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SIMULATION OF PILOT LOAD DURING EMERGENCY LANDING CONDITIONS

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Abstract: *Models of dummy embedded in numerical commercial software packages are calibrated using Anthropometric Testing Dummies (ATD). The dummies vary according to the loading character different for aeronautic or automotive industries. The aim of the article is to find a solution of analysis of loads in lumbar column, based on aeronautical regulation requirements using available dummies in commercial software systems MSC.Nastran and MSC.Dytran. Simulation results were compared with experimental test data obtained from dynamic sled test with implemented ATD.*

Keywords: Aircraft passive safety, Finite element method, Dummy, Dynamic test.

1. Introduction

Present article was initiated within the frame of project "Increased passive safety of TL-ultralight aircraft, deals with passive safety of very small aircrafts. The passive safety is not included into regulation requirements for this aircraft category. The complex solution of the passive safety leads to assessment of a crash landing condition effect on aircraft crew members. This approach is ambitious especially on execution of complex crash tests. Commercial software packages based on finite element method (FEM) might reduce range of the tests.

Assessment of a passive safety in aerospace industry using injury criteria leads to evaluations of a head injury, thorax injury, represented by maximal force in safety belts, and estimation of a lumbar spine injury. An assessment of head and thorax injuries is not a problem from FEM simulation point of view and correlation with experiments. However Tabei (2009) revealed considerable inaccuracies in correlation with experiments for lumbar spine injury assessment. The paper investigates methods, how to evaluate spinal forces obtained from ATB (articulated total body) dummies implemented in commercial FEM software packages.

2. Dynamic test

The dynamic test was executed at Dekra a.s. company on testing facility for automotive industry (Fig. 1). The seat was fixed on a steel frame and mounted on a dynamic sledge. A FAA 50th percentile Hybrid II testing dummy was belted using four point safety belts.

The testing facilities have been primarily developed for testing of automotive safety belts, where testing conditions are different than in aircraft seats testing. In order to comply maximum deceleration defined in aircraft Certification Specifications for Normal Utility and Commuter Category Airplanes CS23, specified in AC 23.562 (1989), the loading pulse had to be changed. An initial velocity has to be increased and time duration on high deceleration level was enlarged. It can be remarked, that seat and dummy during the test absorbed higher energy than would be necessary according to requirements in CS23. After the frame with seats stopped, a slight rebound backward occurred. The Fig. 2 shows comparison between applied deceleration pulse during the dynamic test and pulse defined in CS23.562(b)(1).

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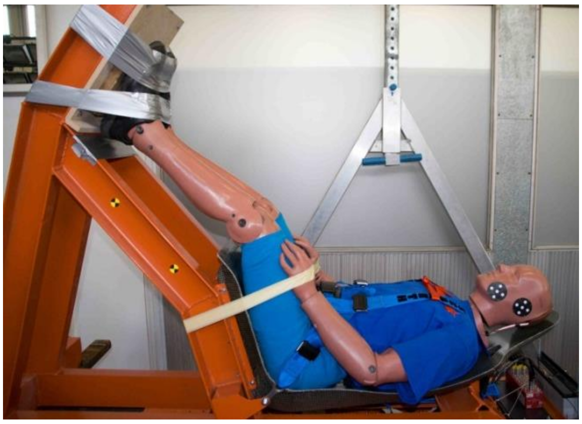

Fig. 1: Dynamic sledge test with 50 % HybridII.

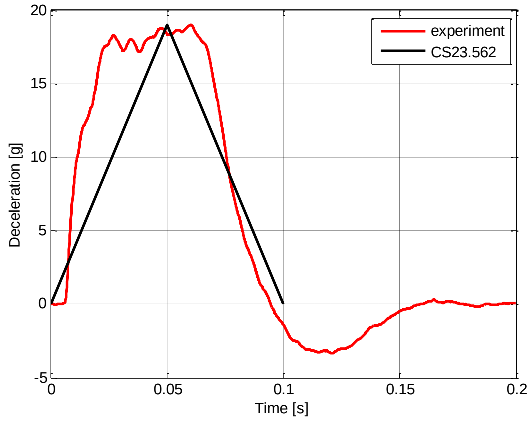

Fig. 2: Test pulse used in experiment and pulse defined in CS23.

