VALIDATION OF EURONCAP FRONTAL IMPACT OF FRAME OFF-ROAD VEHICLE – ROAD TRAFFIC ACCIDENT SIMULATION

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I. INTRODUCTION

Frontal crashes lead to more deaths and serious injuries than any other accident type. A typical scenario is a head-on collision between two oncoming vehicles at relatively high speeds. In most collisions of this type, only a part of the vehicle front width structure is involved, i.e. the two colliding vehicles are offset.

In the full-scale test, the car is driven at 64km/h and with 40 percent overlap into a deformable barrier which represents the oncoming vehicle. The test replicates a crash between two cars of the same weight, both travelling at a speed of 50km/h. Two frontal impact dummies representing the average male are seated in the front seats and child dummies are placed in child restraints in the rear seats [1].

In this research full-scale FE model of SUV was created and then validated according to the data provided by customer.

II. MODELING

As a result of modeling the “smart digital twin” was created – the model which includes all the necessary parameters for prediction of object behavior during any physical interaction. “Smart digital twin” is integral part of digital factory – the complex of processes with the aim of achieving the new level of the process of designing products, structures and approaches to production through the effective use of the entire complex of multi and transdisciplinary technologies of world level.

A production 2016 four-door passenger SUV was used as the basis for the investigated model. Each part was meshed to create a representation of geometry models for finite element modeling that reflected all structural and mechanical features in digital form. Parts were broken down into elements such that critical features were represented consistent with the implications of element size on simulation processing times.

Figure 1 – Actual vehicle

Figure 2 – Full scale FE representation

Material characterization data for the structural components was obtained through sample testing. Material data includes all the necessary nonlinear properties – strain-stress curves with considered viscosity. From the material testing appropriate stress, strain and damage values were determined to include in the model for the analysis of crush behavior in crash simulation. The resulting FE vehicle model has 3 million finite elements. This detailed FE model was constructed to include full functional capabilities of the suspension, the driveline and steering subsystems. A representation of this model in comparison to the actual vehicle is shown in Figure 1 and Figure 2.

The set of elements representing the vehicle was translated into an FE model by defining each as a shell, beam, or solid element in accordance with the requirements for using LS-DYNA software.

III. MODEL VALIDATION

The FE model was validated in several ways to make sure that it was an accurate representation of the actual vehicle. The initial efforts included checks for completeness of elements and adequacy of connection details. The measured properties at customer location for the vehicle were compared to those generated from the FE model.

The FE model EuroNCAP simulation was performed using the LS-DYNA non-linear explicit finite element code. The total duration of the simulated impact was 200 ms to capture the initial impact until the rebound of the vehicle from the EuroNCAP load.

Due to the lack of data provided by the manufacturer, the first virtual tests according to the EURONCAP rules had a low degree of correlation with the full-scale crash test. The following data were not provided:

- results of testing of vehicle materials with viscous properties and high-speed deformations curves;
- stiffness and damping curves of kinematic connections in suspensions;
- virtual model of airbags and seat belts.

