European Commission

Generic vehicle model N1

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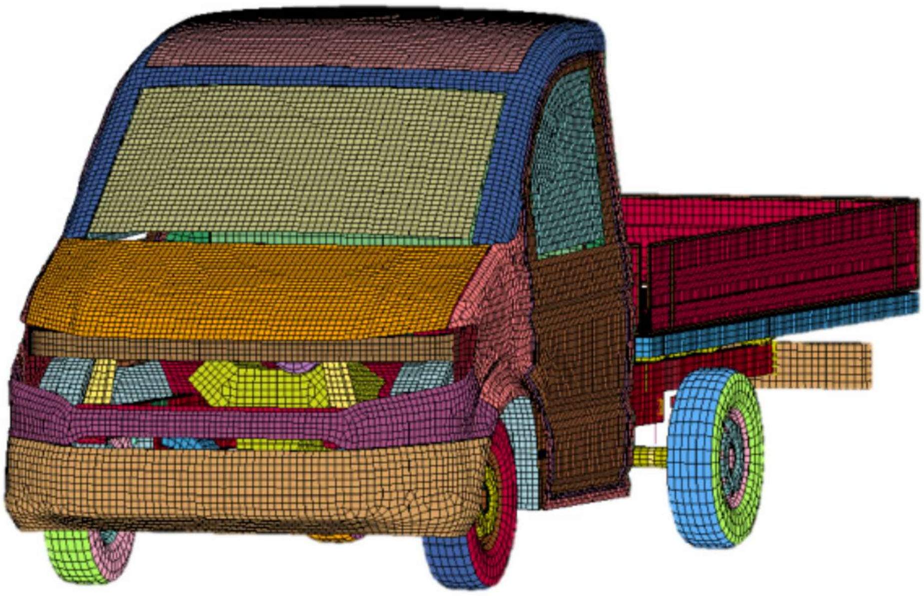

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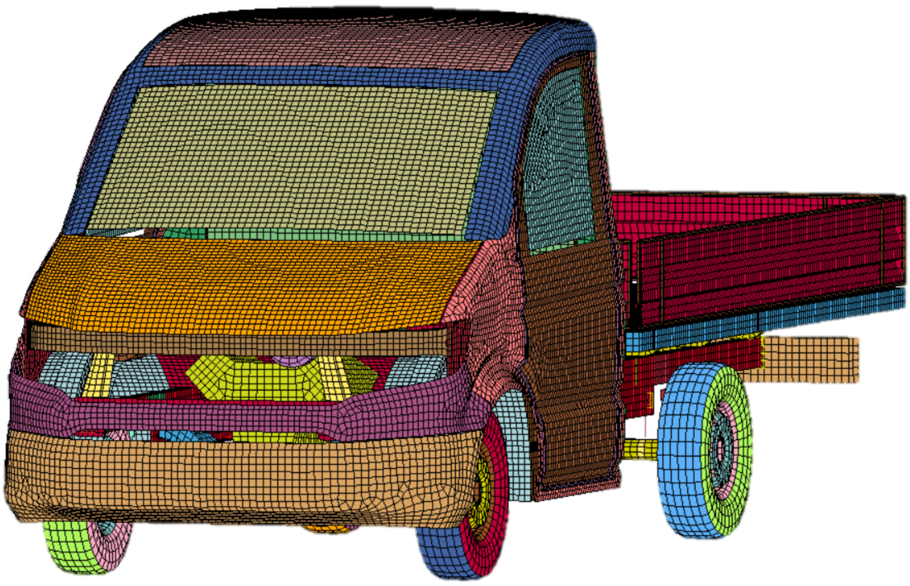
Generic vehicle model N1

Technical report



SVS FEM Services s.r.o.

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Content

1 Introduction

Security in public spaces is one of the key responsibilities of all governments and municipalities in the modern world. These days, the security is threatened also by vehicle attacks, which have already happened in many cities all over the world. This kind of terrorist attack poses a challenge on developers of barrier systems who try to mitigate them with their products. Testing of the barriers plays a key role in the development process. However, real testing of the barriers is very expensive. The development is therefore very often driven by realistic computer simulations (finite element numerical simulations – FE simulations). A tremendous advantage of the simulations is their ability to answer many questions regarding behaviour of the system before the real crash test is performed. Moreover, the simulations can quickly predict results of the crash tests under various conditions such as- various impact angles, various attacking vehicles, various impact velocities.

To support these defensive efforts of both academic and commercial researchers Joint Research Centre (JRC) has started a series of workshops "Numerical simulation for hostile vehicle mitigation". At these workshops various institutions across Europe are sharing their knowledge and experience related to the numerical simulations of vehicle attack mitigation. During these discussions it turned out that there is a need for generic vehicle models that would represent vehicle categories prescribed by standards like IWA 14 or CWA 16221.

Such generic vehicle models could open a new and more generalized approach to virtual barrier testing. According to the standards, for a certification of a barrier a single crash test has to be performed. However, in assessing a barrier in a real application it could be useful to analyse several crash test scenarios with varying conditions. It must be noted that this approach (varying impact speed, impact angle, friction, etc.) has been already adopted by many researchers ([1,2,3,4]). But these sensitivity analyses are exclusively done by keeping the vehicle characteristics fixed, even if in reality vehicles of a same category can vary significantly (brand, fitness, wheelbase, mass distribution, etc.). With a generic vehicle model, which can be modified easily through parameters and which is not computationally expensive, the vehicle properties can also be varied. Furthermore, to get general probabilistic assessment of the barrier performance, a stochastic analysis could be easily applied.

On the initiative of the JRC, SVS FEM Services s.r.o. took the first step in this effort and in cooperation with Transport Research Centre, CZ prepared the first generic vehicle model corresponding to the N1 category (IWA 14, CWA 16221, PAS 68). This technical report is a description of this generic model and can be used as a manual for its applications.

2 Main characteristics

Vehicle category N1

The model represents a vehicle from category N1 (IWA 14).

Generalization

The vehicle model is generic. It does not reflect any specific brand- or model-depending features. The aim is a general model covering the largest possible group of N1 vehicles commonly used within the EU. The vehicles used in model pre-processing (VW, FIAT, Ford) represent the most widespread brands in this category.

Validity of the model

The model is validated by comparisons to available experimental data.

Parametrization

The model is parametrized to allow user to easily modify key attributes of the vehicle (velocity, mass distribution, dimensions, crash related stiffness, suspension properties). This enables the model to represent any real vehicle within the N1 category (various age, fitness, brand, size, mass, …). Parametrization makes the model suitable also for stochastic studies.

Solution efficiency

From computational perspective, the model shall be as effective as possible. There was an effort taken to eliminate too detailed structure features and keep only the parts and features relevant for the crash test. The minimum timestep varies with input parameters. Default version of the model achieves timestep of 3 μs (0.003 ms). The model is computationally effective without mass scaling.

Convertibility to other codes

The original version of the model was developed for Ansys LS-DYNA but is convertible to other FE codes as well. There are no strictly Ansys LS-DYNA related features. In particular, the model is being converted by the JRC for calculations with the EUROPLEXUS software.

3 FE model

3.1 Solution method

The model is prepared for explicit simulations in Ansys LS-DYNA R12. For detailed description of keywords mentioned in this report see LS-DYNA manual [5].

3.2 Unit system

The model is prepared in consistent unit system:

mm, ms, kg, kN, GPa.

3.3 Parameters

Key input parameters are in a separate input file: "\Vehicle\Parameters.k".

The parameters in this input file are divided into 5 groups:

- Initial velocity
- Dimensions
- Mass
- Crash-related stiffness
- Suspension

In the first section of this input file there are collected the main (basic) parameters (*PARAMETER). These parameters are meant to be changed by the user to easily modify the vehicle model. In the second section of the "Parameters.k" input file there are derived parameters. These are prescribed with an expression (*PARAMETER_EXPRESSION) and they are derived from the main parameters.

```
*PARAMETER
$ VELOCITY
$----------
$ Velocity km/h
R VELKMH          18
$
$ DIMENSIONS
$------------
$ Vehicle length mm
$ (5820, 6580)
R VEHL          6200
$
$ Wheel base mm
$ (3095, 4515)
R WHBASE        3280
$
$ Wheel track mm
$ (1500, 1700)
R WHTRCK        1600
$
$ Cab Ground clearance mm
$ (200, 350)
R CGRCLR       243.8
$
$ Bumper rear Z position mm
$ (MIN, MAX)
R RBMPZPOS       560
$
$ Cargo Y position mm
$ (-400, 400)
R CRGYPOS          0
$
$ Cargo X position mm
$ (3300, 6062)
R CRGXPOS       3300
$
```

```
$ MASS
$------
$ Frame mass kg
R FRAMMASS       300
$
$ Cab mass kg
R CABMASS        800
$
$ Flatbed mass kg
R FBMASS         500
$
$ Cargo mass kg
R CARGMASS      1000
$
$ Engine mass kg
R ENGMASS        250
$
$ Gearbox mass kg
R GBXMASS        180
$
$ CRASH-RELATED STIFFNESS
$------------------------
$ Frame crash absorbing zone E GPa
R FCABSE         120
$
$ Frame crash absorbing zone ETAN GPa
R FCABSET          5
$
$ Frame crash absorbing zone SIGY GPa
R FCABSY       0.100
$
$ Cab crash absorbing zone E GPa
R CCABSE         120
$
$ Cab crash absorbing zone ETAN GPa
R CCABSET          5
$
$ Cab crash absorbing zone SIGY GPa
R CCABSY       0.100
$
```

```
$ SUSPENSION
$------------
$ |FRONT|
$
$ Stiffness of linear part of the spring kN/mm
R FSPRING      0.045
$
$ Spring stopper upper bound mm
R FSPUPB          42
$
$ Spring stopper lower bound mm
R FSPLOB          80
$
$ Damper constant kN/(mm/ms)
R FDAMP         2.00
$
$ |REAR|
$
$ Stiffness of linear part of the spring kN/mm
R RSPRING      0.020
$
$ Spring stopper upper bound mm
R RSPUPB         110
$
$ Spring stopper lower bound mm
R RSPLOB          85
$
$ Damper constant kN/(mm/ms)
R RDAMP         2.50
$
$ |TURNING|
$
$ Stiffness of linear part of the torsion spring
R FTSPRING       250
$
$ Damper constant kN*mm/(rad/ms)
R FTDAMP       25000
$
$ Spring turn bound rad
R FSPTB          0.2
$
```

Figure 1: Input of main parameters

Main parameters are always accompanied with comments describing the meaning of the parameter, recommended range and its unit. There are default vales of main parameters already pre-set. The default values are based on real N1 vehicles which were used throughout the initial model testing (see chapter 4). Note that for users' convenience some of the parameters are in different units than the unit system of the model (e.g. Velocity km/h).

Derived parameters are helping to set up the model and to achieve desired model variations. Note that due to the wide potential of model variations some of the input parameters cannot guarantee absolute agreement with final values (for example mass values can be slightly inaccurate due to the dimension parameters).

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1) Initial velocity:

Initial velocity is prescribed with main parameter VELKMH (km/h). This main parameter is then used for calculation of derived parameters: translational initial velocity TRVEL(mm/ms) and angular initial velocity ANGVEL (rad/ms). These derived parameters are the input for *INITIAL_VELOCITY_GENERATION.

2) Dimensions:

Variations of dimensions can be set by the user through main parameters from group “DIMENSIONS” (see fig. 1). Based on the main parameters and dimensions of original mesh a set of derived parameters (translational shifts and directional scaling of mesh) is calculated. These derived parameters are then applied on the model through *INCLUDE_TRANSFORM and *DEFINE_TRANSFORM.

Note that with these parameters also the centre of gravity can be changed.