3. FEM models

Two types of ATB models available in MSC.Software products had been used for experimental evaluation. MSC.Software portfolio uses two explicit codes: MSC.Dytran and MSC.Nastran 700. The MSC.Dytran is an original explicit solver among the MSC. Software products and MSC.Nastran has core taken from LS-Dyna software package with all enhancements including ATB dummy models.

The dummy model implemented in MSC.Dytran is assembled from two parts. The first one is system of rigid ellipsoids (Fig. 3a) with defined mass and inertial properties representing parts of the body. Those ellipsoids are connected by analytical joints to ensure realistic flexibility of the dummy. The second part is skin of the dummy (Fig. 3b) analytically linked with ellipsoids which enables contacts of the dummy with the surrounding. The kinematical properties of the dummy are based on anthropometric fidelity with ATD testing dummy (Cheng, 1989).

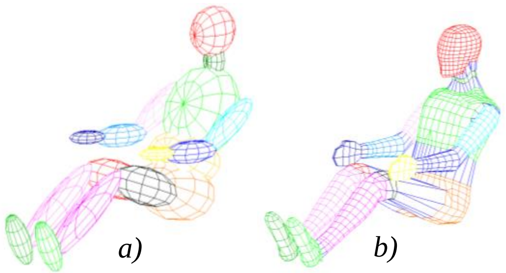

Fig. 3: The dummy in MSC. Dytran.

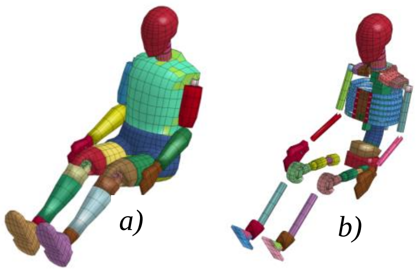

Fig. 4: The dummy in MSC.Nastran 700.

The model of the 50th percentile Std. Hybrid III dummy available in LS-Dyna was developed in Livermore Software Technology Corporation as a full FEM model of the Std. HIII ATD (Fig. 4). Oliva-Perez (2010) mentions that model of the dummy has been primarily designed for frontal crash in the automotive industry and its lumbar spine column does not correspond with the ATD testing dummy accepted by Federal Aviation Administration (FAA) for measurement of spine load. The internal structure of the dummy (Fig. 4b) has been created from rigid objects which are connected by analytical joints and contacts. The model of the external parts of the dummy is assembled partly from objects with rigid material properties (head, legs), and with objects from a low density foam material (pelvis and thorax). The models are available on the internet , with announcement that, FAA HIII is not available yet and the dummy is in a planning stage.

4. Modeling of the experiment

Numerical simulations of the dynamic test have been performed using MSC.Dytran and MSC.Nastran 700 explicit codes. Global properties of the seat models were equivalent with the real tested seat. The models of the seats are stiff without any devices for energy absorbing. The safety belts can be modeled using 2d shell elements in MSC.Nastran 700, because of available material model for orthotropic fabric. The MSC.Dytran allows modeled safety belts using 1d elements (Fig. 5).

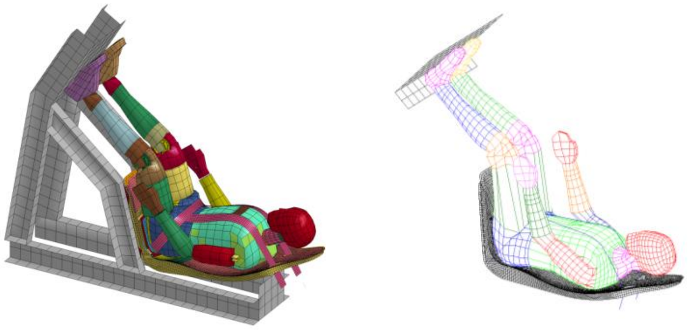

Fig. 5: Model of the test in MSC.Nastran700 (left) and in MSC.Dytran (right).

