occupant safety remain among the most important and challenging design considerations in the automotive industry. In the recent years, there has been rapid and extensive progress in automotive technologies, especially with respect to electronic sensing and control systems, which allowed engineers to develop a wide range of "high-tech" safety systems. These include devices that provide increased crash protection for vehicle occupants, and systems that may allow drivers to avoid collisions or, at least, to mitigate their severity. From these viewpoints, the most important safety devices are considered the Air bags and Safety belts, but the seat belt system is widely regarded today as being the essential component of safety equipment in a vehicle. When used, according to (www.tc.gc.ca), seat belts are approximately 45% effective at preventing fatal injuries and 67% effective at preventing serious injuries. Moreover, nearly all safety experts agree that buckling up dramatically increases the chances of surviving an accident, and that seat belts reduce the risk of death for a front seat car occupant by about 50 percent. Despite this safety record, the performance of the belt systems is continuously being refined.

Recent papers discuss the development of 4-point harnesses for use in production vehicles, while devices such as pretensioners and belt load limiters are becoming common features (<http://www.carsp.ca>, <http://www.nhtsa.gov/>).

Consequently, the development and the evaluation of protection measures against the effects of accidents, require an accurate assessment of the operational behavior in the exploitation of safety systems, and involve a good knowledge of the tolerance of the human body, as well as its mechanical response to impact.

2. THE STUDIED SAFETY BELT SYSTEM AND ITS POSSIBLE DEFECTS

The safety belt (seat belt), as part of overall occupant restraint system is intended to reduce injuries by stopping the wearer from hitting hard interior elements of the vehicle or other passengers, respectively the so-called second impact, <http://en.academic.ru/dic.nsf/enwiki/7248718> and by preventing

the passenger from being thrown-out from the vehicle. A properly secured seat belt offers protection in head-on, side and rollover collisions, by securing in the life space of the vehicle. In fact, the belts system help spread out the energy of the moving body in a collision over the chest, pelvis, and shoulders.

The standard three-point belts shown in Fig. 1a, attaches to the car in three places, two mount near the rear of the seat bottom and one towards the top of the side pillar, offering a maximum of comfort and convenience. The seat-belt latch plate clips into a buckle Fig.1b, which in the front seats of cars is usually placed at the end of a stiff stalk. A pretensioner device, Fig.1c, are included as part of the safety belt system. In the event of an impact, the safety belt system is designed to grip the belt and not allow the occupant to travel forward any more than they already are.

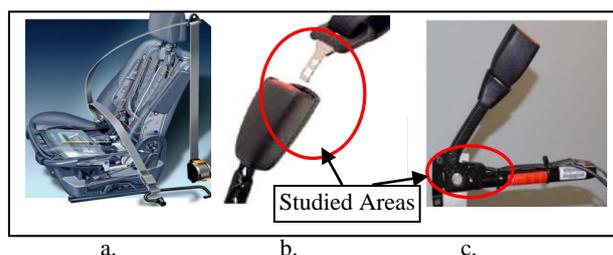


Fig.1. Standard three-point seat belt system and its components

The seat belt buckle assembly, Fig.1b, must be able to withstand extremely high loads during a crash and high accelerations in all direction without opening. At the same time it must be easy to open even when heavily loaded. This feature is critical when the seatbelt system includes a pretensioner, Fig.1c, as such a pyrotechnic device pulls rapidly the buckle in one direction towards the floor and then the pulling force suddenly switches in the other direction.

If the seat belt buckle can not endure the load that was derived by the motion of an occupant motion during a frontal impact, the seat belt can not do the role of a restraint system any more. Thus, proper strength of a seat belt buckle is essential in the case of a frontal impact.

Seat belts can fail to restrain occupants due to both poor design and/or faulty manufacturing. Some of the more common defects include: Inertial unlatching & False latching, or/and the Failure of some component parts of the seat belt buckle. Consequently, the ways to unlatch a seat belt buckle in an accident, <http://www.vehiclesafetyfirm.com>, can be: Overload; Inadvertent contact; False latch/Partial engagement; Inertial release. During a collision in such situations, the seat belt becomes unlatched and can allow the latch plate to pull out of the buckle. As a result, the occupant is essentially unbelted and unrestrained and, frequently, can be ejected from the car.

If a seat belt system failure is suspected, the evidence that a seat belt failed because of design or manufacturing defects is often subtle and can be difficult to detect. Since it is extremely

difficult to prove that a seat belt failed without the physical evidence, it is important to preserve the failed seat belt system and to attach it to the technical expertise.

3. FINITE ELEMENT ANALYSIS OF THE BUCKLE LATCH PLATE

The safety belt buckle device, Fig.1b, is designed to coupling the seat belt that fixes to seat the occupant of the vehicle in order to limit its movement during a shock, and thus, during a strong deceleration, the occupant of a vehicle in motion is not projected in the moving direction as result of the accumulated kinetic energy. The static analysis of the cable-guide subassembly of a pretensioned Seat Belt System, presented in Fig.1c and detailed in Fig.2, followed by the solving of the equations equilibrium (1), give as result the forces in the belt system, $F=635$ daN.

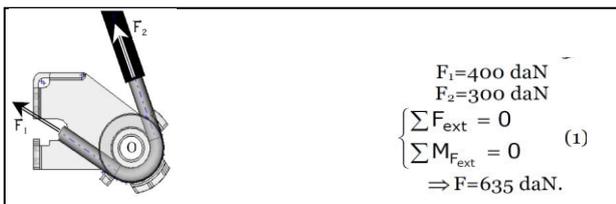


Fig.2. Evaluation of the resultant force in the safety belt system

The belt buckle assembly must have the capacity to transmit the forces being put on the system. In case one of its component parts, in particular the latch plate, can not endure the load that was derived by the motion of an occupant during an impact, the safety belt system can not play the role of a restraining system anymore. Therefore, the latch plates of the seat belts, although have different designs being manufactured by different companies, are an important element of the system. The importance of this element lies in its own security and is related to assure the functional role of the safety belts systems.

