Modelling of muscle forces in aspect of unsymmetrical disabled driver behavior during frontal crash

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Abstract

The paper is related to safety issues of disabled drivers. It concerns an implementation of muscle forces to numerical models which are used to simulate the driver behavior during car crash. The paper describes the preparation of numerical model which contains models of the quadrant of the car, 50th Dummy Hybrid III, full-scale flexible seat, special equipment for disabled driver placed on the steering wheel as well as airbag and seat belt systems. The commercial model of the dummy was modified by adding joints loads to particular limbs. By applying the adequate characteristics of moments versus joint angles, a more realistic reaction of the driver during dangerous road situations is addressed. Using the developed numerical model, five cases were analysed, as a combination of tension occurrences in different parts of the driver body. All the numerical analyses were performed in two steps: the first reflected the subsidence of the driver while the second the simulation of the frontal crash taking into account the residuum from the first one. As a result of performed numerical analysis, charts of dummy's mass centre movements, angles of body rotation and head displacement were obtained.

Keywords: disabled driver, frontal crash, muscle forces, safety, numerical analysis

1. Introduction

According to World Health Organization (WHO) the number of people in the world has exceeded seven billion. Almost 15% of them are disabled persons, among which a big part has movement disabilities. Therefore, human mobility is a very important issue nowadays. It is necessary not only to participate in social and cultural life, but also to work actively. In regions where there is lack of public transport, a good solution is to adopt a personal car to address driver disability. Actually, there are many companies offering several solutions for almost every possible combination of the movement disability. Unfortunately, a great number of offered solutions is not subjected to any testing procedures, although they cause significant changes in posture, support point location and kinematics of the driver. It influences not only comfort and ergonomics, but what is most important, on their safety.

The driver reaction during dangerous situation on the road has a significant impact on his behavior, especially considering the change of body position which directly influences the severity of injuries. It is particularly important in case of drivers with serious disabilities. For instance, when driver has paralyzed legs, he is unable to use them to keep his posture. In addition, in such cases, driver must use a special equipment to operate the car. The most common solution in this case is a combination of special handle on the steering wheel and the second handle placed above the gear stick, which substitutes acceleration and brake pedals. The described system leads to the asymmetrical support of the driver body and hence unsymmetrical behavior during a collision. This issue can escalate when the driver is aware of an approaching danger and tries to counteract generating muscle tension in his body.

The paper is focused on the implementation of muscle tensions to the disabled driver limbs. Based on the obtained results, the authors assessed the influence of driver reactions on his behavior and severity of injuries.

2. Materials and methods

2.1. Numerical model description

In order to perform the research a numerical model was developed. The model is a combination of the following commercial models: Dummy Hybrid III [1], Ford Taurus [2] as well as models of airbag, seat belts system and seat developed by the authors (Fig. 1).

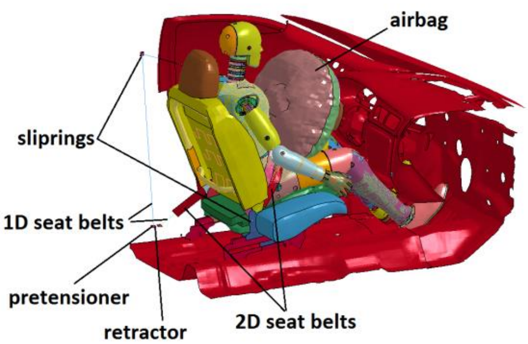

Figure 1: Numerical model overview

The developed model of the airbag represents the airbag in accordance with the European norms and regulations for C and D car segments. The airbag activation during the analysis was triggered using acceleration sensors. The same sensors were used to trigger the operation of the seat belts system which consists of seat belt tapes, sliprings, pretensioner and retractor. All the components were described using real-world characteristics. To properly describe the behavior of the seat, a several material tests were performed.

