Comparison of ES-2re with ES-2 and USSID Dummy –

Considerations for ES-2re model in FMVSS Tests

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Abstract:

For almost 2 years the ES-2 dummy is used to predict occupant injury risk in side impact crashes in EURO-NCAP. Recently, NHTSA announced that a modified version of the ES-2, the ES-2re is likely to substitute the USSID in the FMVSS 214. Hence, the knowledge gained with the ES-2 might be also useful to design cars in accordance with the regulation FMVSS 214. The paper discusses various simulations to investigate the behavior of the models. One emphasis is to penetrate if and under which circumstances the ES-2re dummy behaves different from the ES-2 and if the modeling technique for the ES-2 model is sufficient to achieve accurate results for the ES-2re dummy. The simulations contain simple rigid barriers as well as sub models using a detailed seat model and the deformable door and b-pillar. Another emphasis is a comparison between the ES-2re and the USSID model in barrier tests. Finally, results of the ES-2re and the USSID model from a vehicle side crash simulation are compared.

Keywords:

Side Impact Dummy Model, FAT, LS-DYNA Dummy Model, ES-2 Dummy Model, ES-2re Dummy Model, USSID Dummy Model, FMVSS 214

1 Description of Dummies and the Corresponding Models

The USSID dummy and EUROSID-1 dummy are used since many years to assess side impact safety of passenger cars in American and European regulations, respectively. In the recent past the ES-2 was developed by enhancing the EUROSID-1 dummy. The ES-2 substituted in 2003 the EUROSID-1 dummy in EURO-NCAP to asses the performance for side impact crash with moveable deformable barriers. Finite element models of the USSID dummy and ES-2 dummy are depicted in Figure 1.

The considerably small differences between the EUROSID-1 and the ES-2 are described in [7]. Although the USSID and the ES-2 dummy both represent a 50% male, the dummies differ in many ways. An obvious difference is the modeling of the arm. The arm of the USSID is built by a reversible foam block inside the rubber jacket. For the ES-2 dummy the arm is attached through the clavicle with the spine box. The clavicle can rotate in the spine box. The jacket of the ES-2 dummy is made from thin neoprene and is much more flexible than the jacket of the USSID dummy.

In addition, the thorax designs of the 2 dummies are significantly different. The ribs of the USSID are connected to the spine at the back through a multi-layer textile material. The ribs themselves are connected by steel links and lead blocks, the movement is influenced by one spring damper system and limited by a rubber bottoming out box. The USSSID has 5 ribs, each covered with a solid viscous damping material. The rib cage of the ES-2 is built of three ribs, each equipped with a spring damper system which enables the ribs to move independently. Both models have foam layers between the arm and the steel ribs. For the USSID it consists of several layers of foam and a PU plastic sheet. The foam shows only minor strain rate dependency. For the ES-2 the foam is bonded to the ribs and covered by a thin rubber hull. The rib foam of the ES-2 is highly strain rate sensitive.

The pelvis of the USSID consists of an aluminum cast embedded in PU foam and covered by a vinyl hull. The ES- 2 uses different deformable parts to model the pelvic bone, 2 different types of foams are used to build the pelvis flesh. The foams are also covered with vinyl. Figure 2 depicts finite element models of the thorax and pelvis of the USSID and the ES-2. The legs of the ES-2 and the USSID are similar; the major differences are materials and mass distributions in the upper leg.

Both dummy models have different possibilities to extract injury criteria. The USSID uses accelerations at the ribs, the lumbar spine and the pelvis. Optionally, the rib intrusion can be measured with a potentiometer. More signals can be extracted from the ES-2. Besides the accelerations of the spine and the pelvis the dummy provides information on the rib intrusions, forces can be measured at the pubic symphysis, the abdomen and the back plate. Additional load cells to measure force and moments in the neck, the lumbar spine and forces at the arm are available. Both models allow extracting head accelerations.

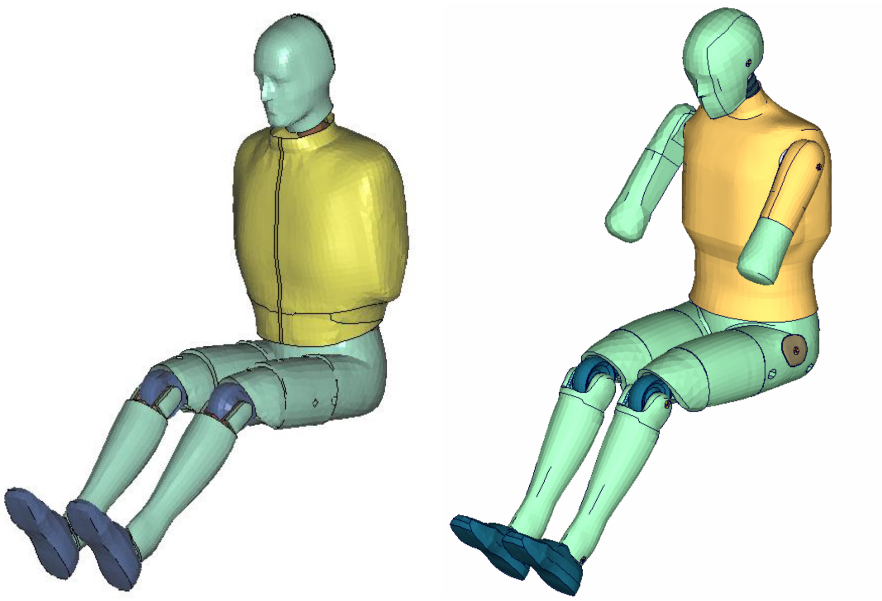

Figure 1 USSID dummy model (left), ES-2 dummy model (right).

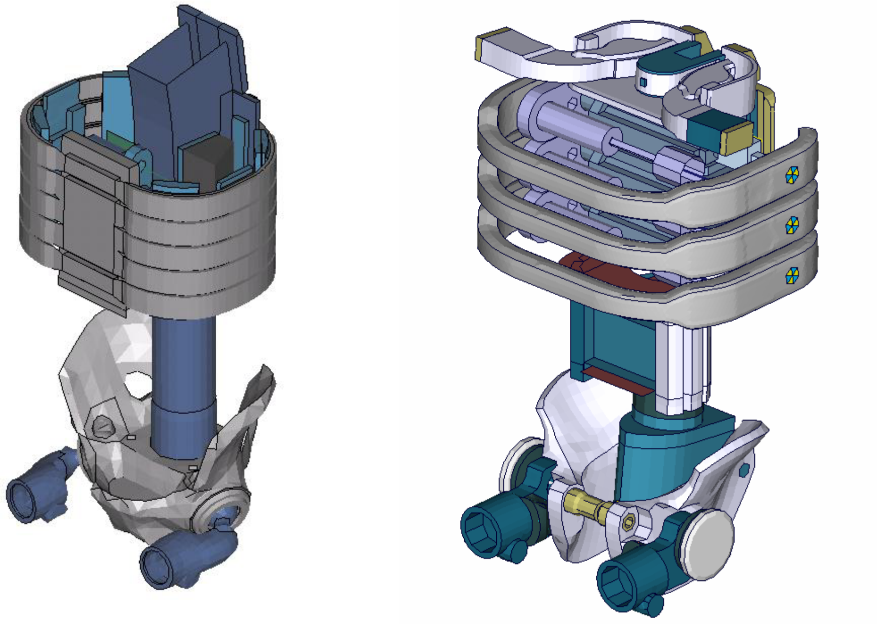

Figure 2 Partial thorax and pelvis of USSID model (left) and ES-2 model (right).