The analyzed latch plate is made of steel grade CK55 (corresponding to OLC 55 X, STAS 880), whose material properties are given in EN10083-1:2002: for $t \leq 8$ mm, $R_{e_{min}}=550$ MPa, $R_m=800-950$ MPa, $A_{min}=12\%$, $Z_{min}=30\%$. The geometry of the analysed latch plate, shown in Fig.3, was based on these functional requirements and is in accordance with the configuration of the belt buckle.

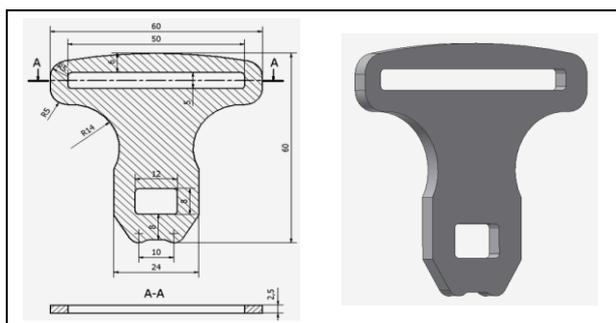


Fig.3. Geometric parameters and 3-D model of the latch plate

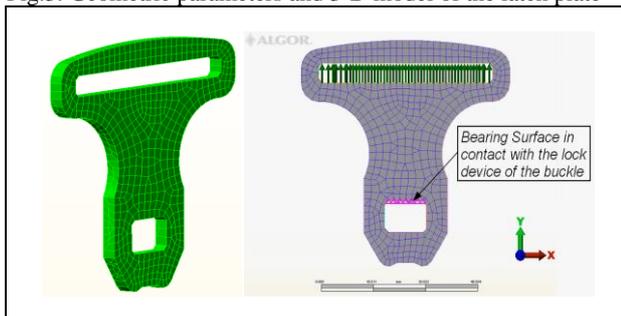


Fig. 4. a- Discretization (meshing) of the latch plate model
b - Boundary displacement constraint and mechanical loads

The finite element analysis performed using Algor software, involved the following steps:

- Conception of the 3-D CAD model of the latch plate, or transfer the model designed in .stp format file;
- Discretization (meshing) of the model (Fig.4a), defining the displacement boundary conditions, applying the mechanical loads (Fig.4b) and the Material Properties;
- Performing of the finite element analysis (matrix equations, solved for the unknown displacements); (Kim & Sankar 2009);
- Analysis and interpretation of the FEA results (Fig.5), and analysis conclusions. (Spiyrakos & Raftoyiannis 1997).

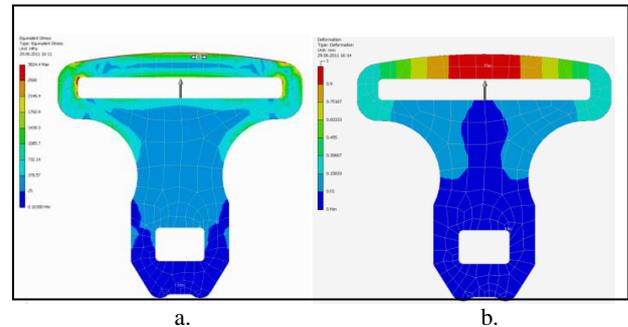


Fig. 5. Finite Element Analysis of the safety belt latch plate:
a - Distribution and values of Stress; b - Deformation

4. INTERPRETATION AND CONCLUSIONS. FUTURES STUDIES

The CAD modeling and the Finite Element Analysis of the seat belt system (buckle assembly and latch plate), was carried out in order to verify the safety of the car occupants in impact conditions. The proper design of a seat belt buckle is essential in a frontal impact, because if the buckle assembly can not endure the load derived by an occupant motion during a frontal collision, the safety belt can not serve as functional restraint system. The effectiveness of the component parts of the safety belt assembly was analyzed using the *Algor V Release* software, based on the Finite Element Method, and the results that we obtained reveal the correct design conception of the examined elements.

In our future studies, we are planning to do further development on the subject of analyzing the passive safety systems using FEA software. This work is motivated by the continuously increasing standards for protection measures against the effects of accidents. These require an accurate assessment of the operational behavior of the safety systems in exploitation, and involve a good knowledge of the tolerance of the human body, as well as its mechanical response to impact.

5. REFERENCES

Spiyrakos, C.; Raftoyiannis, J. (1997). *Linear and Nonlinear Finite Element Analysis in Engineering Practice*, Algor Inc. Publishing Division, ISBN 0-9652806-2-4, Pittsburg, USA

Nam-Ho Kim & Bhavani V. Sankar (2009). *Introduction o Finite Element Analysis and Design*, J. Wiley&Sons Inc., ISBN:978-0-470-12539-7, New York, USA

***.(2009) www.tc.gc.ca - *Transport, Infrastructure and Communities Portfolio/Government of Canada*, Accessed on 2009-04-05

*** (2010) www.carsp.ca/page/111/400 - *High-Tech Vehicle Safety Systems. Canadian Association of Road Safety Professionals*, Accessed on 2010-12-02

*** (2009) www.nhtsa.gov - *National Highway Traffic Safety Administration*, , Accessed on 2011-03-01

*** (2009) <http://en.academic.ru/dic.nsf/enwiki/7248718> , , Accessed on 2011-03-01

*** (2009) <http://www.vehiclesafetyfirm.com>, Accessed on 2011-06-02