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VALIDATION OF FEM MODEL OF INTERACTION OF CAR SEAT CUSHION AND RIGID INDENTER

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Abstract: *The article deals with the creation and validation of a simulation model of a car seat cushion in interaction with a rigid indenter. The geometric data of the cushion are obtained by 3D scanning of the real seat. Based on this, the volumetric mesh model for the FEM analysis is made. Material data, such as elastic properties of the foam material and the coefficient of friction, are obtained experimentally. Simulation of the contact pressure between the seat cushion and rigid indenter is performed in MSC.Marc software and the result is compared with the experiment.*

Keywords: Car seat, Sitting comfort, Polyurethane foam, Pressure mapping.

1. Introduction

Comfort of sitting is an important aspect of car seat design. Computer simulation of passenger – seat interaction requires good simulation model of both interacting objects. This article deals with elaborating of methodology of validation of simulation model of car seat cushion. For more objective definition of validation task the cushion is in interaction with rigid steel cylinder representing the load.

2. Model geometry

Digitization of the seat was performed with a contactless scanning system MetraSCAN 350 (Creaform). It is an optical hand-held scanner working on the principle of active triangulation. The accuracy of the device is according to the ASME B89.4.22 standard in the working range up to 16.6 m^3 up to 0,122 mm. The resolution of the point cloud was set to 1 mm. The seat was digitized separately from its upper and bottom side (Fig. 1a and Fig. 1b).

Processing of scanned data was realized in software GOM Inspect Professional (GOM company). To join the coordinate system of both parts of the seat, overlapping side surfaces were used and mutually aligned using the BestFit function (minimization of the square of deviations). This was followed by the combination of the two meshes into one unit and the optimization of the polygonal mesh (Fig. 1c). Data in STL format were made up from triangular surface mesh. To obtain parametrically defined planes and volumes the model was transformed to planes by automated routine (Fig. 1d) in Ansa software (Beta CAE) and then the edges of planes were edited manually (Fig. 1e). Subsequently the rectangular-triangular (tria-quad) surface mesh was generated with approximate size of an element 5 mm. Then volumetric mesh was generated by function HEXA-POLY which makes hexahedral mesh in location where it is possible (internal volume) and polyhedral mesh on surfaces and transition areas. This model consist of 147 971 tetra, 169 penta, 6 190 hexa elements and 21 796 pyramids which provides good computational stability for large deformations (Fig. 1f).

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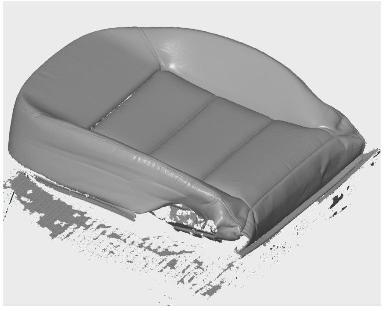
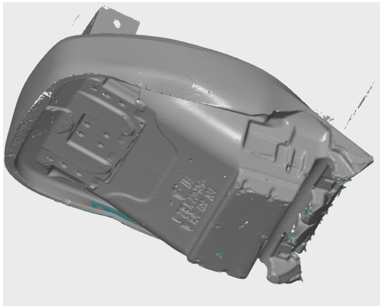
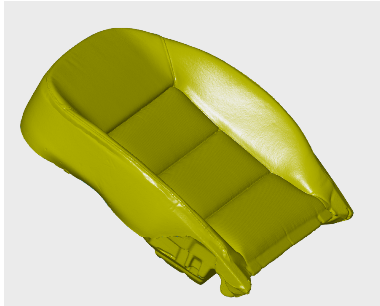


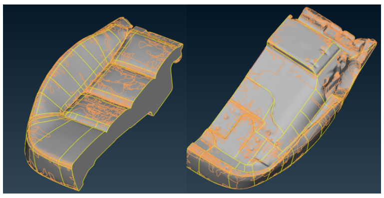
(a) Scan of upper part (GOM)



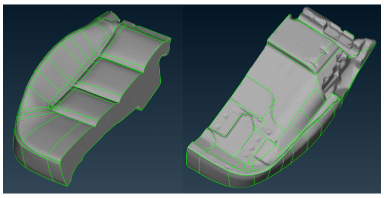
(b) Scan of lower part (GOM)



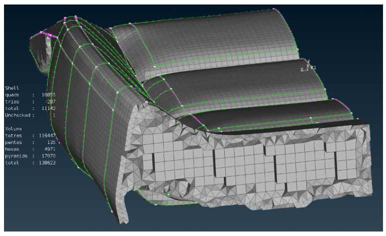
(c) Parts assignment & polygonal mesh optimisation (GOM)



(d) Automated planes identification – Makro function (Ansa)



(e) Manual planes refinement (Ansa)



(f) Final volumetric mesh (Ansa)

Fig. 1: Creation of geometric model of seat cushion

Another part of simulation model is a rigid indenter. It is a cylinder with rounded edge with mass 18,6 kg. indenter of such properties has an ability to cause similar values of pressure in contact with a cushion as a human body. To lower computation time and for more effective data post-processing an additional surface mesh is used to define contact between steel indenter and seat cushion.