Recently NHTSA announced that the ES-2re is likely to substitute the USSID in a revised FMVSS 214 regulation. The ES-2re is derived from the ES-2 by altering the rib modules and the back plate. The ES-2re and the ES-2 differ in the rib and back plate area. Figure 3 depicts the rib cages and the connection to the spine of both models. For the ES-2re the ribs of the ES-2 are shortened at the impact side and extended by three bended stripes of steel that are guided by a needle bearing system in the back plate. Therefore the back plate is redesigned.

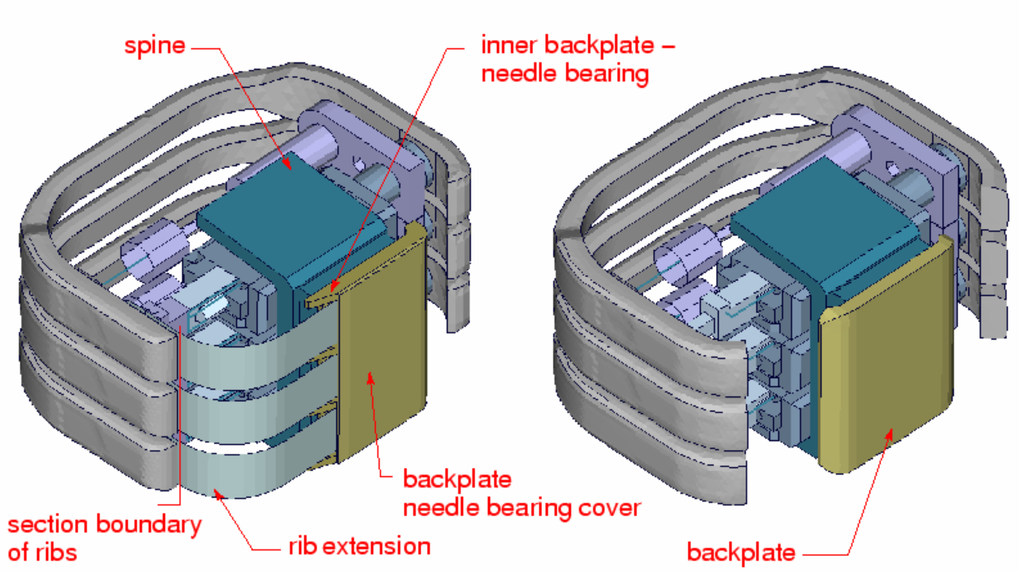

Figure 3 ES-2re thorax module (left), ES-2 thorax modul (right); view from back.

Finite element models for LS-DYNA for all above described models are developed in a joint project between the FAT and DYNAmore GmbH. The FAT is the abbreviation for German Association for Automotive Research [2], the German automotive companies join parts of their research activities within the FAT. The models are used world wide to develop vehicles in accordance to the different demands.

In the following a brief outline of the modeling techniques used for the models is given. A detailed description of the models can be found in [4, 5]. For modeling the foam materials usually material type 83 (Mat_Fu_Chang_Foam) is used. Very few parts are modeled with material type 62

(Mat_Viscous_Foam). For modeling the venyl coverings mainly material type 6 (Mat_Viscoelastic) is used. Other rubber parts are modeled with material type 62 (Mat_Viscous_Foam). Steel or aluminum parts are modeled with material type 20 (Mat_Rigid).

The models work with one major single surface contact type 13 (Automatic_Single_Surface) with the 'Soft Constraint' option. In the ES-2 and ES-2re a tied contact is used to link the fairly fine mesh of the rib foam to the much coarser mesh of the steel inlet of the ribs.

The recent models use the stiffness based joint definition in combination with the generalized joint option. Global damping is not applied. The models run with LS-DYNA version 960 upwards on computers with SMP and MPP architecture with time steps of approximately 1 micro second.

The ES-2re model release consists of 80.041 nodes, 24.942 hexahedron elements, 97.114 tetrahedron elements, 218 beam elements, 64.724 shell elements, and 12 discrete elements. A detailed description of the ES-2 can be found in [9]. The model size of the ES-2 is similar to the ES-2re model. The USSID model release 4.5.1 consists of 61.096 nodes, 96.042 solid elements 47 beam elements, 46.055 shell elements, and one discrete element. Figure 4 depicts selected parts of the ES-2re model to illustrate the mesh density of the models.

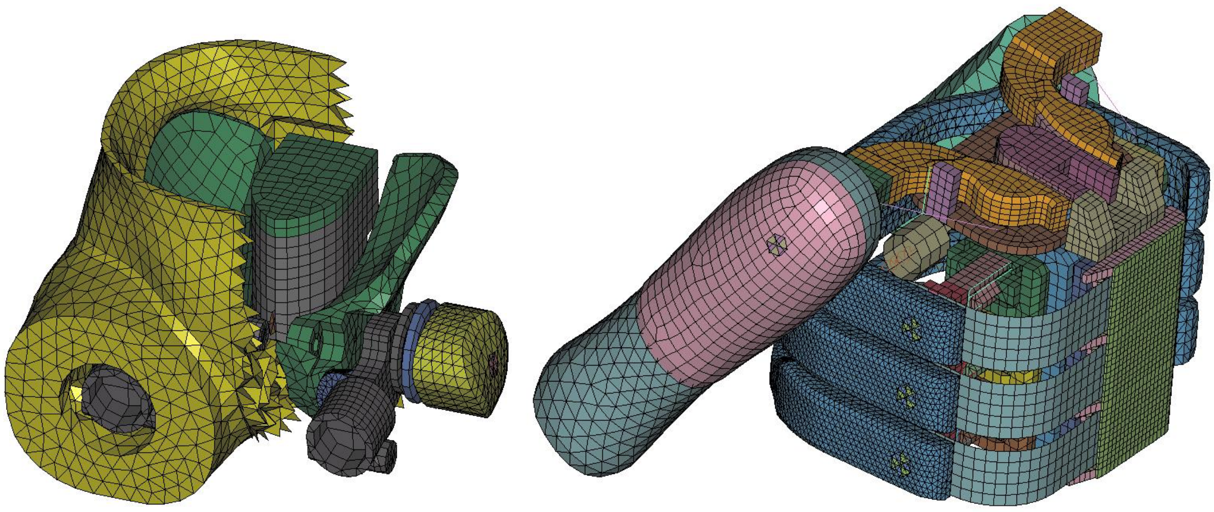

Figure 4 Cut through pelvis model (left) and partial thorax model (right) of ES-2re.

2 Validation of the Dummy Models

The tests used to develop the finite element dummy models are described more detailed in [3, 4, and 5]. The methodology of development is described in [4]. Since the ES-2 and the EUROSID-1 share many parts and since the tests to determine material properties were often performed for the EUROSID-1, this model is also mentioned.

2.1 Material tests

Almost all specimens were taken from new parts delivered by FTSS. In order to get more general applicable data the specimen were chosen from areas where the materials appeared to be homogeneous. The following types of tests were performed: Static tension tests, dynamic tension tests, static compression tests, dynamic compression tests, relaxation tests, hydrostatic triaxial compression tests, static shear tests and dynamic shear tests. Emphasis was directed towards strain rate dependent foams used in many areas of the dummies. Details on specific material tests are presented in [2].

2.2 Component tests

To develop the EUROSID-1 and USSID model a large variety of component tests were performed such: Head drop tests, dynamic shear tests for the lumbar spine, pendulum tests of the lumbar spine, neck pendulum tests, drop tests of the damper, partial and complete thorax impact tests, pendulum tests of the abdomen, impact tests on the pelvis and on pelvis/upper leg, and impact tests for the shoulder foam cap. If possible, standard test devices used in dummy calibration were used. The tests were performed usually for a large variety of speeds and masses. For the ES-2 model fewer component tests were performed. It was mainly the rib module that has been investigated by pendulum tests. Different masses, different speeds and impact locations and angles were considered. Along with the standard measurements the motion of the damper piston was measured. Furthermore, pendulum tests for the neck and lower spine were performed.