During the performed numerical analysis, it was assumed that the geometry of the vehicle interior (which may contact with the driver) is rigid. The rest of the vehicle was not modelled, which significantly shortened the computation time The car interior velocity was controlled by the pre-defined curve, obtained during preliminary simulations of the car frontal crash using commercial numerical model [3]

2.2. Implementation of muscle forces

To implement the muscle forces in the numerical model, the authors took advantage of the fact, that the core of dummy model is composed of rigid entities. Therefore, it was possible to use a relatively simple joints with adequate characteristic of moment as a function of joint angle (Fig. 2). This approach assumes that there is a certain angle of the joint which is eligible by the driver (neutral angle). During the simulation, when the current angle is lower than the neutral angle, the force momentum is applied to the joint. The applied force momentum is equal to the maximal values obtained in experimental tests for particular limbs. The experimentally obtained characteristics represents for each joint flexion and extension separately (Fig. 2.)

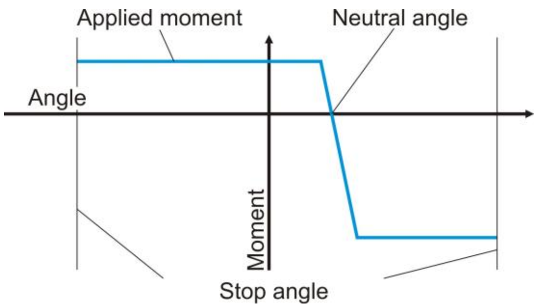

Figure 2: Example characteristics of joint momentums used in numerical model to introduce muscle forces.

2.3. Strategies of numerical research

All the numerical analyses were performed in two steps. In the first one the subsidence of the dummy on seat and handling equipment under gravity load was carried out. The second stage of the analysis included the residuum (displacements and stress components) from the first stage and was focused on frontal crash simulation.

3. Results

During the numerical research five scenarios were studied: without any tensions, with tension in the left hand, with tension in the left hand and the left leg, with tension in the left hand and the right leg, with tension in the left hand and both legs. The differences between the obtained results are mostly visible on the chart of dummy's head displacements (Fig. 3), pelvis transverse displacements (Fig. 4) and angle of rotation of his shoulders (Fig. 5).

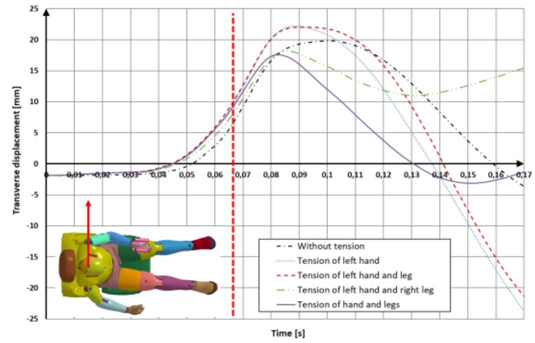

Figure 3: Transverse displacement of the driver's head

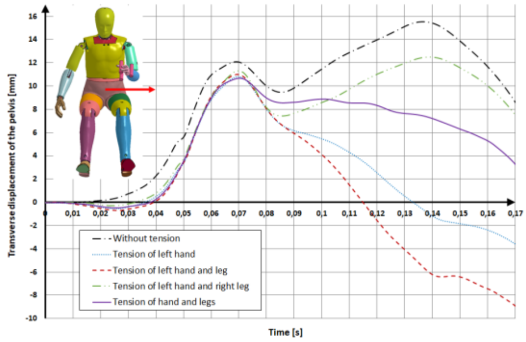

Figure 4: Transverse displacement of the driver's pelvis

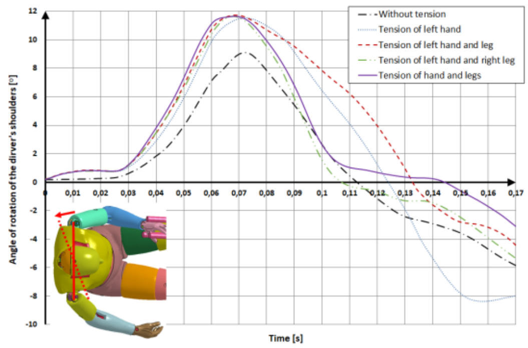

Figure 5: Angle of rotation of the driver's shoulders.

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