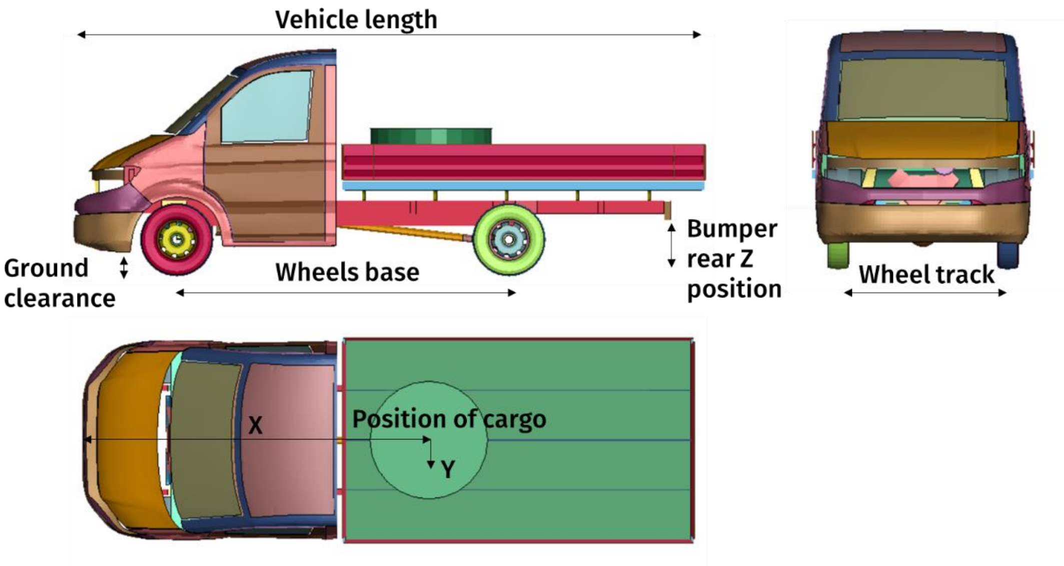

Figure 2: Main parameters of dimensions

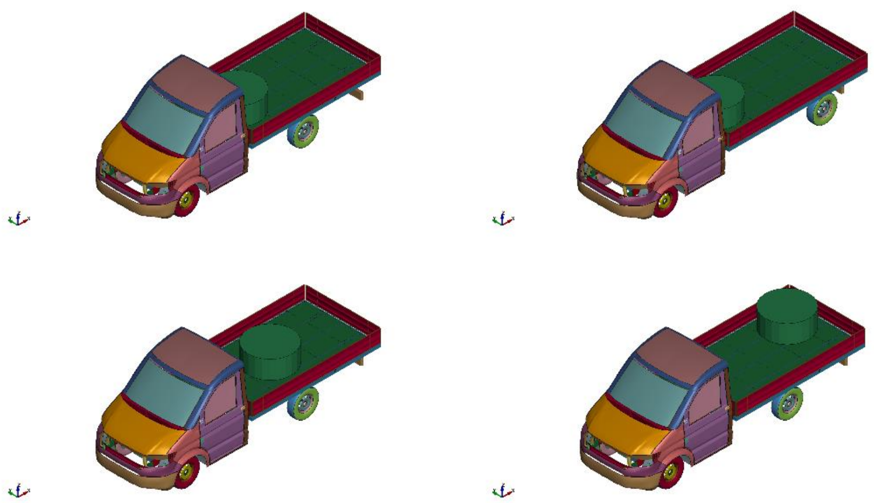

Figure 3: Examples of dimensions variations

3) Mass:

Mass distribution can be changed by the user through main parameters from group "MASS" (see fig. 1). With these parameters, the user defines mass of the main vehicle parts: frame, cabin, flatbed, engine, gearbox, cargo. These main parameters are then transformed to derived density parameters. Density values are then referenced by material models. This means that every mass change is uniformly distributed over several corresponding parts. Figure 4 shows which parts are related to which mass parameter. Note that with these parameters also the centre of gravity can be changed.

For the final check of total mass and mass distribution at the initial time, the user shall read summary of mass in d3hsp file. D3hsp is a key output file of LS-DYNA run. It contains a section "summary of mass" which includes exact final values at the initial time of all parts of the model (even after redistribution due to the constraints and bonds).

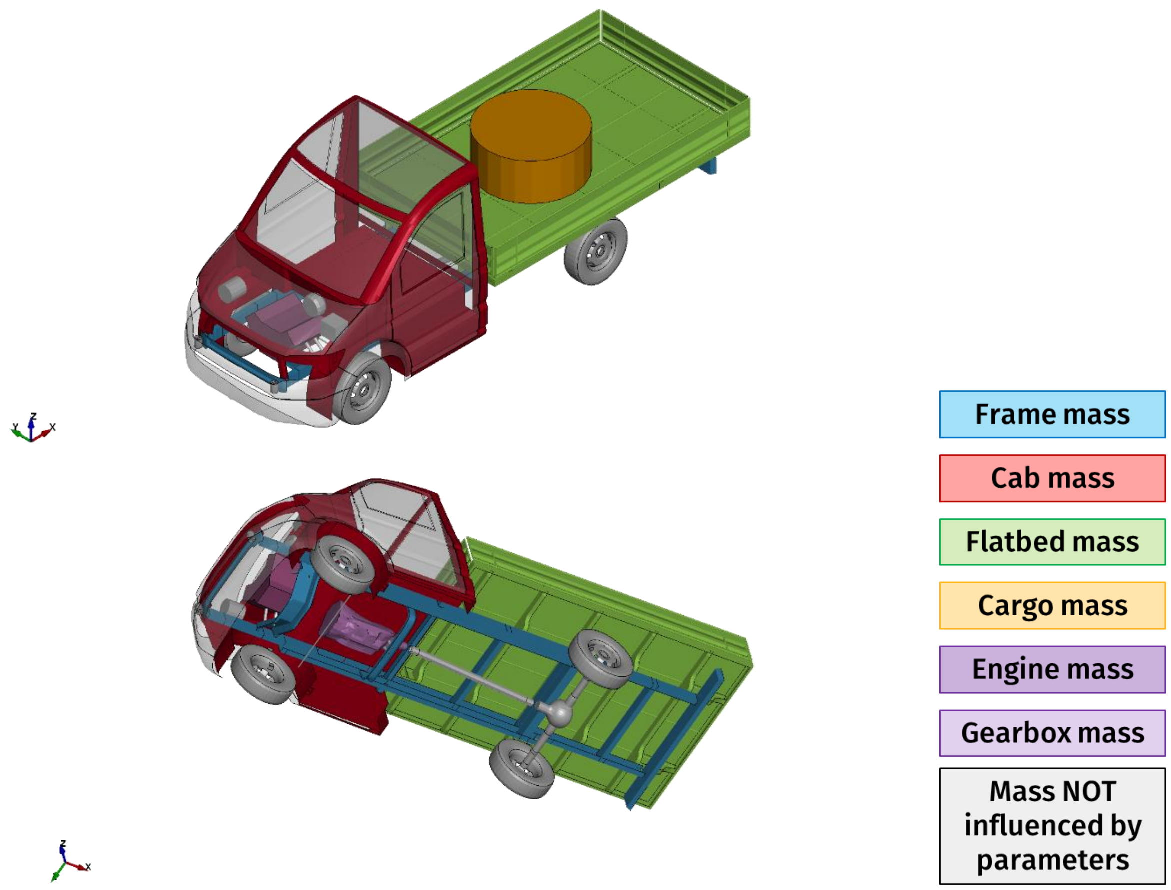

Figure 4: Sets for different mass parameters

4) Crash-related stiffness:

Crash-related stiffness parameters can be changed by the user through main parameters from group "CRASH-RELATED STIFFNESS" (see fig. 1). These parameters define bilinear elastoplastic behaviour of selected parts which have major impact on the energy absorption during a crash event (see fig. 5 and 6).

These parameters allow the user to adapt crash-related stiffness parameters according to the age, the fitness or the construction of the front parts of the vehicle.

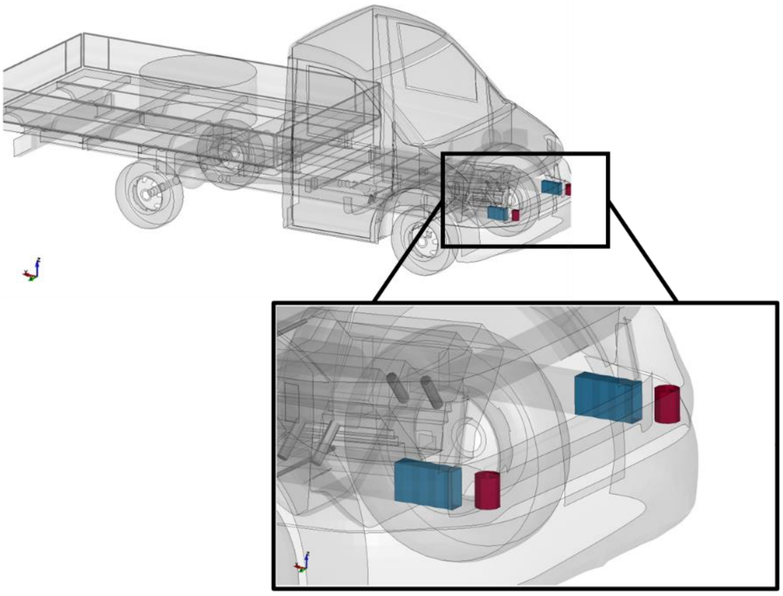

Figure 5: Parts influenced by crash related stiffness parameters

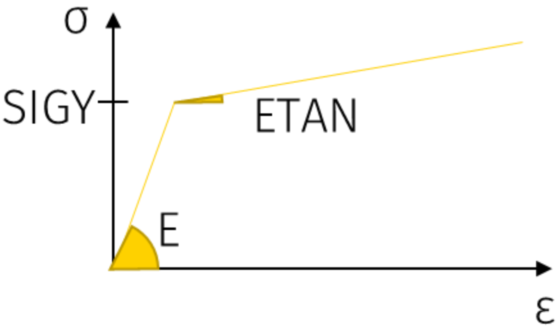

Figure 6: Bilinear elastoplastic behaviour of selected parts governed by crash related stiffness parameters

5) Suspension:

Nonlinear stiffness of suspension consists of 3 springs (see fig. 7) and one damper for each wheel:

I. Linear spring
II. Upper bound
III. Lower bound
IV. Linear damper

User can vary stiffness of linear spring, distance offset of lower and upper bound and damping coefficient of linear damper separately for front and rear wheels. Both left and right front wheels use the same suspension parameters. Similarly, both left and right rear wheels use the same suspension parameters. Moreover, stiffness of turning of front wheels can be also changed with parameters.

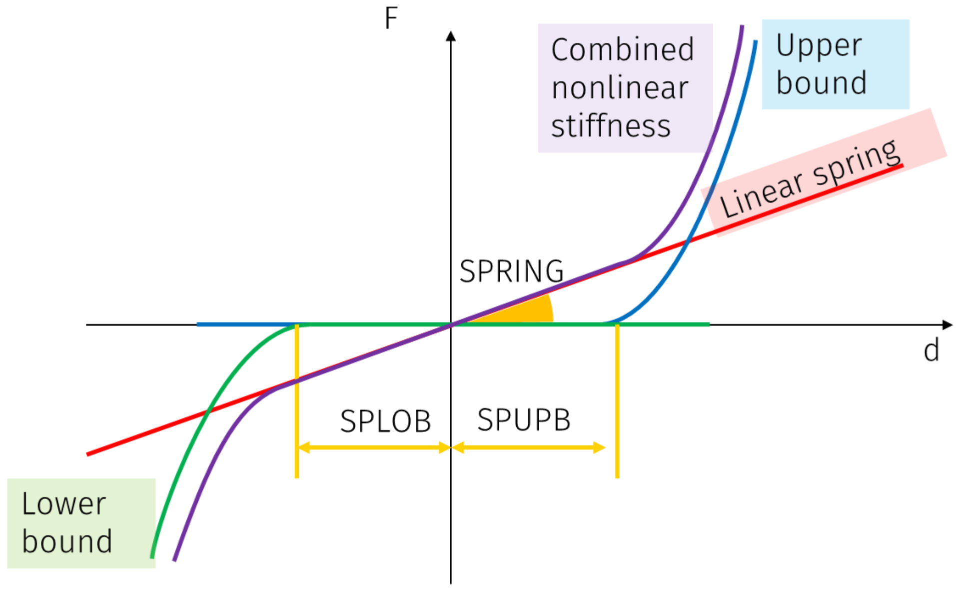

Figure 7: Nonlinear stiffness of suspension

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3.4 Model structure

The model is split into several input files for clarity and easier editing of individual parts.

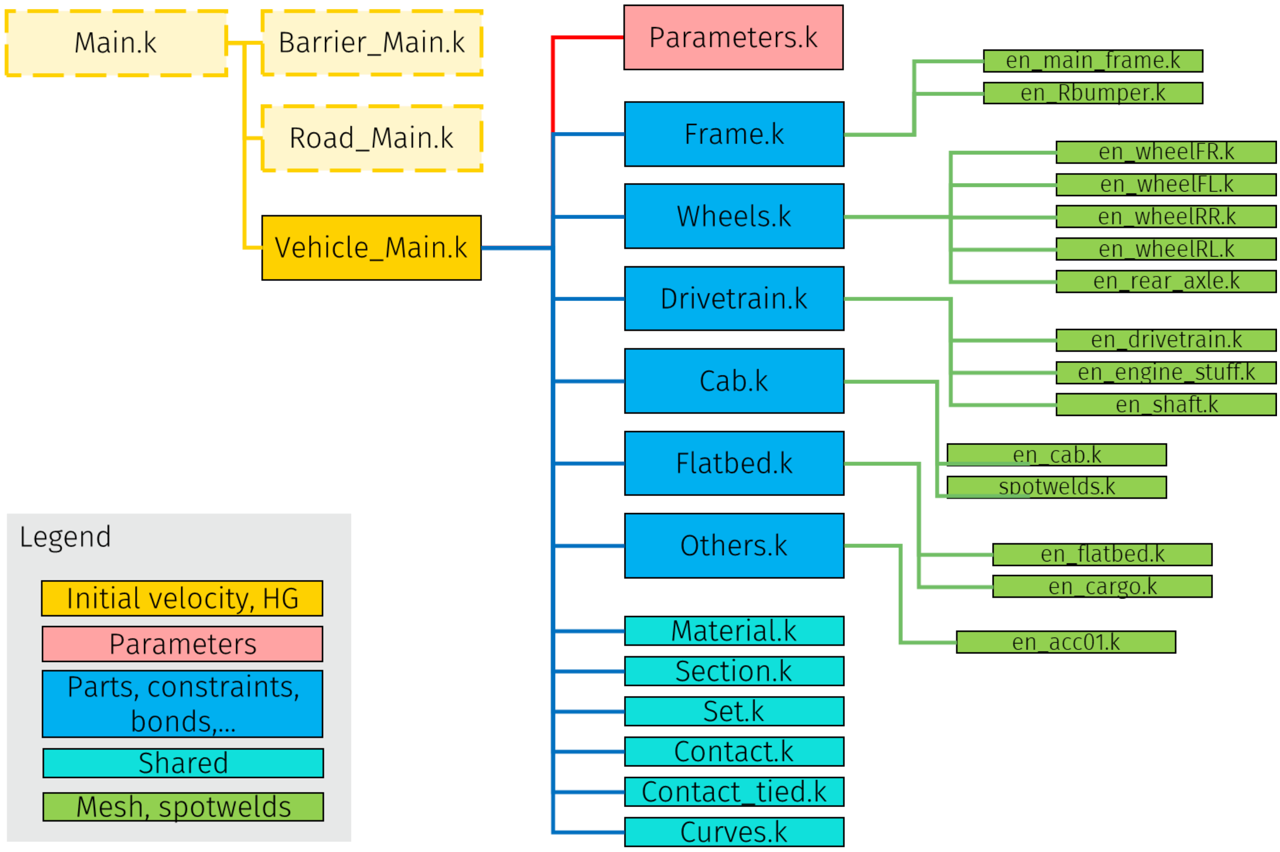

Figure 8: Model structure

The recommended model structure for a crash test simulation with this vehicle model is: main input file (Main.k) which references main input files of the barrier (Barrier_Main.k), the road (Road_Main.k) and the vehicle (Vehicle_Main.k). Content of input files Main.k, Barrier_Main.k and Road_Main.k depends on specific crash test scenario and is not a subject of this work nor this report. Because of the structure, Barrier_Main.k and Road_Main.k can be changed independently from the vehicle model. In this recommended model structure, the analysis settings (*CONTROL keywords) and output settings (*DATABASE keywords) are in the Main.k input file.