2.3 Pendulum tests on fully assembled dummy

For the validation of the EUROSID-1 and USSID no pendulum tests on the fully assembled dummies were performed. However, for the ES-2 model a considerably high number of tests were made to validate the model. Usually the test is performed at two different impactor speeds. Pros and cons of pendulum and sled tests are given in [7]. Figure 3 (left) depicts the different impacting positions. Figure 5 (right) depicts an additional pendulum test on the rib extension to calibrate the rib module of the ES-2re.

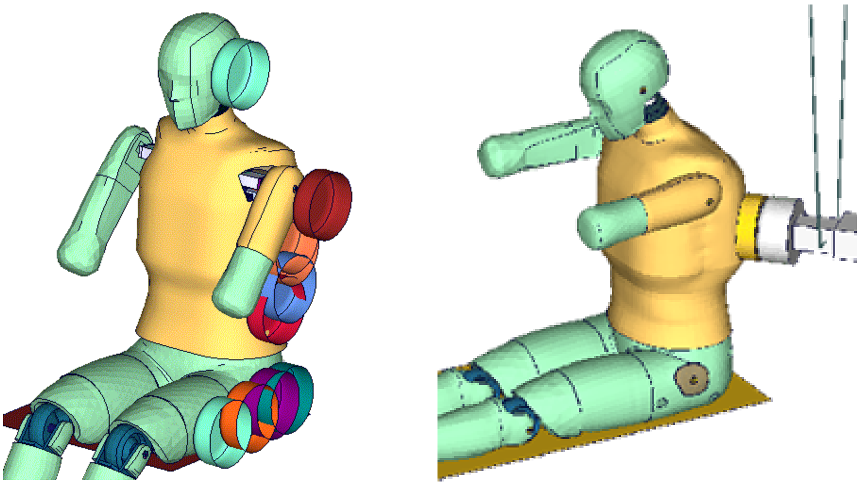

Figure 5 Dummy (left) and model (right) in pendulum test.

2.4 Barrier tests with fully assembled dummies

Many experiments were performed with rigid (rather stiff) barriers. The speed varied from 4 to 7 m/s with barrier masses above 1 t. The dummies were fully instrumented and accelerations, forces, moments, and displacements were recorded. Furthermore, the dummies were equipped with contact foils to determine the time of contact between several parts. For the ES-2 model all shapes of the barriers were designed to have comparable loads to a vehicle test. For the EUROSID-1 and USSID model additional barrier shapes were used to validate specific parts of the dummy model. The different barrier shapes implied for the validation are depicted in Figure 6. The impacting surfaces were inclined in some barrier tests for the ES-2 model. A discussion wether a good correlation in the barrier tests is sufficient to achieve good dummy models for a full vehicle test is presented in [6].

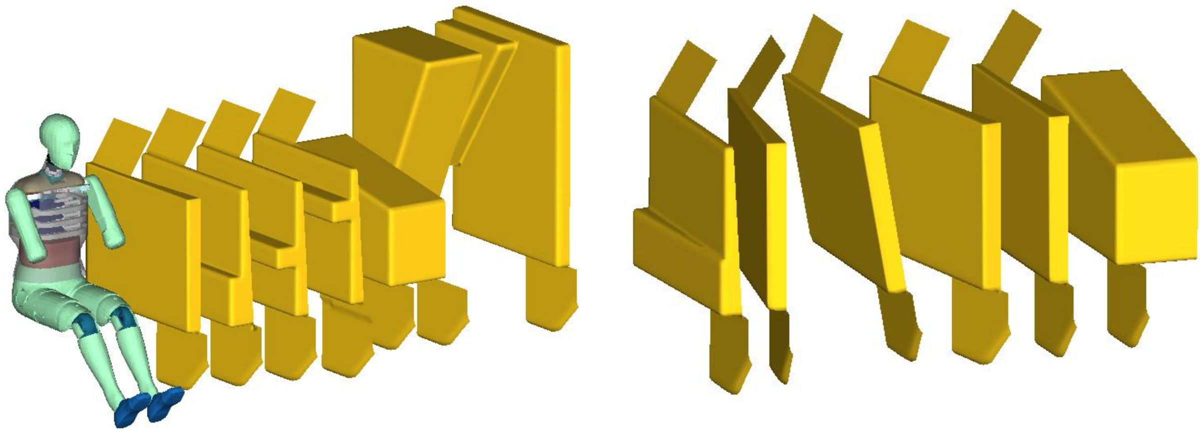

Figure 6 Barrier shapes used to validate the USSID and EUROSID-1 (left) and ES-2 model (right).

The correlation of the ES-2 dummy model in the barrier tests is considerably high. The performance of the model in all tests is shown in [9]. The correlation for the USSID was validated with slightly different shaped barriers; the correlation is presented in [5].

3 Considerations in Sled Tests

Two barrier shapes are selected to compare the models in the following. One will be called plane barrier, it is the first barrier from left in Figure 6 (left). The other is called oblique barrier, it is the third barrier from right in Figure 6 (right). The oblique barrier contacts the dummy first on the back left side to point out differences of the back plate behavior. For both barrier models speeds of 4 and 6 m/s are analyzed.

3.1 Differences of ES-2 with ES-2re in sled tests

The ES-2 and ES-2re models show no remarkable differences in the plane barrier test and the oblique barrier test. This is valid for the 4 m/s and the 6 m/s impact. The lack of differences was expected since the tests put no load to the back plate and the impact surface is plane.

3.2 Reduced rib intrusions due to back plate load of ES-2 model

The ES-2 spine box can be accelerated during side impact by loading the dummy at the back plate with a lateral force from the seat. This is not possible for the ES-2re due to the design of the ribs. Any load in this are will result in a rib deflection. For the ES-2 this effect might be used to reduce the velocity between dummy and door trim before the door impacts the dummy. To avoid that this mechanism is used to reduce rib intrusions of the ES-2 dummy EURO-NCAP defines a modifier if the load of the back plate exceeds a certain force level.

To estimate the potential for a reduction in rib intrusions by loading the back plate the following simulations were performed. A force in y direction is applied to the back plate. The force accelerates the spine box and reduces the severity of the impact of the barrier. Two load cases are considered; a high force of 5 kN it is applied for 5 ms it is referenced as “load high”. The force is above the ‘Low Performance Limit’ [1] and would lead to 2 point modifier in EURO-NCAP. In the second load case the force ramps during 2.5 ms to a value of 995 N, this value is constant for 5 ms, then the force is ramped to zero in 2.5 ms. The load will not lead to a modifier in the EURO-NCAP. The forces were applied during a sled test with a plane rigid barrier with speeds of 4 m/s and 6 m/s. The results are summarized in Table 1 and 2.

	No artificial back plate load	Back plate load high (5kN)	Back plate load low (< 1kN)
Max T1 accl. [g]	20	55	25
Max. T12 accel. [g]	30	34	28
Max Pelvis accel. [g]	52	52	52
Upper rib intrusion [mm]	17	8	12
Middle rib intrusion [mm]	18	10	14
Lower rib intrusion [mm]	21	13	18

Table 1 ES-2 in sled tests with rigid plane barrier, 4 m/s

	No artificial Back plate load	Back plate load high (5kN)	Back plate load low (< 1kN)
Max T1 accl. [g]	27	55	27
Max. T12 accel. [g]	65	62	62
Max Pelvis accel. [g]	80	78	80
Upper rib intrusion [mm]	37	30	33
Middle rib intrusion [mm]	35	30	33
Lower rib intrusion [mm]	37	33	35

Table 2 ES-2 in sled tests with rigid plane barrier, 6 m/s

Even for the back plate load that meets the high performance limit a reduction for rib intrusions can be observed. If a high load is applied to the back plate the rib intrusions can be reduced significantly. The considered high force reduced the rib intrusions from 20 to 10 mm. The models are more sensitive regarding a back plate load if the rib intrusions are close to the 'High Performance Limit' than loads close to the 'Low Performance Limit' of EURO-NCAP.