5. Results

Results of the compressive loading in the lumbar spine simulations were executed in MSC.Nastran 700 and MSC.Dytran and compared with the experiment. The forces in lumbar spine were evaluated using two approaches for both solvers. The first approach uses resulting force directly from ATB dummies; the second one evaluates contact forces between seats and dummy. It was assumed, that the force acting to the seat produced by dummy equals the force acting to the lumbar spine. The Results pulses were filtered with SAE J211 CFC digital filter described by Alem (1995). The main evaluated parameters were correlation of maximal forces in the lumbar spine with the experiment related on the CFC filter used.

5.1. Simulation in MSC.Nastran 700

The dummy implemented in MSC.Nastran enables to obtain the force in lumbar spine directly from the spine column. Force in „z" direction is acting in the spine direction. A force tangential to surface of lumbar load cell is acting in „x" direction. Raw results obtained from simulation are considerably noisy and therefore the results were filtered by CFC filters. The filtering causes distortion of signals.

Selection of the filter has to be done to avoid of "over-filtering". Forces in lumbar spine were filtered with CFC30 and the results are presented in the Fig. 6 for X and Z direction. Total force was calculated using vector sum of the X and Z components. It could be emphasized, that the Std. HIII dummy used in model is primarily designed for frontal impact test in automotive industry, where realistic response of dummy especially in bending is required for contact analysis with an airbag or steering wheel. Compressive loading in lumbar spine for that type of analysis are not demanded. The Fig. 6 revealed the load pulses divided into two peaks. The first one corresponds with initial contact of the body with the seat. The second one arises at the time of maximal tangential forces in lumbar load cell. This pulse can be caused by bending of the lumbar spine. Fig. 7 displays contact force between dummy and seat pan. The resulting pulse is not filtered and it is raw signal obtained from the simulation.

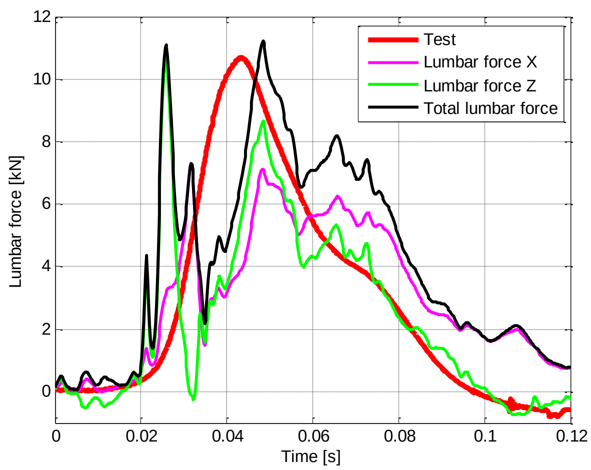

Fig. 6: Force obtained from directly from lumbar spine in MSC.Nastran.

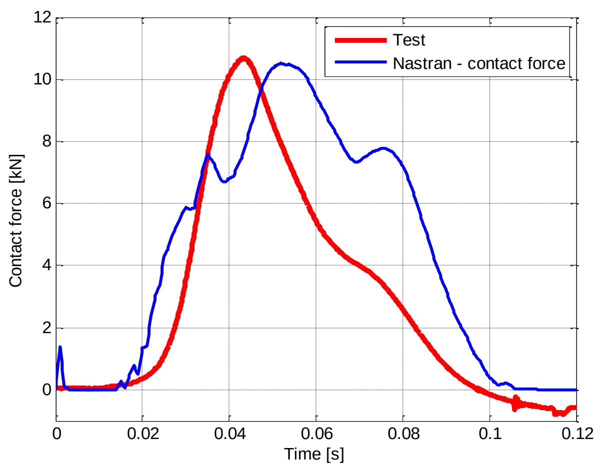

Fig. 7: Force in contact between seat pan and the dummy in MSC.Nastran.