Vehicle_Main.k includes the initial velocity definition and the hourglass control. Input file Parameters.k contains key input parameters (see chap. 3.3 Parameters). Frame.k, Wheels.k, Drivetrain.k, Cab.k, Flatbed.k and Others.k are input files devoted to major sections of the vehicle. These input files reference corresponding input files with the mesh (element, nodes) and constraints like rigid bonds or kinematic joints. Input files from the category "Shared" contain the material library (Material.k), the element type definitions (Section.k), various sets like sets of nodes, sets of segments, sets of parts,…(Set.k), contacts (Contact.k), tied contacts (Contact_tied.k) and curves (Curves.k).

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3.5 Geometry model

As it was already mentioned, the aim of this model is not to represent any particular vehicle but to represent the whole group of vehicles of category N1 (IWA 14). For this reason, it is important to include in the model only the features of the vehicle structure which are brand and model independent and are present (in some form) on any car in this category. Another aspect which governs the decision which parts of the vehicle should be included and which should be omitted, is the requirement for speed of solution while achieving sufficient accuracy. The vehicle model is designated for the design process of the barriers and will be used in simulations in which the barriers are the main subject of interest. The vehicle model therefore includes only parts relevant for the global stiffness, mass distribution and global behaviour of the vehicle during the crash event. In these analyses, the vehicle model must produce a correct loading on the barrier. On the other hand the crash effects on parts which do not (or very little) contribute to the overall behaviour of the vehicle like dashboard, seats, components of passive safety and so on are unimportant for these analyses and they can be omitted.

The geometry of the generic model was based on VW Crafter, Ford Transit tipper and Fiat Ducato. Since the technical drawings and CAD data of contemporary vehicles are proprietary, the geometry for this model is based on reverse engineering (physical measurements of several complete or partially disassembled vehicles, photos and product brochures). Examples of photos from this process are attached in appendix A.

Ansys Spaceclaim was used for the geometry creation, editing and preprocessing. All the parts had to be prepared for meshing, which means eliminating components and features considered as insignificant.

a) 

b) 

c) 

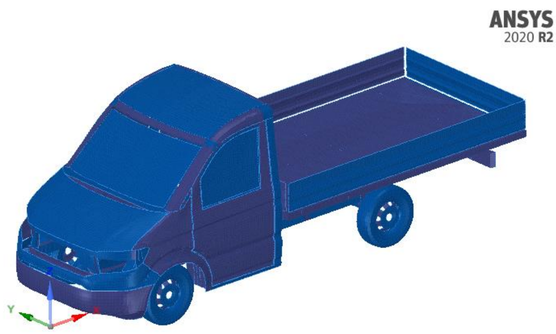
d) 

Figure 10: Vehicle geometry: a) VW Crafter, b) Ford Transit, c) Fiat Ducato, d) Generic vehicle geometry

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3.6 FE mesh

The finite element mesh was created in Ansys LS-PrePost based on the geometry of the vehicle presented in the section above. The mesh consists of solid, shell and beam elements. However, with respect to the nature of most of the vehicle parts the majority of them are modelled with shell elements. Only engine, gearbox, cargo and accelerometer were modelled with solid elements. Beam elements are used for minor reinforcements of cabin and flatbed.

The mesh was created with the focus on uniformity and shape regularity. The characteristic length of the elements is 11 - 50 mm. Warpage of elements was kept below 20 degrees. Quadrilateral linear elements are strongly preferred over triangular linear elements due to their stiffness.

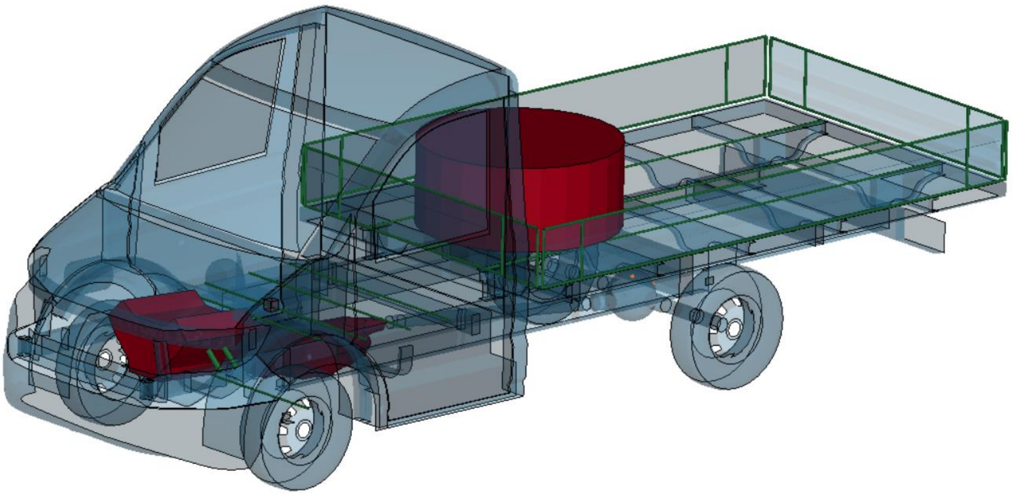

Figure 11: Element types on the vehicle model (solids – red; shells – blue, beams – green)

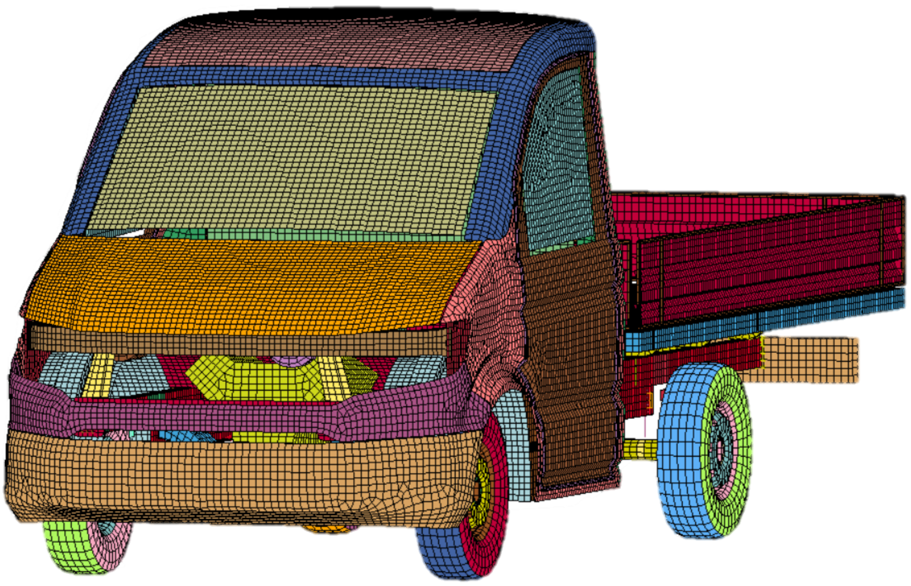

Figure 12: FE mesh

Tab. 1: Mesh statistics			
Nodes	Solid elements	Shell elements	Beam elements
73 035	16 694	62 573	1 516

3.7 Material models

There are only 4 basic constitutive laws used in the FE model in order to increase the convertibility of the model to other FE codes. These are:

- Rigid material model
- Elastic material model
- Bilinear elasto-plastic material model
- Piecewise linear elasto-plastic material model

Majority of materials defined in this vehicle model include simple failure criterion based on equivalent plastic strain.

It must be noted that for the purposes of mass parametrization of the model, the density of particular material models can be altered to artificial higher or lower values. More details on this are provided in the chapter *Parameters*.

Figure 13: Materials of generic N1 FE model

Rigid material model is used for engine, gearbox, battery, brake booster and alternator. Also “dummy” parts (usually single shell elements) helping with attachment of certain parts or allowing parametrized FE mesh transformation (e.g. attachment of wheels) are defined with rigid material model.

Elastic material model is used for windows and tires. For windows there is E = 72 GPa and μ = 0.22. Elastic material model of tires is prescribed with E = 0.15 GPa and μ = 0.45 to match overall stiffness of composite structure of tires modelled with single layer of shell elements (details in chapter *Model testing*).

Majority of parts are prescribed with conventional structural steel (see fig. 13). Conventional structural steel #1 (S235 [7]) is defined as bilinear elasto-plastic material model with E = 207 GPa, μ = 0.28, S_y = 0.270 GPa, E_{tan} = 1.14 GPa and ε_{fail} = 0.3. Conventional structural steel #2 (S355 [8]) is defined as elasto-plastic material model with E = 210 GPa, μ = 0.28, S_y = 0.350 GPa, plasticity is governed by curve (see fig. 14) , ε_{fail} = 0.3.

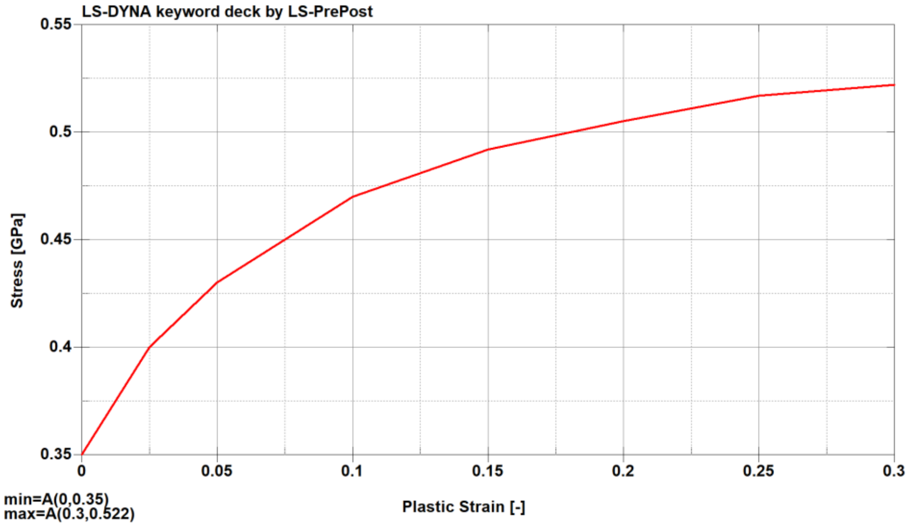

Figure 14: Conventional structural steel #2 plasticity curve

Plastic front bumper is modelled with bilinear elasto-plastic material with E = 20 GPa, μ = 0.30, S_y = 0.05 GPa and E_{tan} = 0.10 GPa, ε_{fail} = 0.1.

During the vehicle testing it was found that rigid part "engine" causes a significant contact force peak when the vehicle impacts to the barrier. To avoid this, there was an extra part introduced which covers the rigid engine block and which is deformable. The role of this part is to mimic deformable behaviour of the soft parts which are located in the surroundings of the engine (plastic covers, hoses, tubes etc). This part uses bilinear elasto-plastic material model with E = 0.1 GPa, μ = 0.28, S_y = 0.05 GPa and E_{tan} = 0.01 GPa. This deformable part helps to sufficiently flatten the impact force peak.

It also turned out that rigid connection frame – engine and frame – gearbox is not sufficient. For this reason, there were added several beam elements which represent the engine mounts and allow elasto-plastic behaviour and even failure of the connection. The material properties of these beams are: E = 210 GPa, μ = 0.28, S_y = 0.350 GPa and E_{tan} = 2 GPa, ε_{fail} = 0.3. This kind of simplified modelling of the engine mounts allows convenient control over the behaviour of this connection.

Detailed definitions of all material models used in the vehicle model can be found in \Vehicle\Shared\Material.k.

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3.8 Bonds and constraints

Weld connections are modelled with rigid connections *CONSTRAINED_SPOTWELD, *CONSTRAINED_NODAL_RIGID_BODY or tied contact *CONTACT_TIED (see chapter *Contacts*) with no failure criterion. Attachment of the windows is also realised with rigid connection *CONSTRAINED_SPOTWELD. In cases which include rigid bodies the connection is done with *CONSTRAINED_EXTRA_NODES keyword.