3.3 Comparison of ES-2re with USSID in sled tests

To compare the ES-2re with the USSID model the same simple sled test setup as in Section 3.2 was used. Four simulations were considered by using 2 barrier types; a plane barrier (Figure 7) and oblique barrier with a first contact in the spine area each impacting with 4 and 6 m/s. Since the injury criteria of the model differ significantly it is not obvious how to compare the models. In the following the resultant spine and pelvis accelerations are compared. Additionally, the maximum rib intrusion for the ES-2re and the accelerations for the USSISD are compared. Tables 3 to 6 summarize the results.

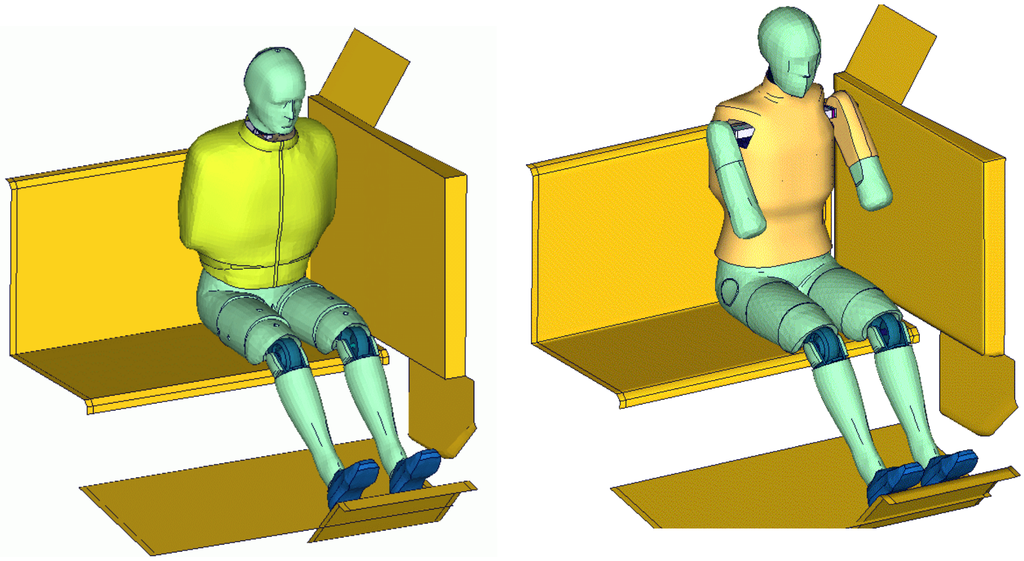

Figure 7 USSID and ES-2re model with plane rigid barrier.

Max. values	USSID	ES-2re
T1 accl. [g]	--	18
T12 accl. [g]	36	39
Upper rib accel. [g]	51	--
Lower rib accel. [g]	51	--
Upper rib intrusion [mm]	--	15
Middle rib intrusion [mm]	--	16
Lower rib intrusion [mm]	--	19
Pelvis accel. [g]	46	55

Table 3 USSID and ES-2re in sled tests with rigid plane barrier, barrier speed 4 m/s.

Max. values	USSID	ES-2re
T1 accl. [g]	--	35
T12 accl. [g]	69	70
Upper rib accel. [g]	113	--
Lower rib accel. [g]	118	--
Upper rib intrusion [mm]	--	37
Middle rib intrusion [mm]	--	36
Lower rib intrusion [mm]	--	37
Pelvis accel. [g]	102	91

Table 4 USSID and ES-2re in sled tests with rigid plane barrier, barrier speed 6 m/s.

Max. values	USSID	ES-2re
T1 accl. [g]	--	25
T12 accl. [g]	46	49
Upper rib accel. [g]	59	--
Lower rib accel. [g]	59	--
Upper rib intrusion [mm]	--	40
Middle rib intrusion [mm]	--	40
Lower rib intrusion [mm]	--	40
Pelvis accel. [g]	67	60

Table 5 USSID and ES-2re in sled tests with oblique barrier, barrier speed 4 m/s.

Max. values	USSID	ES-2re
T1 accl. [g]	--	32
T12 accl. [g]	56	57
Upper rib accel. [g]	68	--
Lower rib accel. [g]	68	--
Upper rib intrusion [mm]	--	45
Middle rib intrusion [mm]	--	44
Lower rib intrusion [mm]	--	44
Pelvis accel. [g]	87	76

Table 6 USSID and ES-2re in sled tests with oblique barrier, barrier speed 6 m/s.

For both barriers and speeds the ES-2re and the USSID show a surprisingly good correlation in respect to the spine and pelvis acceleration. The oblique barrier shows it can not be expected that low rib accelerations of the USSID are correlation with low intrusions of the ES-2re. For the oblique load the ribs of the ES-2re measure a much higher load than the USSID.

4 Considerations in Sub Model of Vehicle

With the above described tests the loads are close to vehicle tests as outlined in [6], but effects due to the curvature and softness of the environment can not be considered. In the following a more complex sled device is used to compare the ES-2 and the ES-2re. Two independently accelerated sleds were used to move the seat and the outer hull of the door in accordance to the EURO-NCAP side impact crash. The door and the seat are modeled in high detail with validated material properties. Figure 8 depicts the sled for the seat movement in blue and the sled for the door movement in green. Due to confidentiality reasons the seat and door are not depicted. The target of the simulations is to investigate if the seat influences the ES-2 differently than the ES-2re. Therefore simulations with no contact between the dummy and the seat are performed as well as simulations with proper contact definitions. An airbag is not considered in the analysis. Figure 9 depicts the 2 dummy models in the seating position. The behavior of the lower rib during impact and the influence is depicted in Figure 10 to 13. Figures 14 to 18 summarize important results of the simulations in graphs.

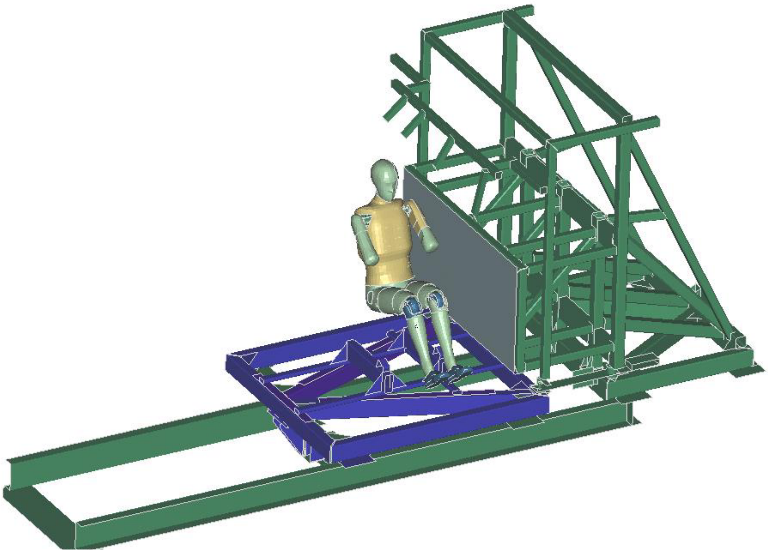

Figure 8 Sled device, door and seat not depicted due to confidentiality. Deformable door and seat move independently according to the crash pulse.