5.2. Simulation in MSC.Dytran

The dummy used in MSC.Dytran does not allow obtaining load in lumbar spine directly. The force has to be calculated for acceleration in centers of gravity of selected rigid. The ellipsoids representing the head, neck, abdomen, thorax and both hands were considered to the calculation of the spinal load.

The results of the simulation (Fig. 8) analyzed in MSC.Dytran suffer distinct oscillation of the signal. This may be due to the contact between rigid ellipsoids and rigid seat. Therefore filtering using CFC filters with different cut - off frequency were performed.

Fig. 9 presents the results of contact forces between seat pan and the dummy. The result demonstrates that the cut –off frequency of the filter considerably affects the results. The Fig. 9 shows comparison of the results filtered by the CFC 15 and the CFC 30 with the experimental data. The reason of the signal oscillation from simulation is probably the same as reason for the force analyzed directly from ellipsoids of the dummy. The frequency of oscillation in both evaluation methods is identical, only the maximum forces differ.

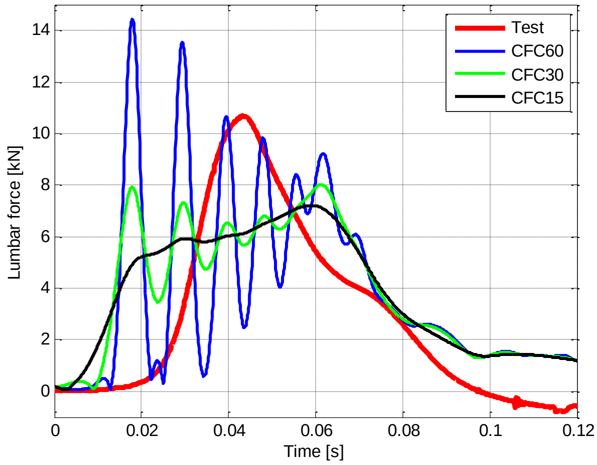

Fig. 8: Comparison of the spinal load calculated from ellipsoids with the test.

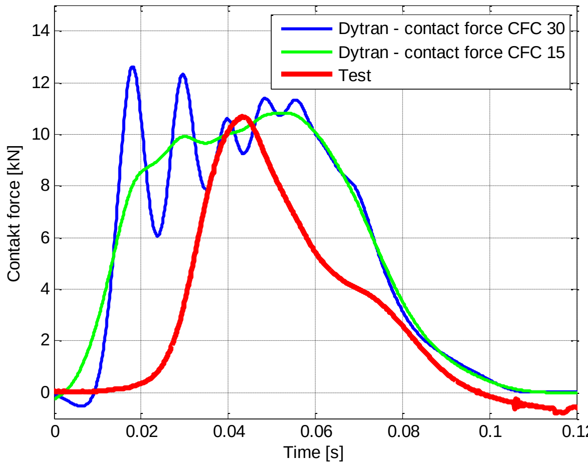

Fig. 9: Comparison of contact force between the dummy and the seat pan form MSC. Dytran with the test.

6. Conclusion

In frame of presented work the dynamic laboratory sledge test according to CS23.561(b)(1) was executed with the rigid seat. The 50 percentile FAA Hybrid II testing dummy was used for measuring the force in the lumbar spine. Afterwards numerical simulations have been performed using commercial explicit codes produced by MSC.Software (MSC.Nastran 700 and MSC.Dytran) and the results were compared with experiment. An approach for lumbar spine evaluation was selected according to correlation with the experiment. The most promising result of force of the lumbar spine was obtained from analysis of the contact force between seat and the model of the ATB Std. Hybrid III testing dummy analyzed in explicit code MSC.Nastran 700.

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