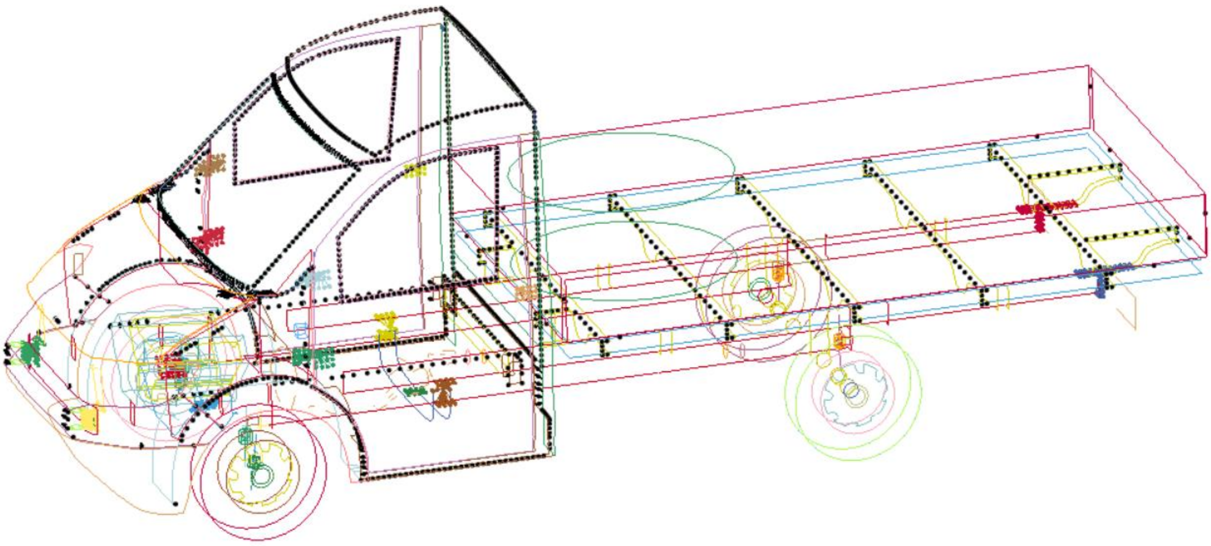

Figure 15: Spotwelds and nodal rigid bodies

Connection between the engine and the gearbox is also regarded as rigid. However, connection between these two parts and the frame is realised with small number of relatively stiff beam elements with failure criterion which allows detachment of the engine and the gearbox from the frame.

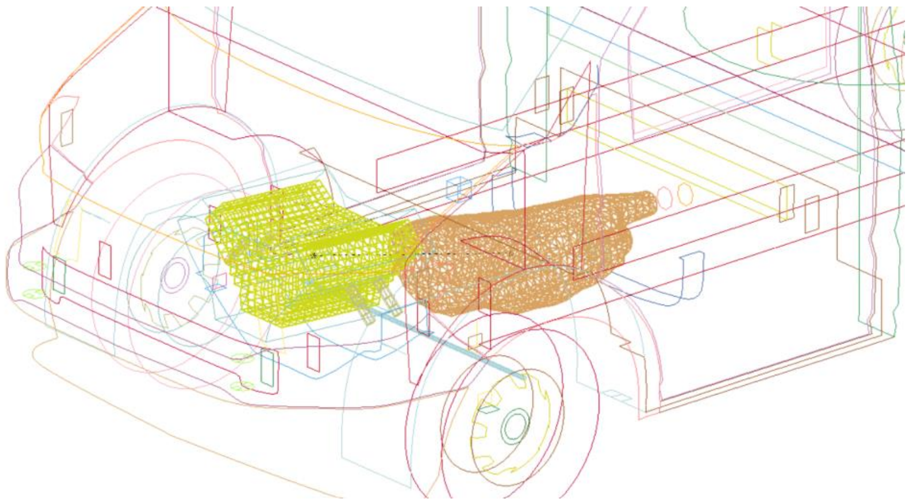

Figure 16: Beam elements connect the engine and the gearbox to the frame

Wheels are attached to the frame with kinematic joints and spring and damper elements. Detail description of the spring and damper elements is in chapter *Parameters*. Up-down movement of the wheels is allowed due

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to the translational joints. Front wheels' turning is allowed due to the revolute joints. Rotation of each wheel is allowed due to another revolute joints.

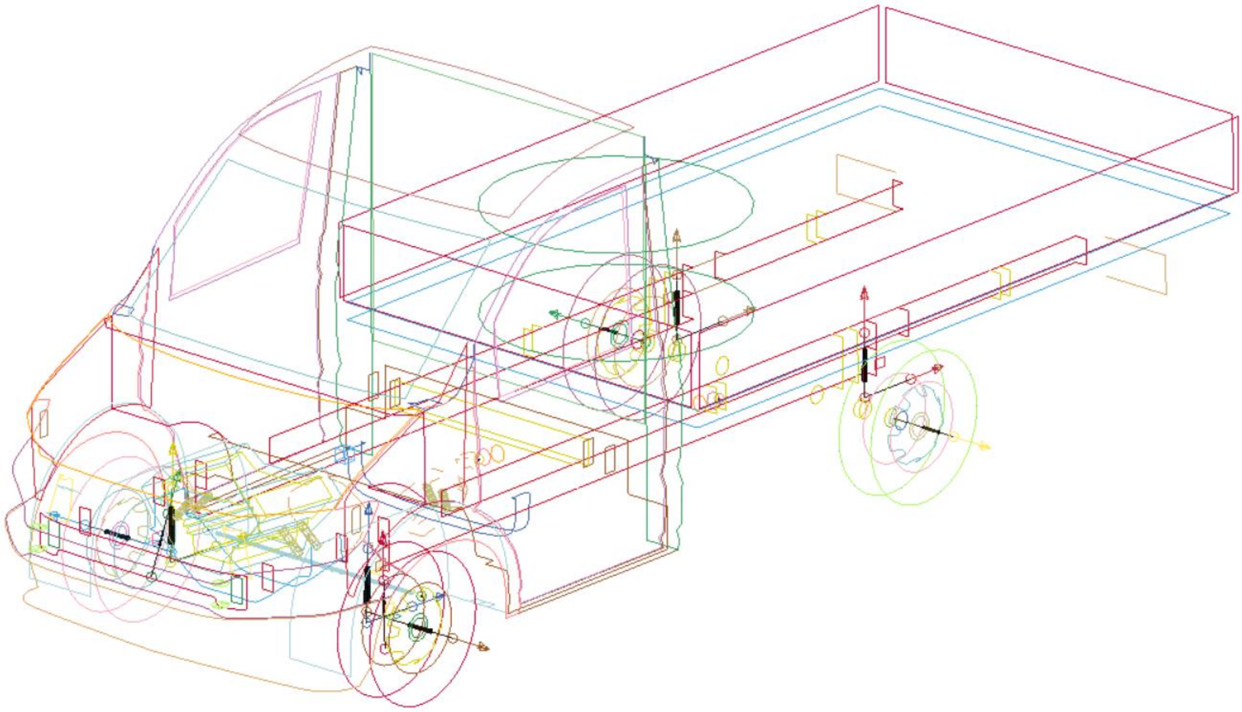

Figure 17: Kinematic joints for wheels

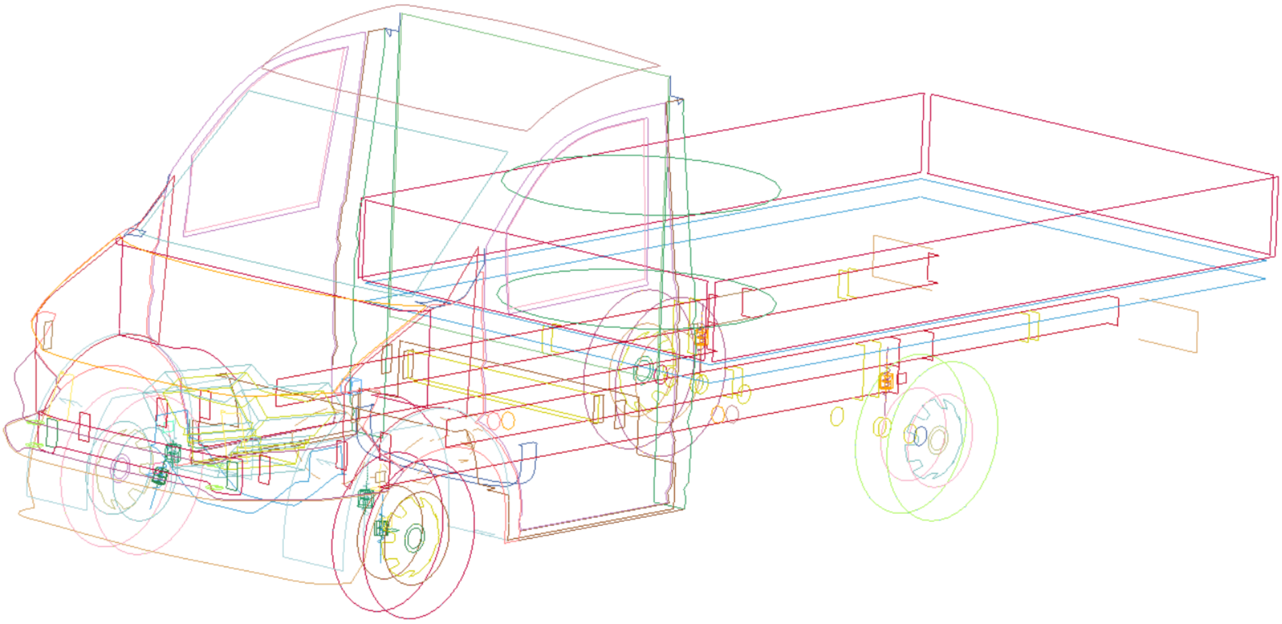

Figure 18: Spring and damper elements for wheels

3.9 Loading

Gravity

Gravity is prescribed on the model with the keyword *LOAD_BODY_Z which applies acceleration on all parts of the model. This keyword is present in the input file “Main.k”.

Tire Pressure

Tires are loaded with uniform internal pressure of 250 kPa (front wheels) and 300 kPa (rear wheels).

3.10 Initial and boundary conditions

The vehicle model is given an initial velocity through the keyword “INITIAL_VELOCITY_GENERATION”. This condition is applied to all parts of the vehicle except wheels to prescribe translational initial velocity. Two additional initial conditions are applied on the front and rear wheels to prescribe translational and angular initial velocities. The values of translational and angular initial velocities are derived from the parameter “VELKMH”.

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3.11 Contacts

Interaction between parts of the vehicle is prescribed with
*CONTACT_AUTOMATIC_SINGLE_SURFACE and
*CONTACT_AUTOMATIC_SURFACE_TO_SURFACE. Friction coefficient for these contacts is 0.3.

All of them can be found in \Vehicle\Shared\Contact.k.

Tied contacts (or bonded contacts) are prescribed between parts whose connection is considered as rigid and whose location can vary due to parametrization of dimensions (cargo, flatbed).

These contacts can be found in \Vehicle\Shared\Contact_tied.k.

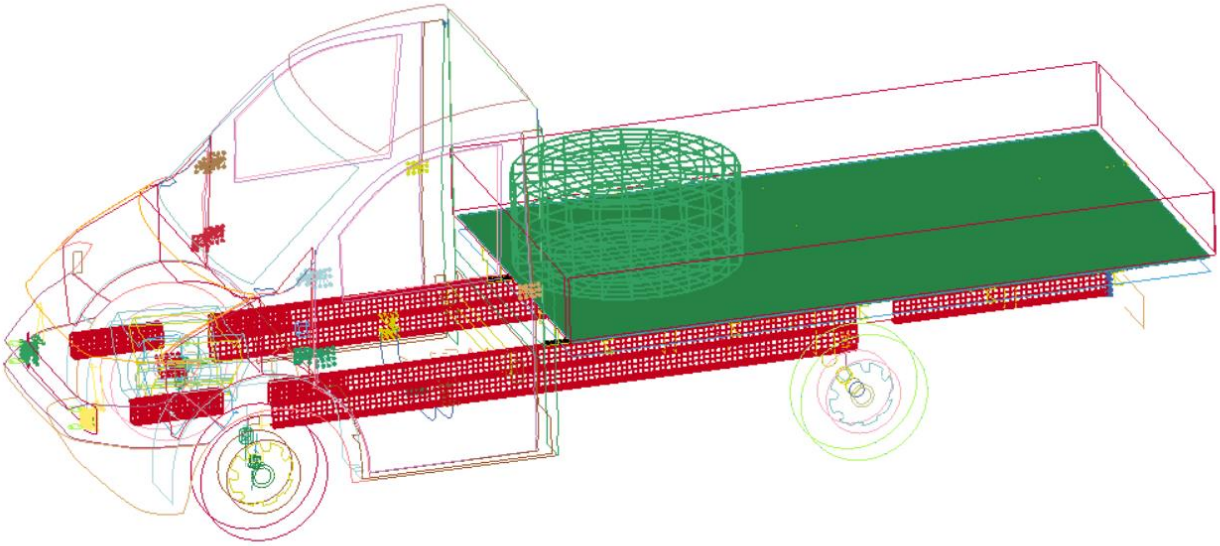

Figure 21: Tied contacts: flatbed – frame and cargo – flatbed

4 Model testing

The first series of model testing was performed by SVS FEM Services s.r.o. The testing was based on the procedure described by CEN/TR 16303. Since it is not possible to test all of the variations of the parametric vehicle model in all test scenarios, it was tested with the default values only.