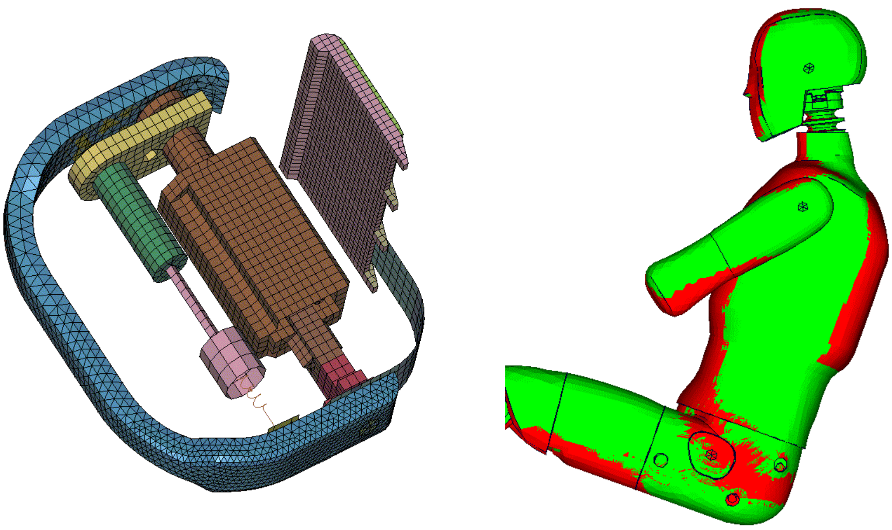

Figure 9 ES-2 in green and ES-2re in red in seating position (right). Rib module of lower rib with back plate of ES-2re (left).

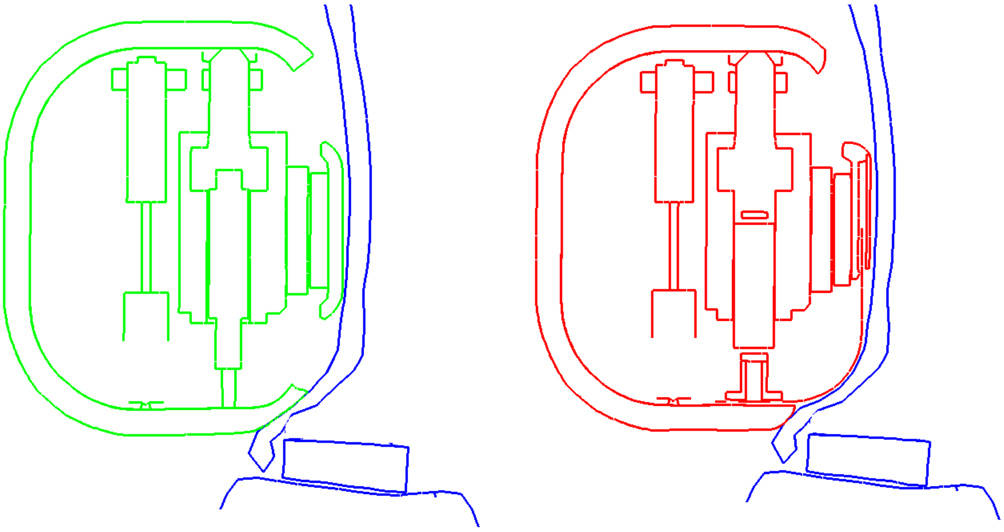

Figure 10 Cut through lower rib module of ES-2 model (left) and ES-2re model (right) at 40 ms. Dummy models in green or red; seat cushion, seat frame, and b pillar symbolized in blue.

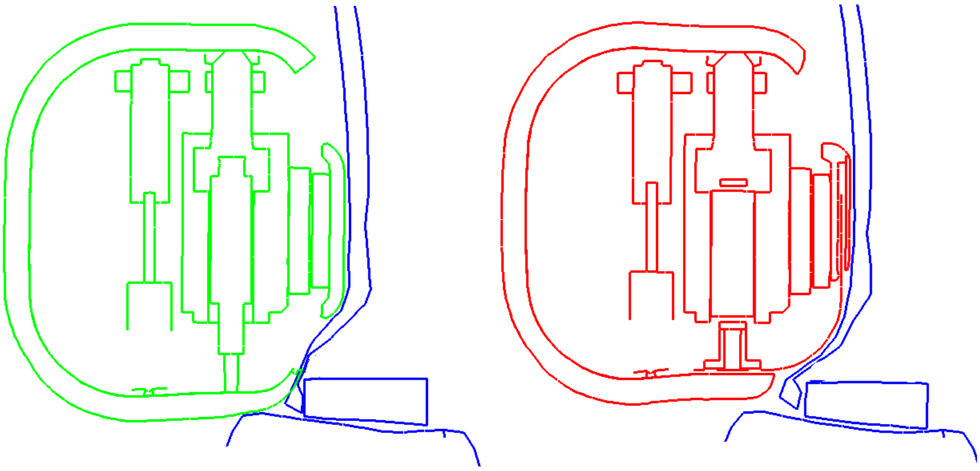

Figure 11 Cut through lower rib module of ES-2 model (left) and ES-2re model (right) at 50 ms. Dummy models in green or red; seat cushion, seat frame, and b pillar symbolized in blue.

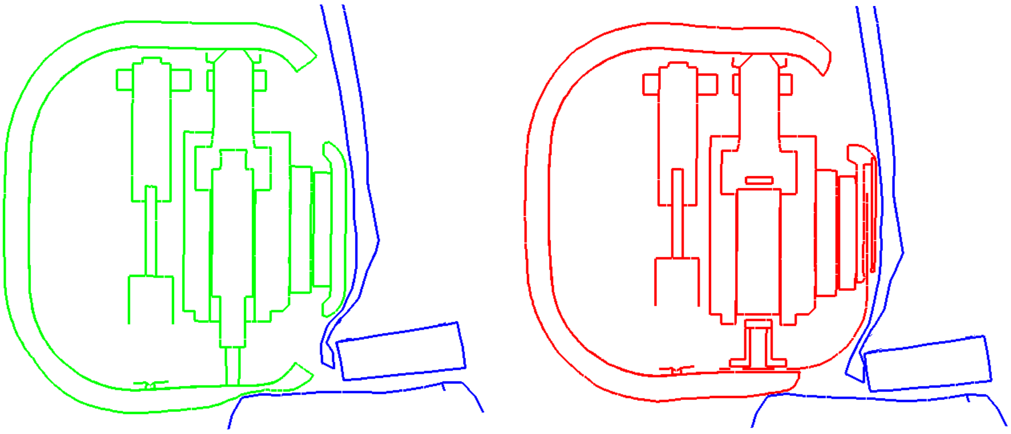

Figure 12 Cut through lower rib module of ES-2 model (left) and ES-2re model (right) at 60 ms. Dummy models in green or red; seat cushion, seat frame, and b pillar symbolized in blue.