In reality the seat cushion lies on steel frame of the seat. From this it could be deduced that for definition of boundary conditions it is enough to fix rigid that the nodes of the lower part of cushion which are in contact in seat's frame. But this idea appeared insufficient because between steel frame and lower surface of cushion there was a certain gap in our case. Therefore the relevant part of steel frame was modelled as a thin plate (green colored part in Fig. 3a) and the contact problem in interaction with the foam cushion (grey colored part) was solved.

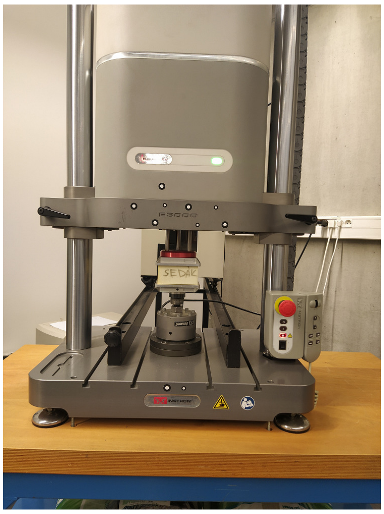
3. Material testing and identification

The seat cushion is made of polyurethane foam. Mechanical properties of foam material were investigated experimentally by compression test (Fig. 2a) of foam cube cut out from the cushion. This specimen of size $(100 \times 100 \times 50)$ mm was compressed by triangular course of displacement with constant velocity $v = 0,6$ mm/s and maximum deformation 30 mm therefore maximum relative deformation 60 %. Dependence of measured force on displacement has typical non-linear character with hysteresis behaviour, see (Cirkl and Hruš, 2015; Deng, 2006). Only non-linear elastic behaviour of foam represented by back bone curve considered as restoring force was taken in to account. For identification the FOAM material model was used in MSC.Marc (see MSC (2000)). It is a modification of Ogden model for compressible materials and it is described by constitutive energy function

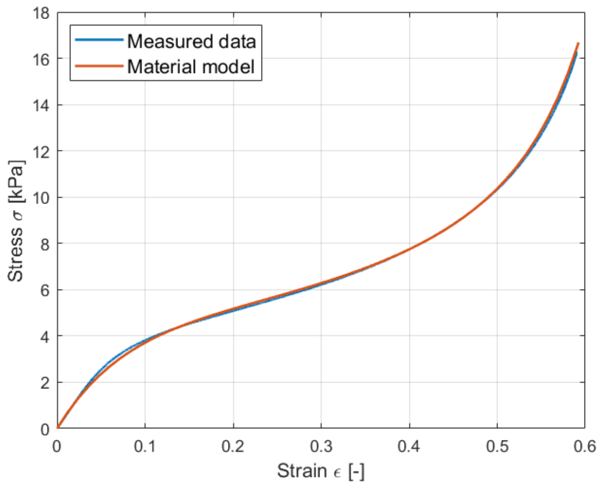
$$W = \sum_{n=1}^{N} \frac{\mu_n}{\alpha_n} (\lambda_1^{\alpha_n} + \lambda_2^{\alpha_n} + \lambda_3^{\alpha_n} - 3) + \sum_{n=1}^{N} \frac{\mu_n}{\beta_n} (I - J^{\beta_n}), \tag{1}$$

where the material constants are $\alpha_1 = -10,1147$, $\alpha_2 = 14,8761$, $\beta_1 = 0,103211$, $\beta_2 = -0,151797$, $\mu_1 = -0,984644$ MPa, $\mu_2 = 4368,21$ MPa, $N = 2$. Comparison of the model response and experimental data is in Fig. 2b. The model shows a good correspondence with the experiment.

For definition of contact problem also coefficient of friction between cushion cover and steel indenter was taken into account. It was measured by tribometer based on ball-on-disc method. Measured value of a friction coefficient independent on velocity was $f = 0,14$.