4.1 Vehicle in idle

4.1.1 Objective

The model must remain stable in idle for a time, which should correspond to the time needed for the simulations of the crash test. For these purposes the vehicle FE model must stay in idle for 1.5 sec. There is no initial velocity prescribed to the vehicle model. The only load is gravity acceleration. There is no barrier nor obstacle in front of the vehicle model in this test. The aim of this test is to prove robustness and stability of the model. The behaviour of the model is observed with focus on displacements, stresses, energy balance and contact interfaces.

4.1.2 Results

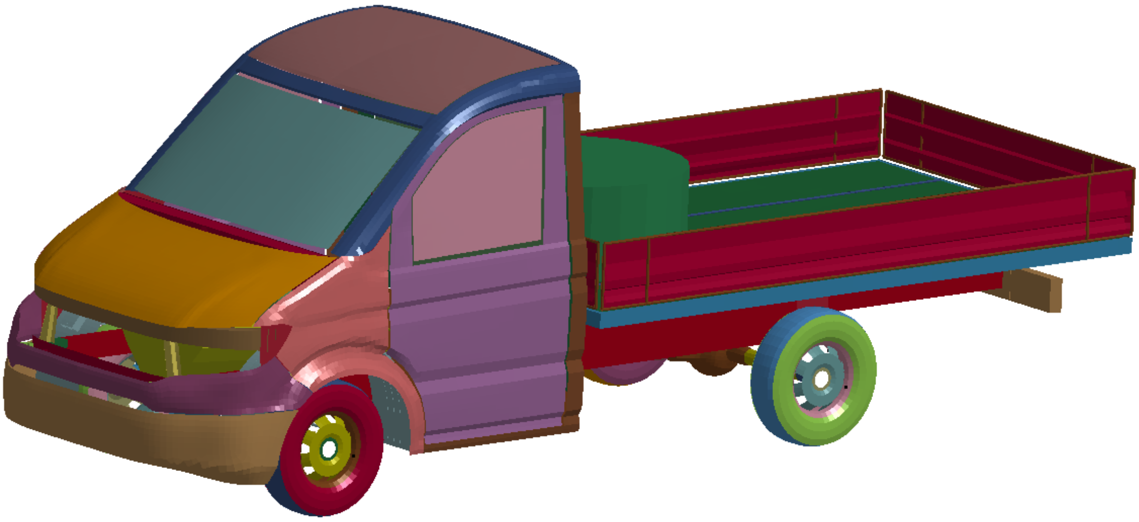

Figure 22: Vehicle in idle after 1.5 sec

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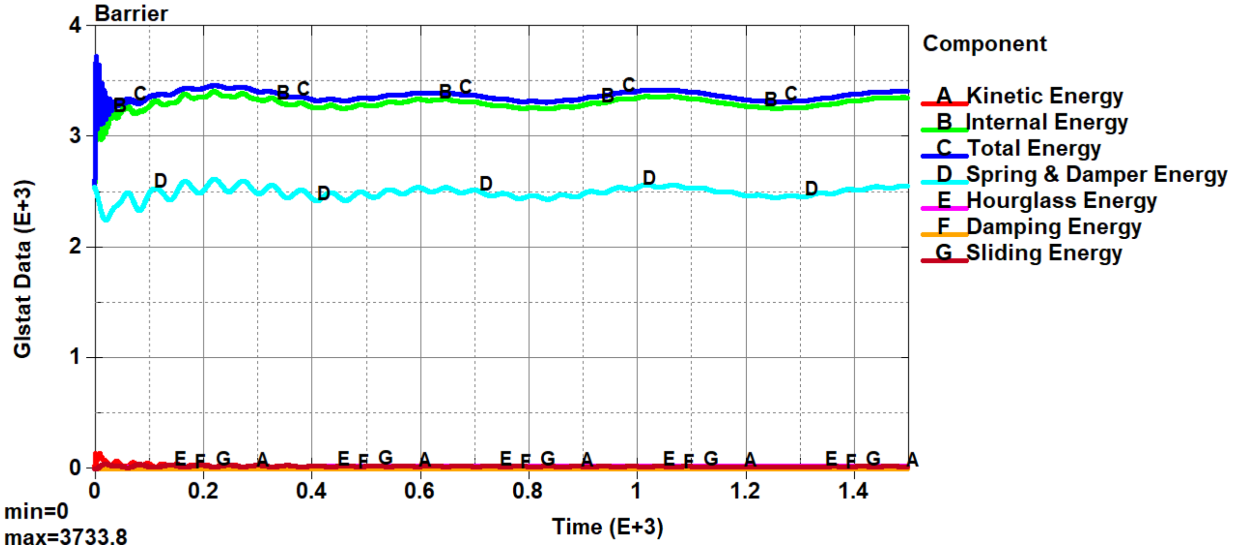

Figure 23: Energy balance

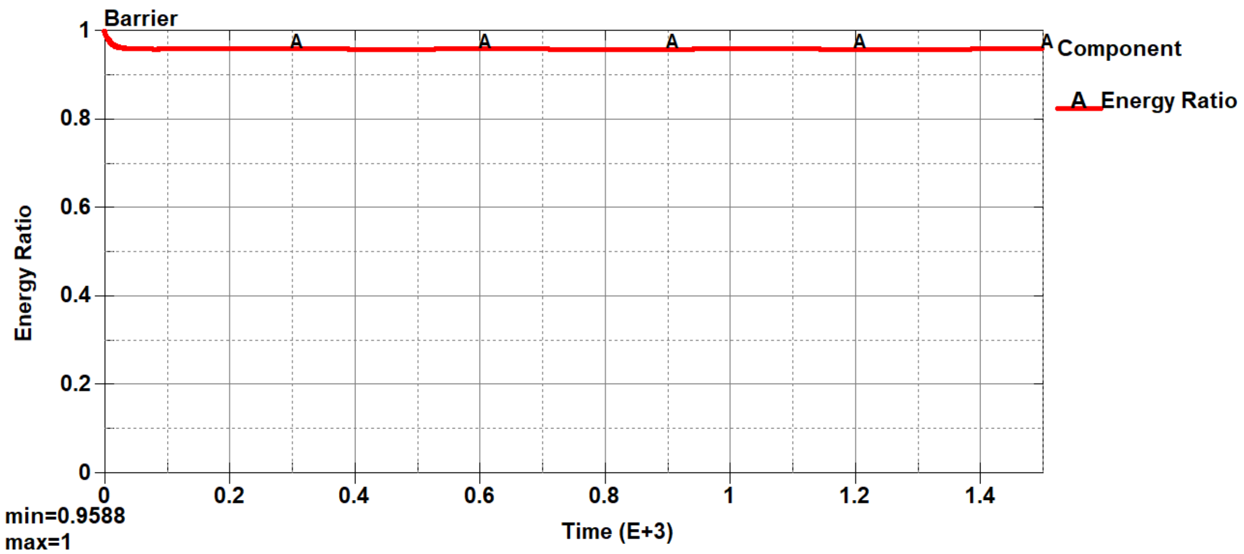

Figure 24: Energy ratio

No abnormal deformation nor stresses were observed on the model. Energy balance and energy ratio correspond to vehicle staying in idle.

4.1.3 Conclusion

The FE model proved its stability while staying in idle for 1.5 sec.

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4.2 Linear track

4.2.1 Objective

The vehicle FE model is given an initial velocity of 56 km/h and its subsequent motion is observed for another 1.3 sec. The vehicle travels over 20 m during this time period.

4.2.2 Results

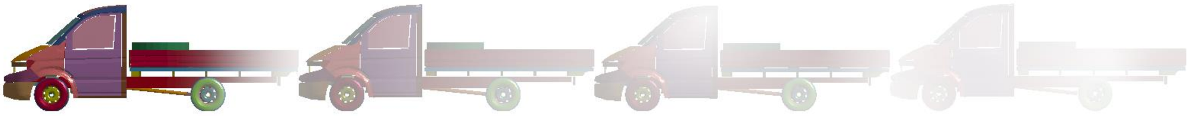

Figure 25: Fe model in linear motion (0, 400, 800, 1200 ms)

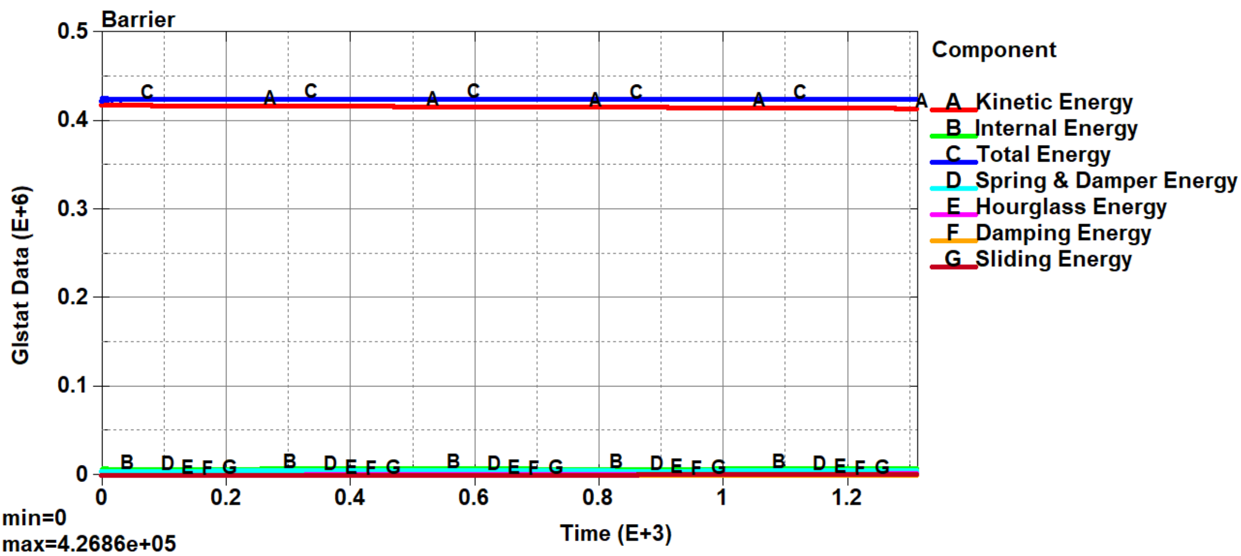

Figure 26: Energy balance

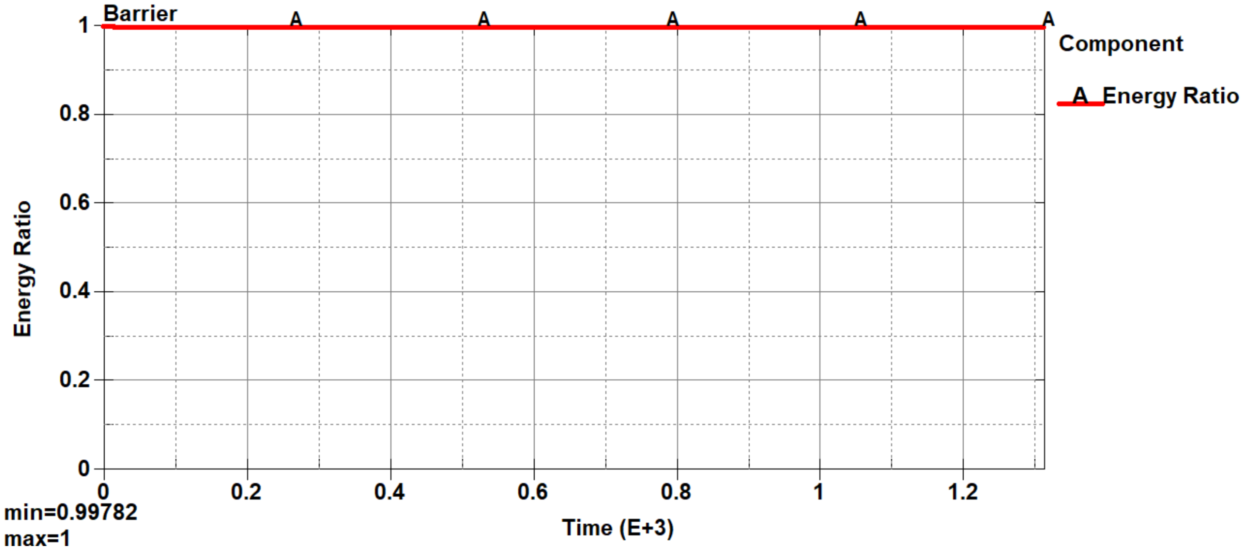

Figure 27: Energy ratio

No abnormal deformation nor stresses were observed on the model. Energy balance and energy ratio correspond to vehicle going straight forward for 20 m at 56 km/h. The vehicle kept straight forward linear trajectory with no substantial deceleration.

4.2.3 Conclusion

The FE model proved its stability while going straight for 20 m at 56 km/h (1.3 sec).

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4.3 Curb test

4.3.1 Objective

In this test the vehicle model is placed in front of a rigid speed bump (see picture below) and it is given initial velocity of 18 km/h. The speed bump is fixed to the ground. The vehicle model is observed as it goes over the obstacle.