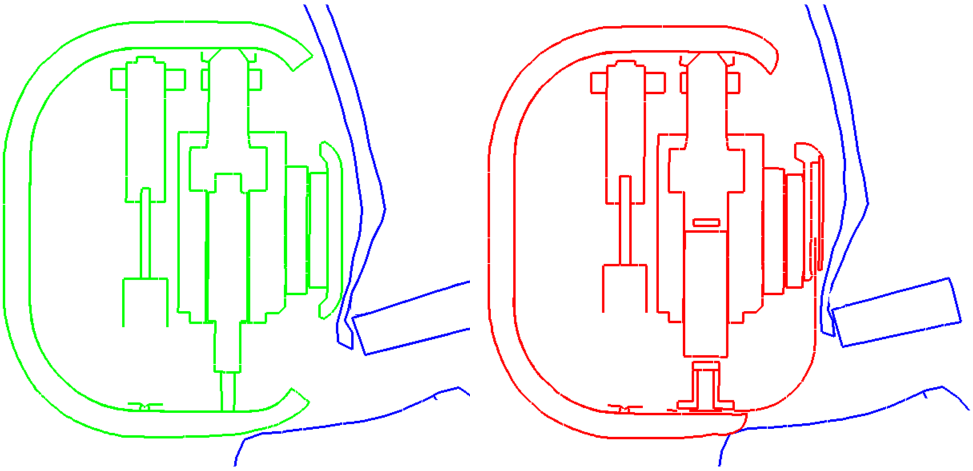

Figure 13 Cut through lower rib module of ES-2 model (left) and ES-2re model (right) at 80 ms. Dummy models in green or red; seat cushion, seat frame, and b pillar symbolized in blue.

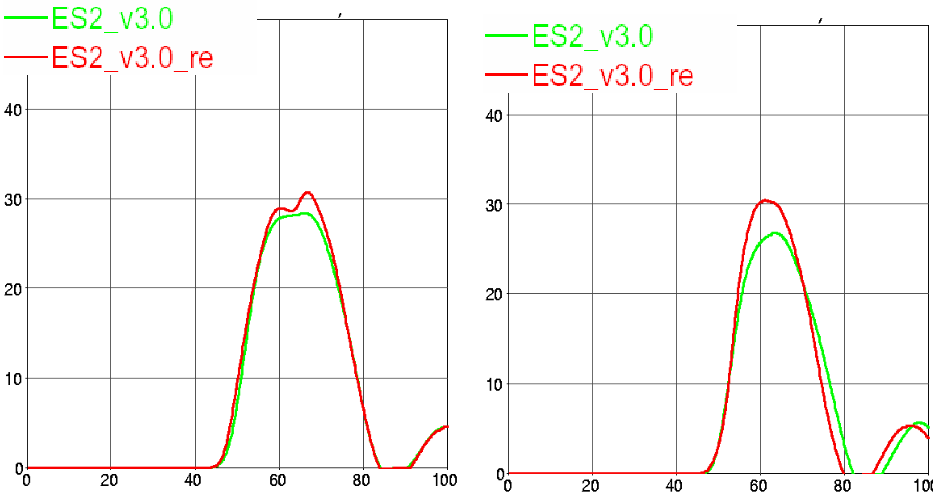

Figure 14 Rib intrusions [mm] of upper rib (left) and lower rib (right) versus time [ms]; Dummy models are not in contact with seat.

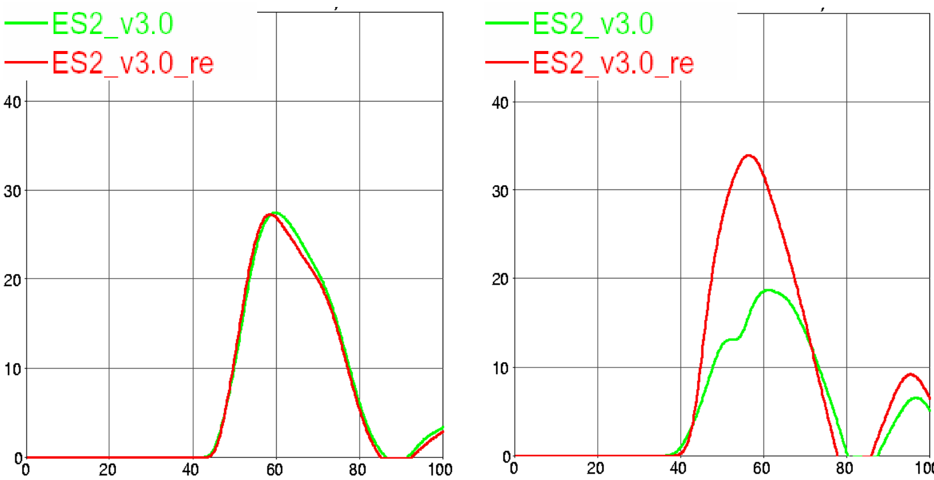

Figure 15 Rib intrusions [mm] of upper rib (left) and lower rib (right) versus time [ms]; Dummy models are in contact with seat.

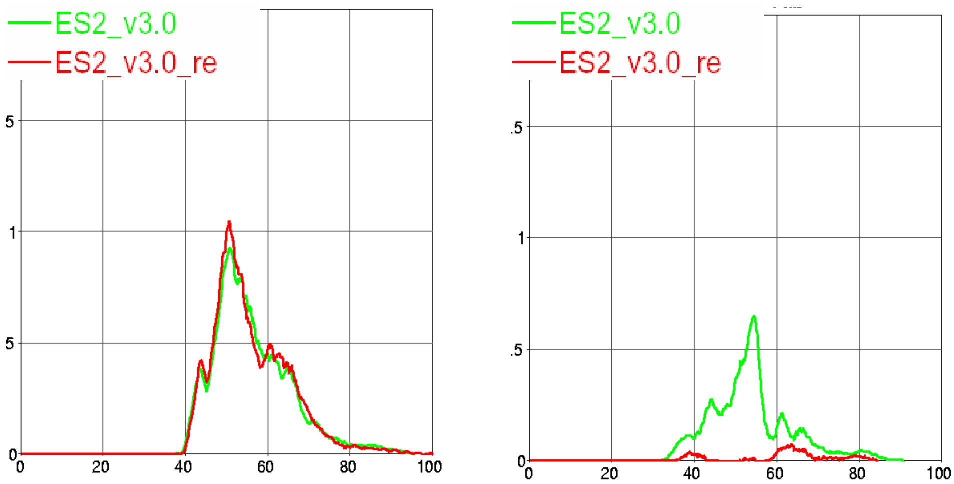

Figure 16 Force [kN] at foam covered ribs versus time [ms] of ES-2 in red and ES-2re in green. Upper rib (left) and lower rib (right). Dummy models are in contact with seat.

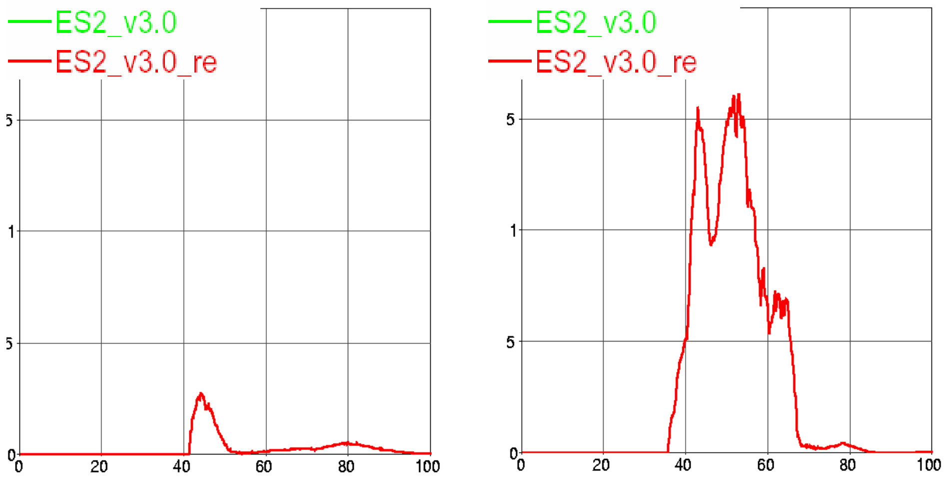

Figure 17 Force [kN] at rib extension versus time [ms] of ES-2re. Upper rib (left) and lower rib (right). Dummy models are in contact with seat.