(a) Experimental arrangement



(b) Model fitting

Fig. 2: Experimental identification of the FOAM model

Tab. 1: Properties of pressure mapping systems

Brand	Xsensor	TekScan
Sensor matrix	48x48	33x33
Sensor spacing	0,5 inch	14,7 mm
Technology	capacitive	resistive
Scale	$0 \div 27$ kPa	user calibration

4. Model validation

FEM model validation is based on experimental verification. The real seat (Fig. 3b) was loaded with steel indenter and the contact pressure distribution was measured. Two pressure mapping systems, Xsensor and TekScan, with properties presented in Tab. 1 were used and results were compared (see Fig. 4b).

5. Conclusions

The aim of the work was creation and validation of FEM model of a car seat cushion. Its geometry was obtained by 3D scanning method and subsequently the FEM model was created. Material model was identified by experimental methods. Experimental verification of seat cushion was performed by means of two different pressure mapping systems TekScan and Xsensor. Both systems show some kind of discrepancy in comparison with simulation. TekScan system works well in sharply localised pressure peaks, and fails in sharply localised pressure bottoms while Xsensor system shows the opposite behavior. One of the reasons may be the different bending stiffness of pressure sensors where Xsensor provides more flexibility. In parts of more evenly distributed pressure both systems give good conformity with simulation. Taking this into account we consider the FEM model of car seat cushion as experimentally validated.

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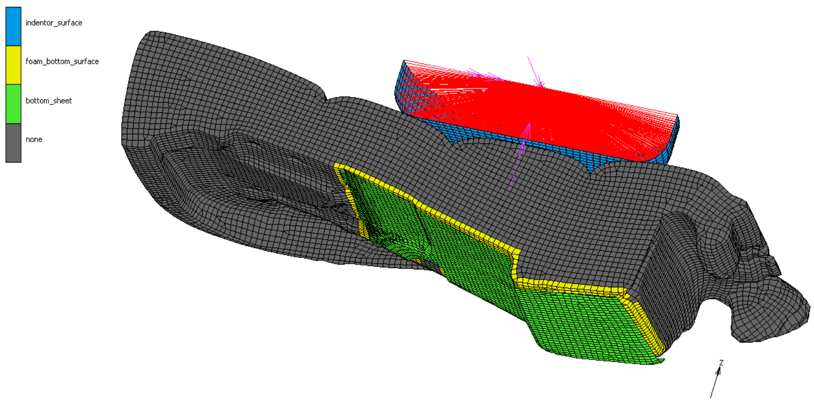
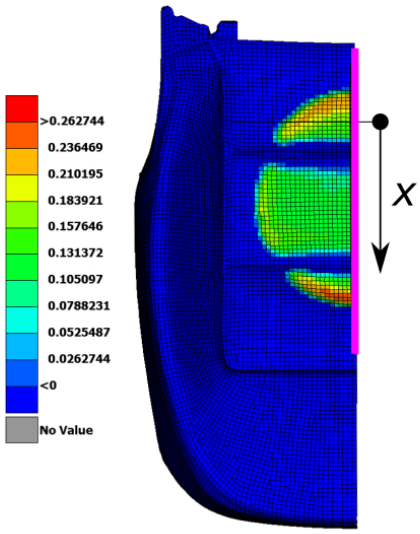


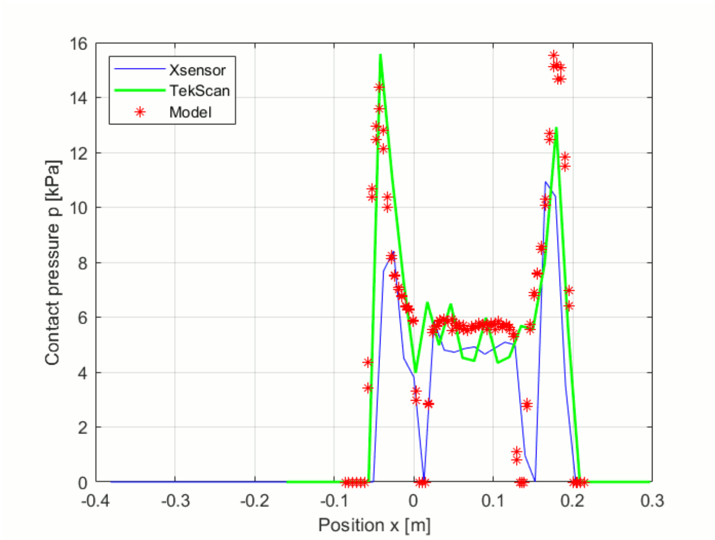
(a) Simulation model arrangement

(b) Experimental arrangement

Fig. 3: Seat cushion loaded by rigid indenter



(a) Simulation – normal force [N] distribution (control line – pink)



(b) Contact pressure value over control line (simulation vs experiment)

Fig. 4: Simulation end experimental results

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