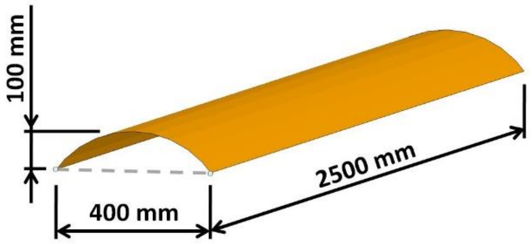
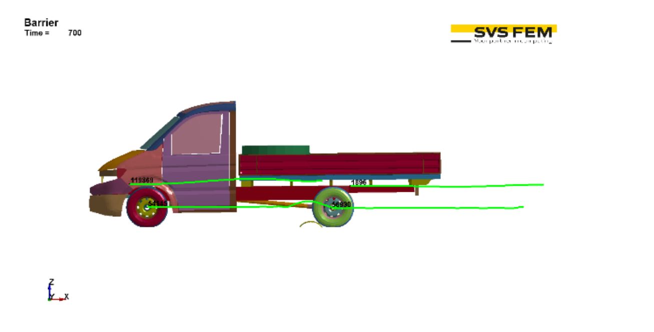
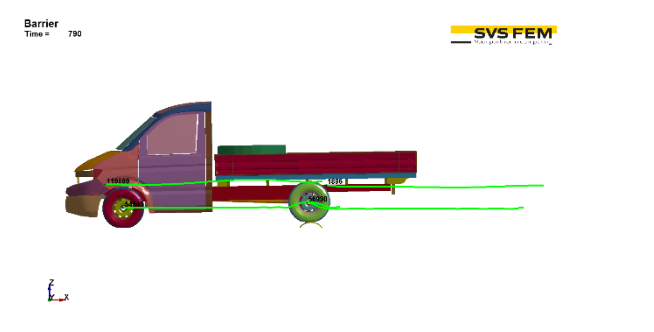


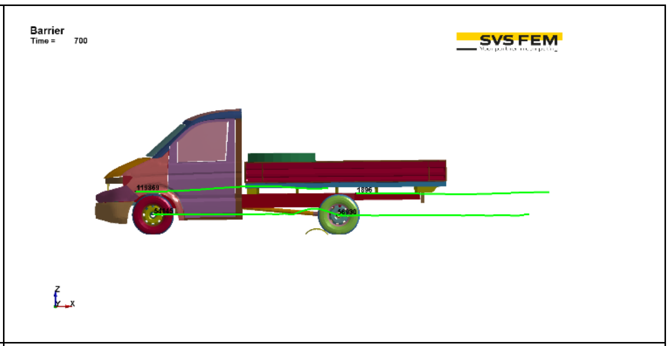
Figure 28: Speed bump

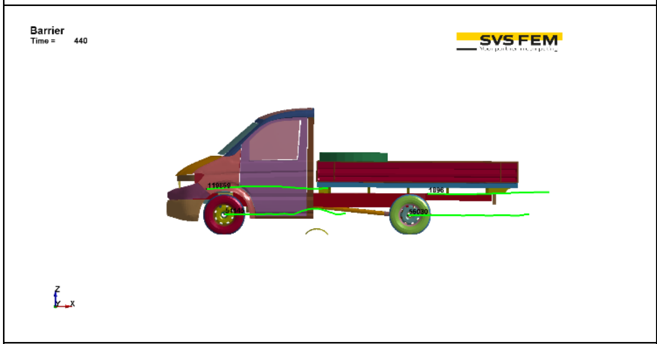
4.3.2 Results

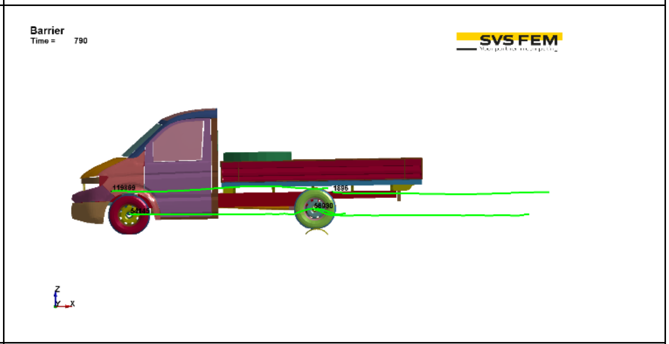
Tab. 1: Curb test Simulation – N1 at 18 km/h

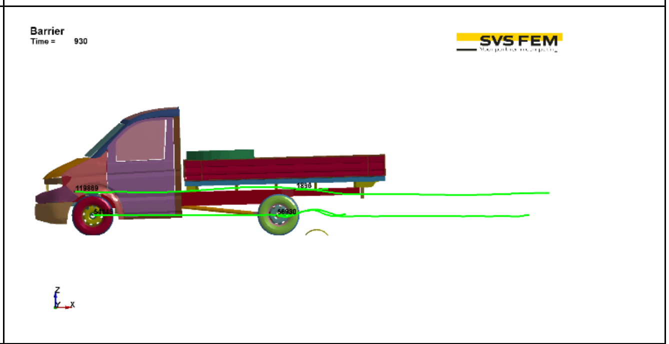
Front axle	Rear axle
	
	

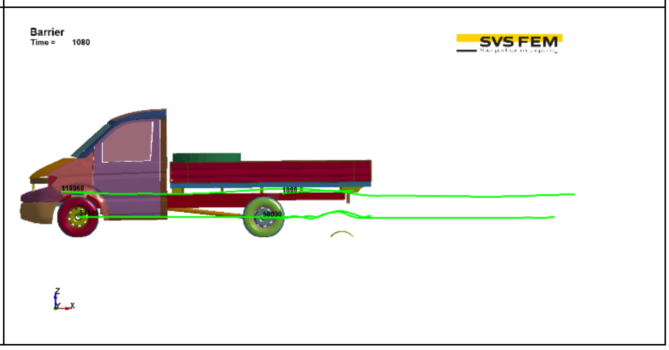

Barrier
Time = 250


Barrier
Time = 700


Barrier
Time = 440


Barrier
Time = 790


Barrier
Time = 930


Barrier
Time = 1080

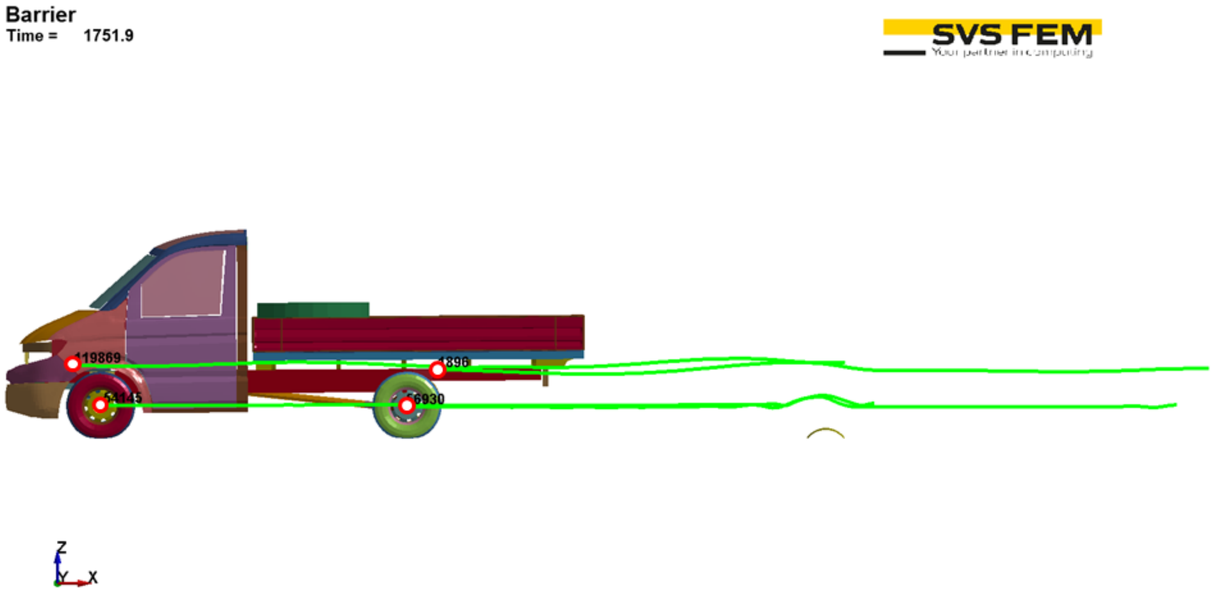


Figure 29: FE vehicle in curb test – trajectories of marked points

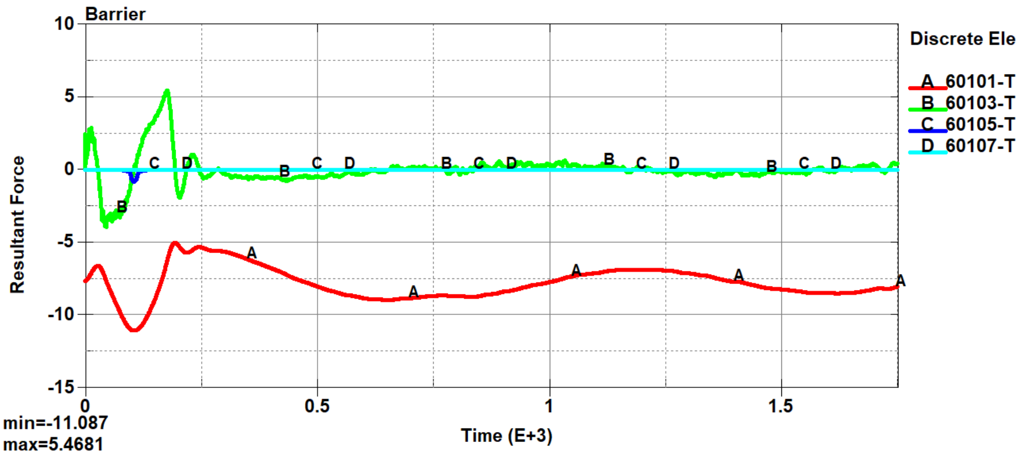


Figure 30: Forces on front wheel suspension (A – Linear spring, B – Damper, C – Upper bound, D – Lower bound)

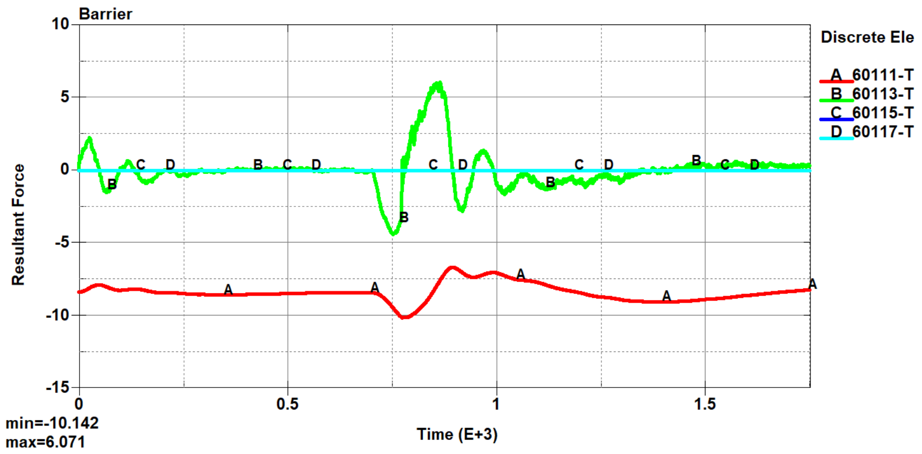


Figure 31: Forces on right rear wheel suspension (A – Linear spring, B – Damper, C – Upper bound, D – Lower bound)