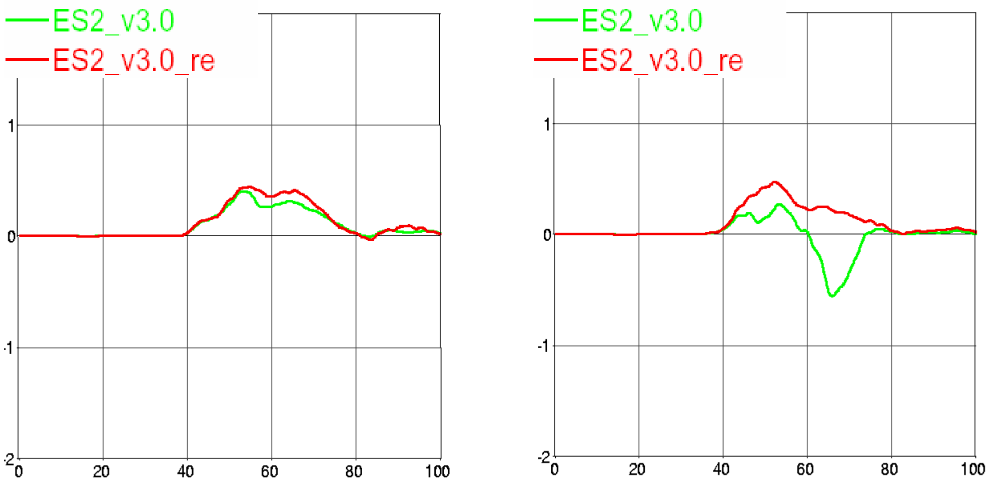

Figure 18 Lateral back plate force [kN] versus time [ms] of ES-2 in green and ES-re in red. Dummies not in contact with seat (left) and contact between dummies and seat (right).

4.1 Discussion of Sub Model Simulations

The dummies ES-2 and ES-2re give similar results if the seat is not in contact with the dummy. A small difference in the intrusion of lower rib can be observed. The differences are forced by geometric details of the intruding door.

Much higher differences occur if the seat is considered in contact with dummy. The rib extension amplifies the load path from the side part of the seat to the ribs. This load path is also present for the ES-2 dummy, but due to a forward movement of the dummy the load path is interrupted early. For the ES-2re the load path remains, even if the dummy moves slightly forward. Hence, the seat causes significantly higher rib deflections as shown in Figure 15 on the right. The influence of the load paths are quantified in Figure 16 and 17. The models are equipped with force transducers that measure the forces at the rib foam and the forces at the rib extension. At approximately 35 ms a force at the rib extension of the lower rib of the ES-2re model occurs. The force is larger by almost a factor of 3 than the rib force on the lower rib of the ES-2 model. Hence, a larger rib deflection of the ES-2re can be observed. The force is applied by the frame of the seat, as depicted in Figure 10 and 13 on the right.

The ES-2 back plate forces are influenced by the seat, as shown in Figure 18. For the ES-2re the influence of the seat on the back plate force is virtually zero. Hence, the design of the ES-2re model is avoiding any load at the back plate in the considered load case.

5 First Results in Vehicle Simulations

Finally, the USSID and the ES-2re model are compared in a full vehicle run. As load case the SINCAP side impact load case is chosen. The difference between the SINCAP and the FMVSS 214 is the slightly higher barrier speed. The vehicle is a mid size sedan. Its finite element model consists of approximately 1,500,000 elements. The simulation contains detailed seat and interior models. The seat is equipped with a side airbag. Figure 19 depicts the dummy models in the FMVSS 214 seating position. Since the geometrical differences do not allow an equivalent positioning the models fit with their H-Point and as good as possible for the center of gravity of the head and the angle of the upper leg. Due to confidentially reasons the vehicle, seat, and airbag model is not depicted.

The SINCAP simulation with the USSID shows in the early stage of the crash that the deploying airbag inflates in the rather narrow gap between the arm foam and the door trim. This leads to very small rib displacements before the intruding door trim contacts the dummy arm foam and the abdominal area as depicted in Figure 22 and 23. Consecutively, the dummy is accelerated rather homogeneously with equal accelerations on the rib module and the pelvis as depicted in Figure 22 and 24.

The SINCAP simulation with the ES-2re shows in the early stage that the deploying airbag fills the gap between the dummy thorax and door trim below the arm. This leads to initial accelerations of the ribs with an equal rib displacement in all three ribs (see Figure 22 and 23). Consecutively, the door trim contacts the arm and rotates the arm as depicted below. Then the prominent armrest contacts the abdominal area and leads to abdominal forces that exceed the legal limit for a European side crash. Later on the pressure in the airbag is very low and the dummy contacts the upper door trim with the upper rib. The large displacement of the upper rib shows the severity of the contact. The dummy starts to rotate around the x axis.

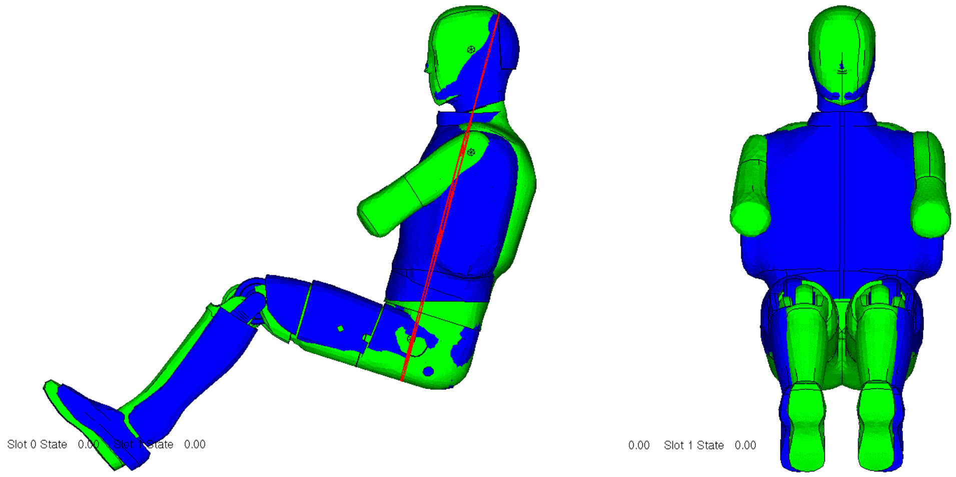

Figure 19 USSID (blue) and ES-2re (green) in seating position. Side (left) and front (right) view.

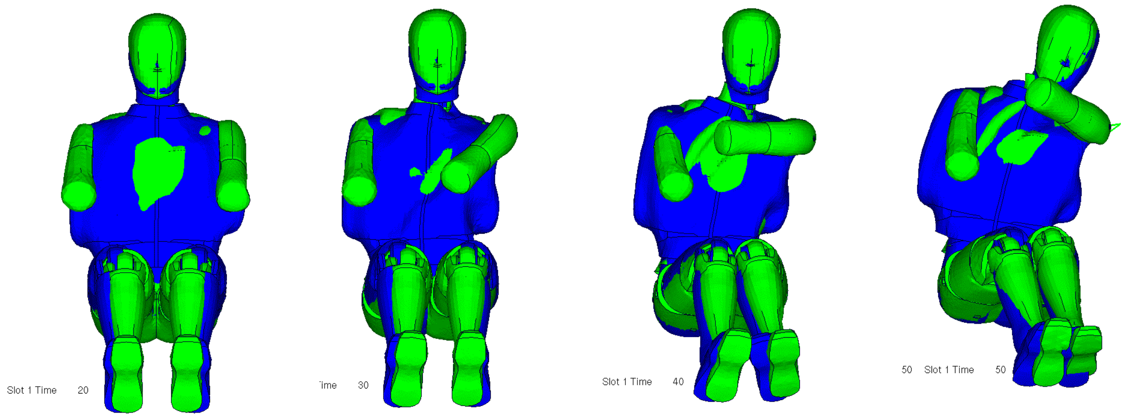

Figure 20 Dummy models during impact from left to right at: 20, 30, 40, 50 ms. USSID model in blue and ES-2re in green.