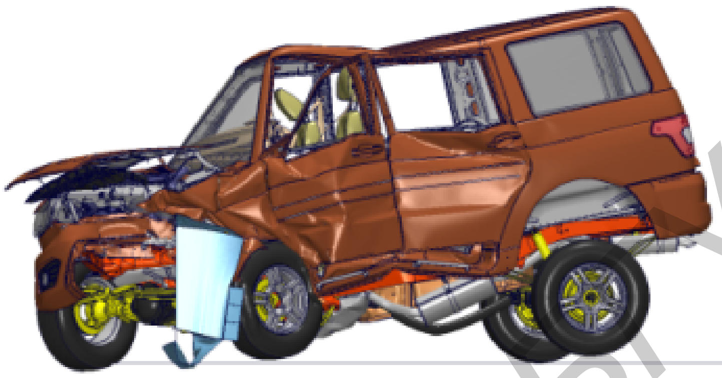

Figure 3 – Deformation with customer material models

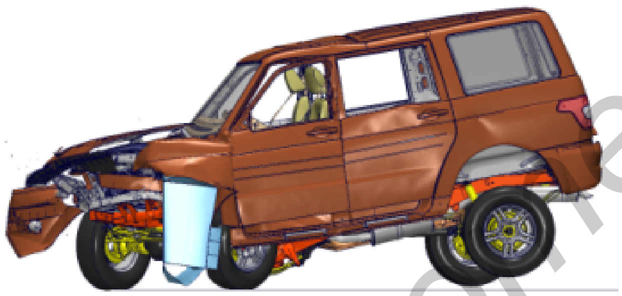

Figure 4 – Deformation with optimized material models

Figure 5 – Deformation on actual crash-test

To select appropriate material models a series of crash simulations was performed in order to achieve a coincidence of deformations. The customer provided material models that do not take into account high-speed hardening, therefore, at high strain rates, deformations significantly exceeded the values reached in the actual EuroNCAP test. Figure 3 shows body deformation with materials that do not take into account high-speed hardening. Figure 4 shows body deformations with selected material from the database of contractor, with strain-stress curves for high-speed deformations.

For comparison figure 5 shows deformation from actual crash impact. As a result of the multivariant optimization, it was possible to achieve a similar character of deformation of the frontend, the body sill, doors of the off-road vehicle.

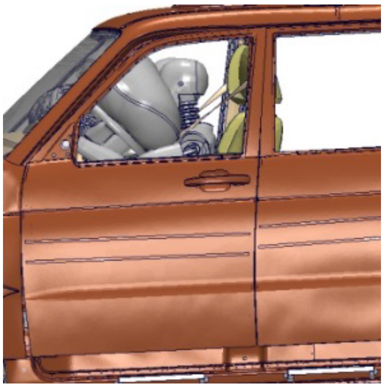

Figure 6 – Collision of dummy head with airbag, virtual crash-test 90 ms

Figure 7 – Collision of dummy head with airbag, actual crash-test 90 ms

Virtual model of airbags and seat belts were not provided by customer, so they were adjusted according to EuroNCAP test results. On the figures 6 and 7 one can see comparison of driver airbag behavior in simulation and in the actual test at the moment of head collision with surface of airbag on 90 ms.

Figure 8 shows side view of the frontal deformations taken at five intervals during the impact. It can be noted that the actual and simulated views reflect similar at each time point.

80 ms 120 ms 160 ms

Figure 8 – Sequential side views of the actual and simulated EuroNCAP Frontal deformable barrier test for the off-road frame vehicle

The side view shows a high degree of coincidence of deformation of the front part of vehicle. In both cases the hood does not interact with the barrier and ejects forward due to high inertial forces. The fenders and front car body part have almost identical deformations. The rear part of the vehicle rises up in both tests due to the high position of center of gravity.

Figure 9 shows top view of the frontal deformations taken at three intervals during the impact. The top view for full scale and virtual tests shows the same turning angle of the vehicle after the impact, the similar picture of the opening of the hood and deformation of the left wing.

50 ms 100 ms 150 ms

Figure 9 – Sequential top views of the actual and simulated EuroNCAP Frontal deformable barrier test for the off-road frame vehicle

Figure 10 shows bottom view of the frontal deformations taken at three intervals during the impact. The bottom view shows a high degree of coincidence of frame deformations in full scale and virtual tests. One can see that fractures appear in the same places, the deformation paths have a similar pattern, the fastening point between the torque divider and the front cardan is broken in both cases, and the same support damage between car body and frame can be noticed. Also in both cases, the front wheels rotate with the subsequent destruction of the car body floor and a breakdown of the integrity of the living space of driver and passengers.

50 ms 100 ms 150 ms

Figure 10 – Sequential bottom views of the actual and simulated EuroNCAP Frontal deformable barrier test for the off-road frame vehicle

IV. SUMMARY AND CONCLUSIONS

A FE model of the 2016 passenger SUV was created and validated using LS-DYNA solver. The modeling led to a detailed model that consisted of 3 million elements, included all vehicle structural and interior components, and has functional representations of the steering, suspension and driveline systems. A multistage process of selecting the missing characteristics was carried out. As a result of the iterative process of off-road vehicle model validation high degree of coincidence with the full-scale test was achieved. Missing characteristics of SUV were selected and fitted during the validation process, the selected characteristics showed a sufficient degree of correlation. The final model will be used to conduct virtual tests to determine the passive safety according to EURONCAP rules in the process of developing the off-road vehicle for future production.

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