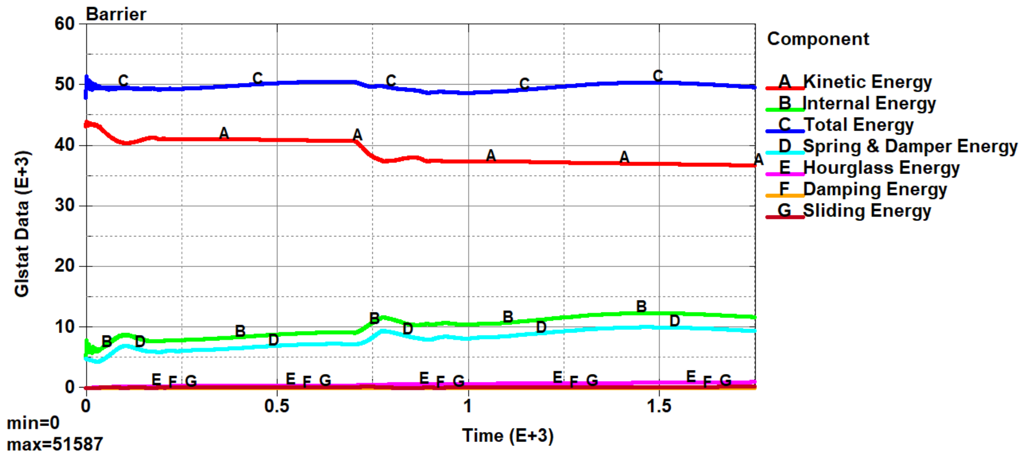


Figure 32: Energy balance

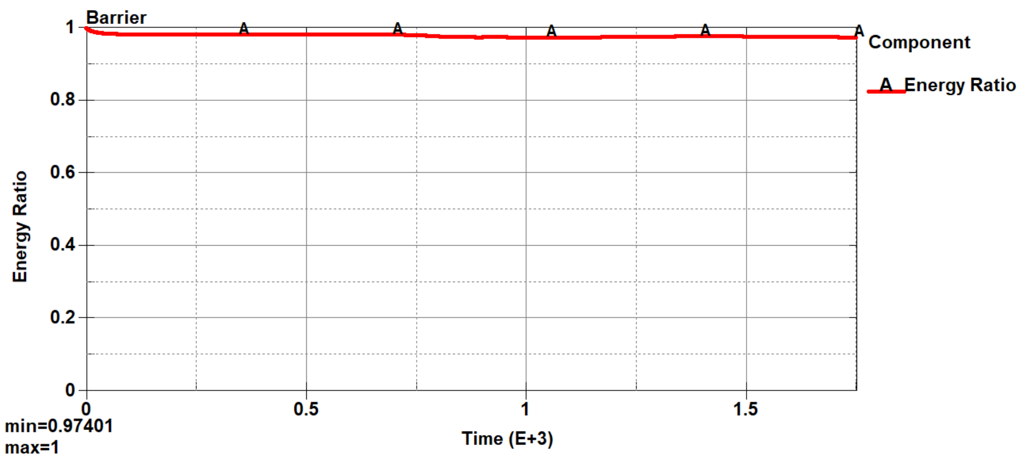
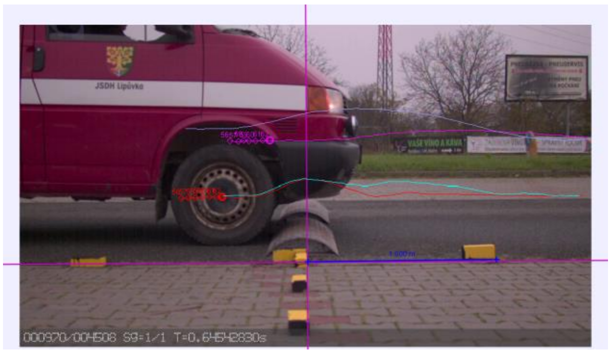
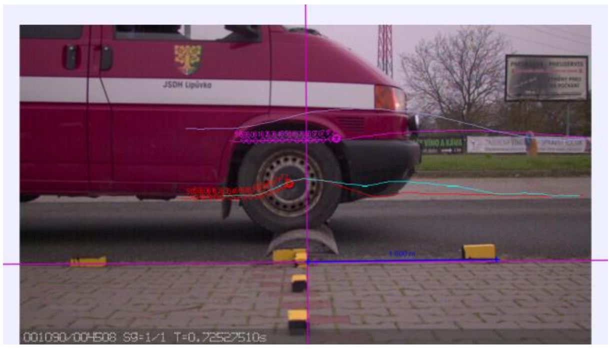
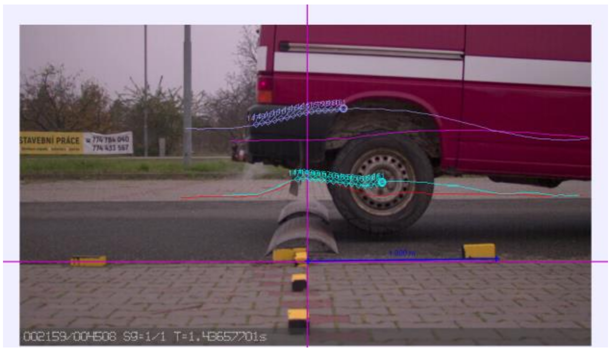
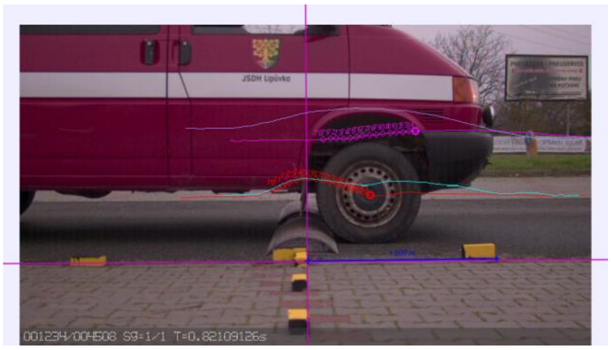
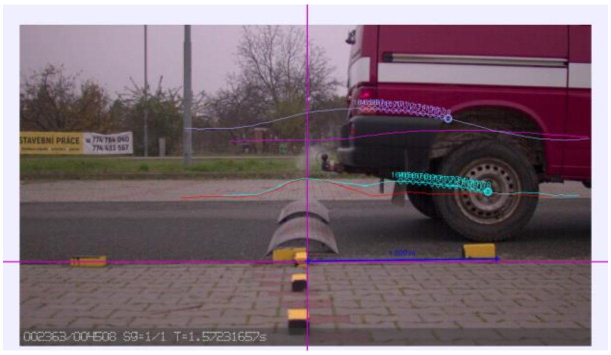


Figure 33: Energy ratio

Tab. 2: Curb test experiment – N1 at 18 km/h

Front axle	Rear axle
	
	
	

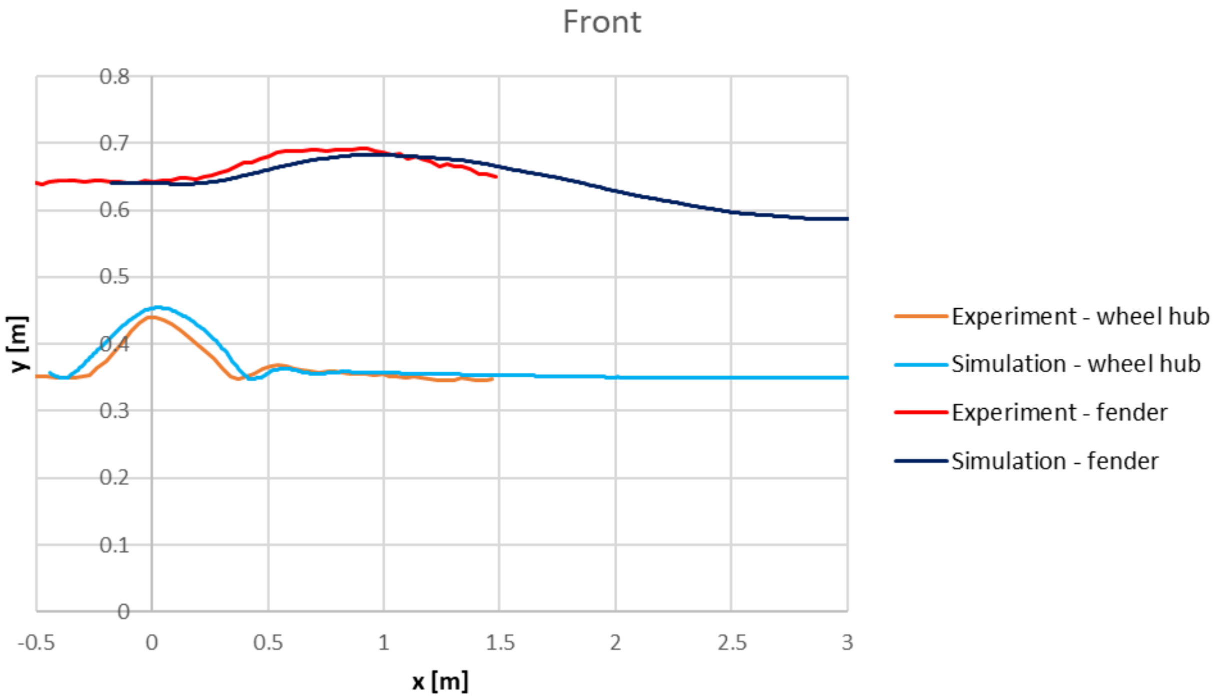


Figure 34: Curb test – sideview trajectory comparison simulation vs experiment – front axle

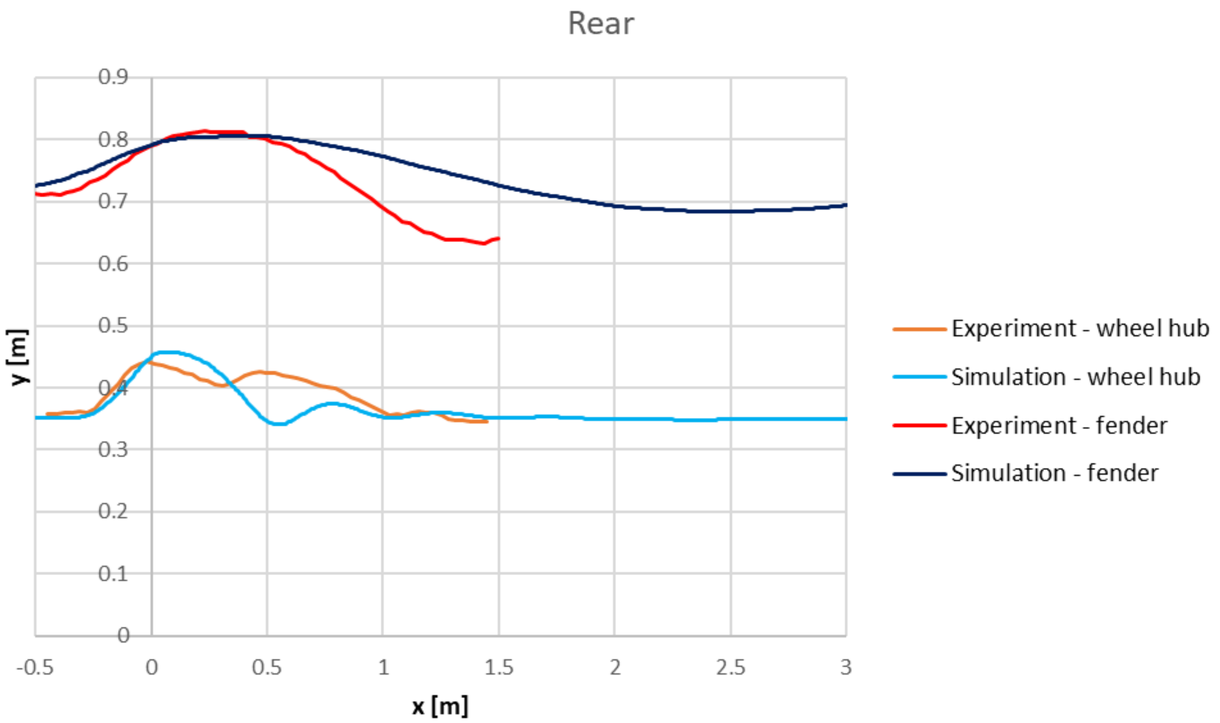


Figure 35: Curb test – sideview trajectory comparison simulation vs experiment – rear axle

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4.3.3 Conclusion

The FE model proved stability. Comparison of trajectories of Model suspension showed agreement between the behaviour of the real N1 vehicle and vehicle model.

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4.4 Crash test – rigid wall

4.4.1 Objective

Full scale crash test simulation is the last step in vehicle model assessment. In this test the vehicle model is set in front of a rigid wall, given initial velocity and global response of the model is observed as it impacts the barrier. This test was compared with experimental results of Ford Econoline NCAP crash test [6]. The vehicle mass was 2400 kg and impact velocity was 56 km/h. The results were compared both with the experiment results and with the results of FE simulation from FHWA / NHTSA National Crash Analysis Center, The George Washington University [6]. Friction coefficient vehicle – barrier in this simulation was set as 0.6.

4.4.2 Results

a)

b)

c)

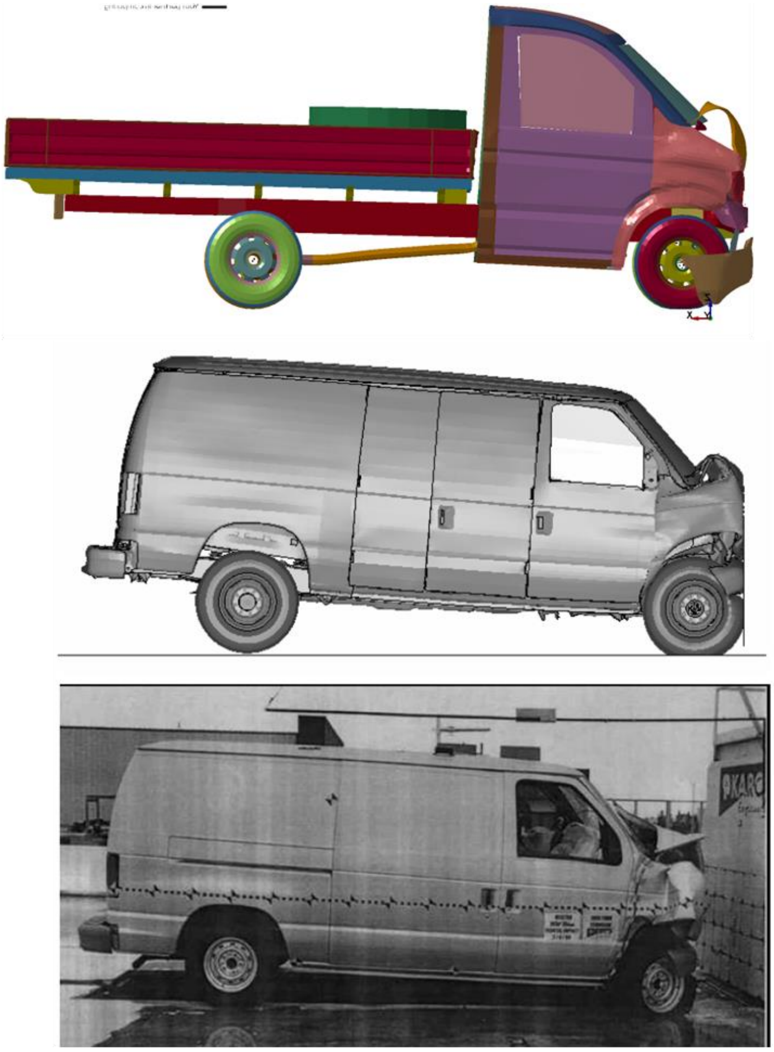

Figure 36: Rigid wall crash test: a) N1 generic model, b) Ford Econoline FE crash test by FHWA / NHTSA National Crash Analysis Center, The George Washington University, c) Ford Econoline NCAP test

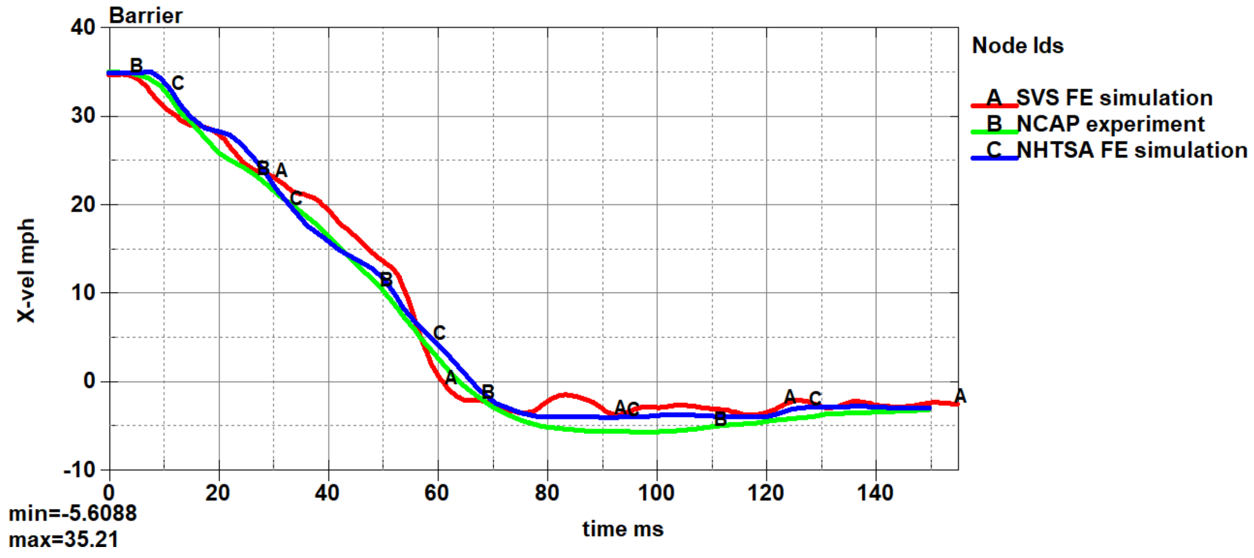

Figure 37: *FE models and experiment comparison: Velocity of the vehicle (filter SAE 60Hz)*

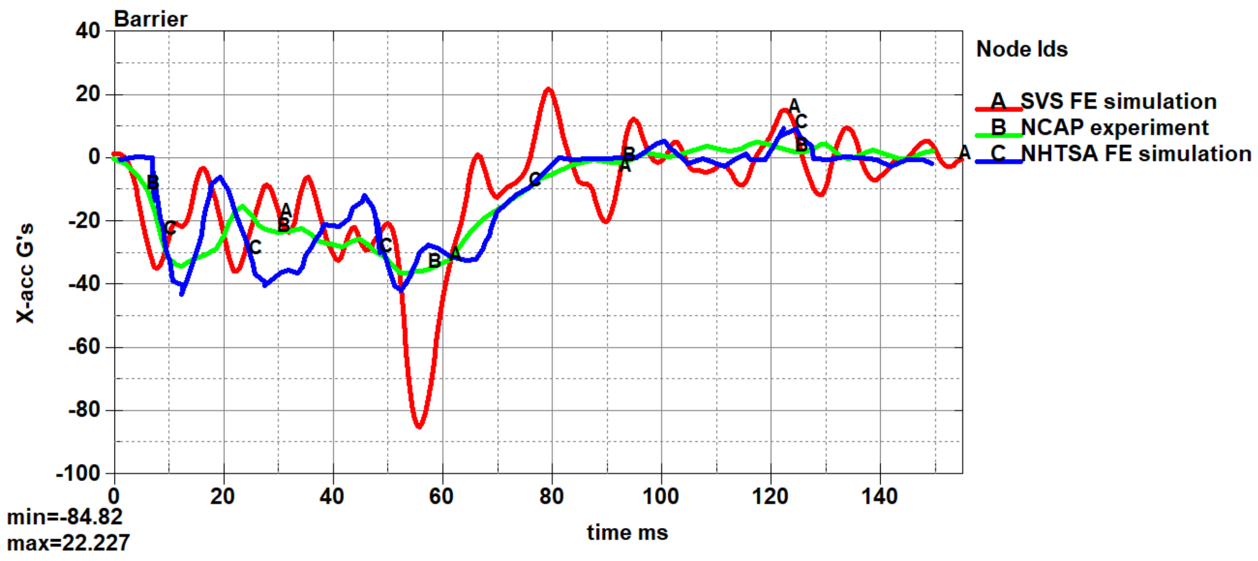

Figure 38: *FE models and experiment comparison: Acceleration of the vehicle*

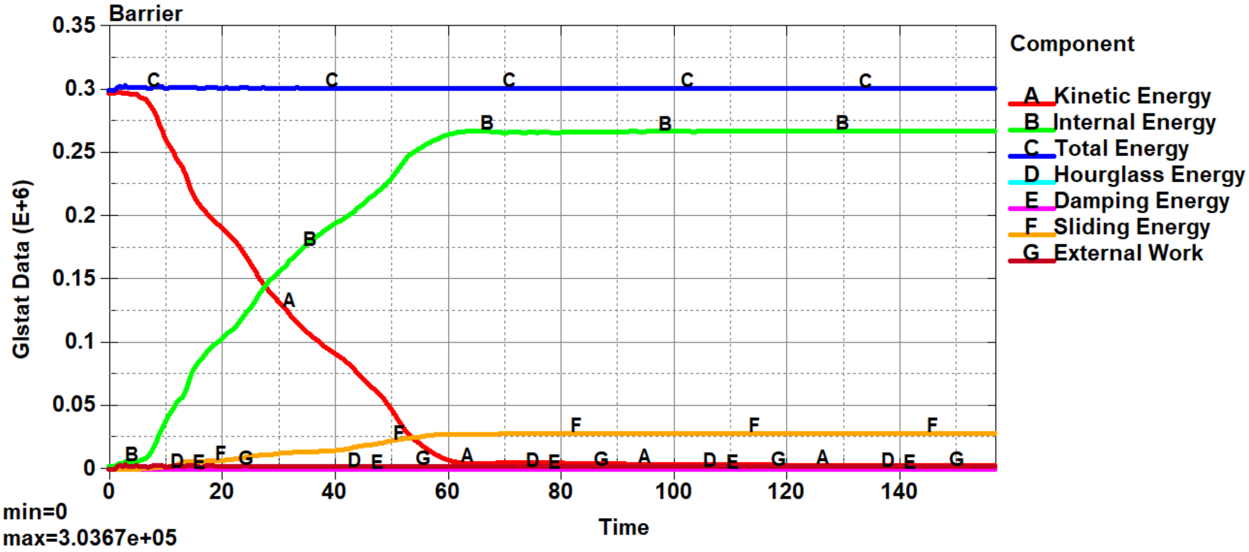

Figure 39: Generic N1 FE model energy balance

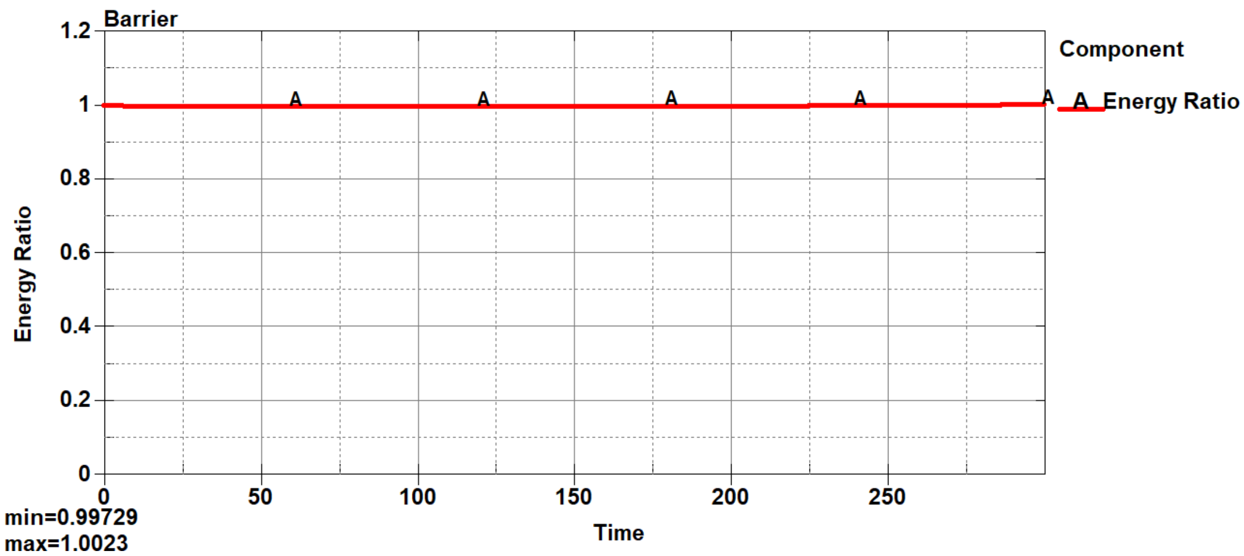

Figure 40: Generic N1 FE model energy ratio

4.4.3 Conclusion

Global response of the vehicle model agrees with experimental results. The stability of the model was proved during the crash test simulation as well. The time step did not drop below 2.9e-3 ms.

5 Summary

On the initiative of the JRC, SVS FEM Services s.r.o. in cooperation with Transport Research Centre, CZ prepared a generic vehicle model corresponding to the category N1 (IWA 14, CWA 16221, PAS 68). This numerical model is released as Generic Vehicle N1 R1.1. Key properties of the model are parametrized in order to allow convenient model modifications, which might reflect various conditions of real N1 vehicles (various dimensions, mass distribution, age, fitness, etc.). The model is therefore suitable for stochastic analyses, which allow advanced, probabilistic assessment of barrier performance. The variability of the model is its greatest strength.

The vehicle model was validated by several tests (corresponding to CEN/TR 16303). The validation procedure included tests that confirmed stability and robustness of the model and tests, which confirmed its reliability by comparing the results with experiments (curb test, full-scale test as rigid wall crash). For further validation it would be necessary to have more experimental crash data with various N1 vehicles.

Since the variability of this vehicle model and the variability of possible impact scenarios is endless, the development and enhancement process is expected to continue among the participants of the stakeholders of the concerned working group of the JRC or other interested parties. Further development will be focused on exploration of the performance of the model in particular concerning crash scenarios, which have not been tested and compared to experiments yet. Another aspect if the modelling of engine and gearbox, whose rigid body approach might be too stiff for a realistic impact. This development approach driven by researchers from various organizations and various countries will maximize the genericity of the model and should lead to updated versions of the model.

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6 References

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7 Attachments

Attachment 1: Input files for Ansys LS-DYNA „ JRCVehicleN1_R1_1.zip“

Archive contains all input files for the generic vehicle model N1 release 1.1.

8 Appendix A: Geometry reverse engineering example

Collection of geometry data of mentioned vehicles was based on physical measurements, photos and product brochures of several complete and partially disassembled vehicles.

Figure 1: Measuring front frame dimensions

Figure 2: Rear wheel suspension

Figure 3: Main frame of the vehicle and reinforcement of the flatbed

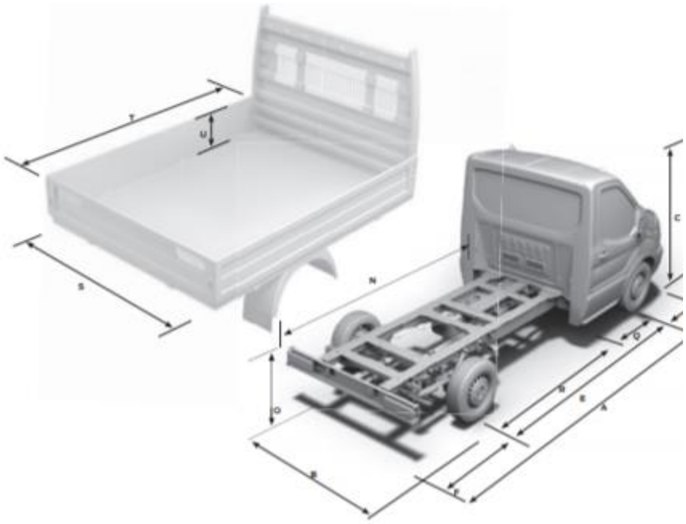

Figure 4: Scheme of vehicle structure

Figure 5: Measuring main frame dimensions

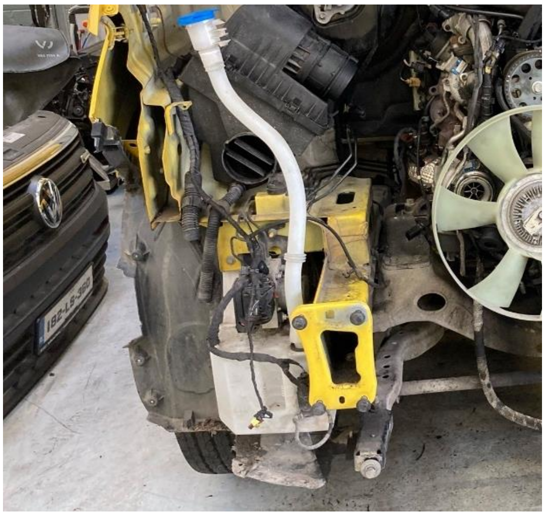

Figure 6: Partially disassembled front of the vehicle

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