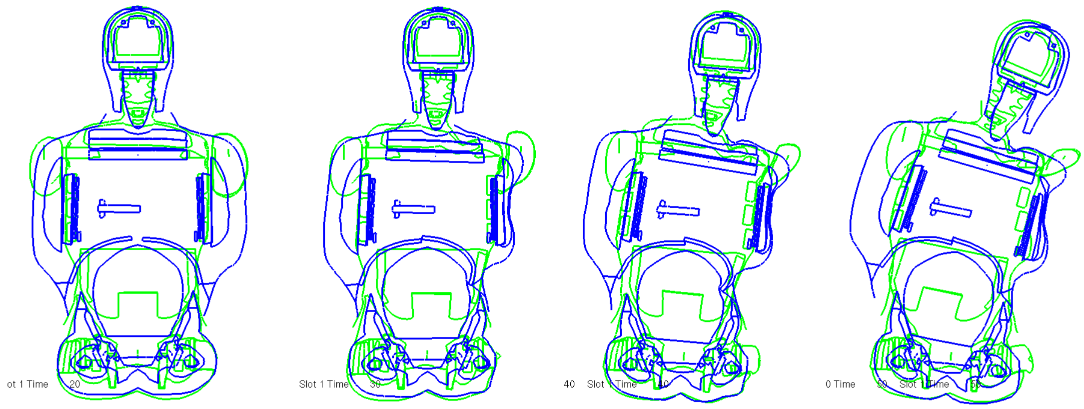

Figure 21 Cut through dummy models during impact from left to right at: 20, 30, 40, 50 ms. USSID model in blue and ES-2re in green. Cut location is marked in red in Figure 9.

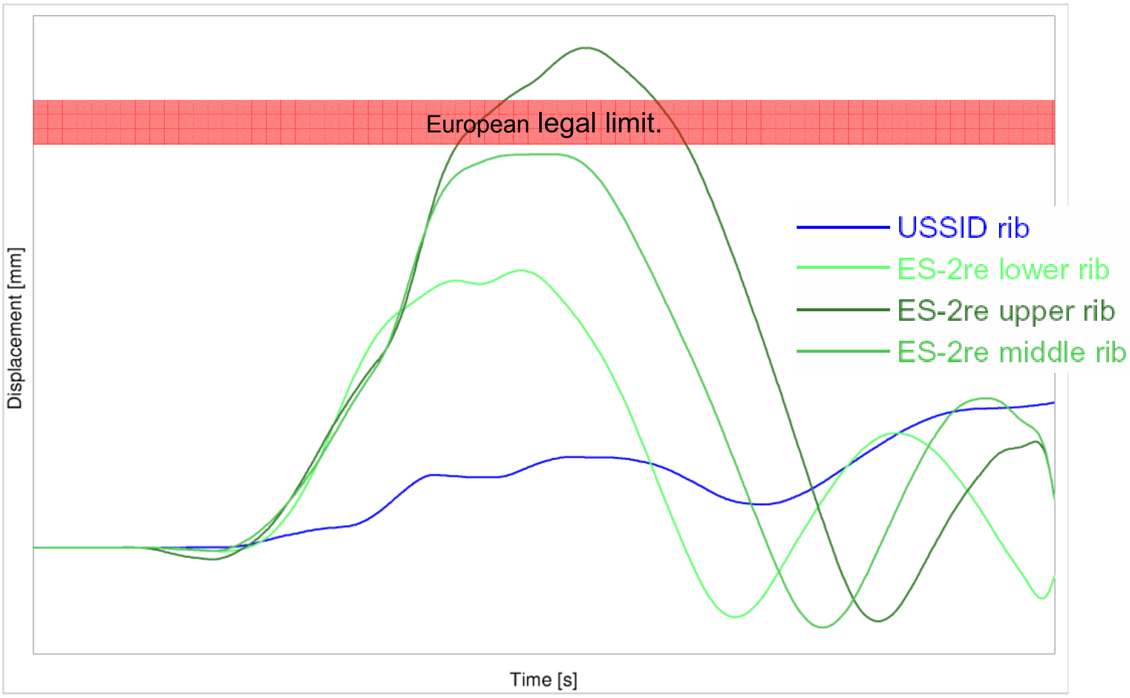

Figure 22 Comparison of the simulated rib displacements for USSID and ES-2re in SINCAP load case.

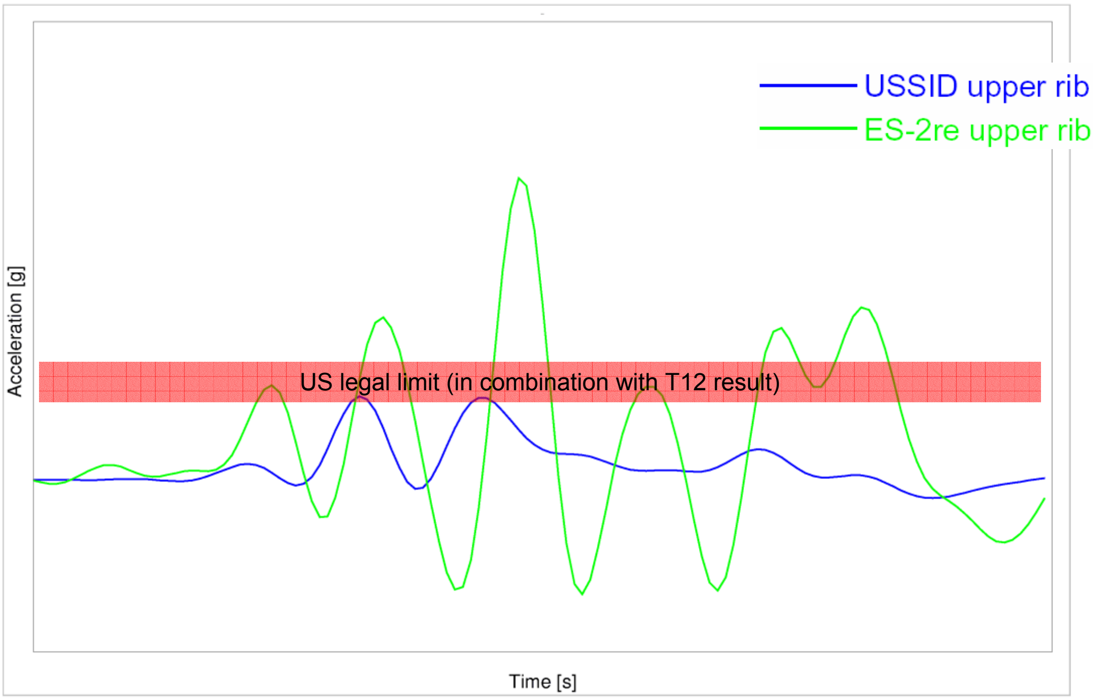

Figure 23 Comparison of the simulated rib accelerations for USSID (fir100) and ES-2re (SAE180) in SINCAP load case.

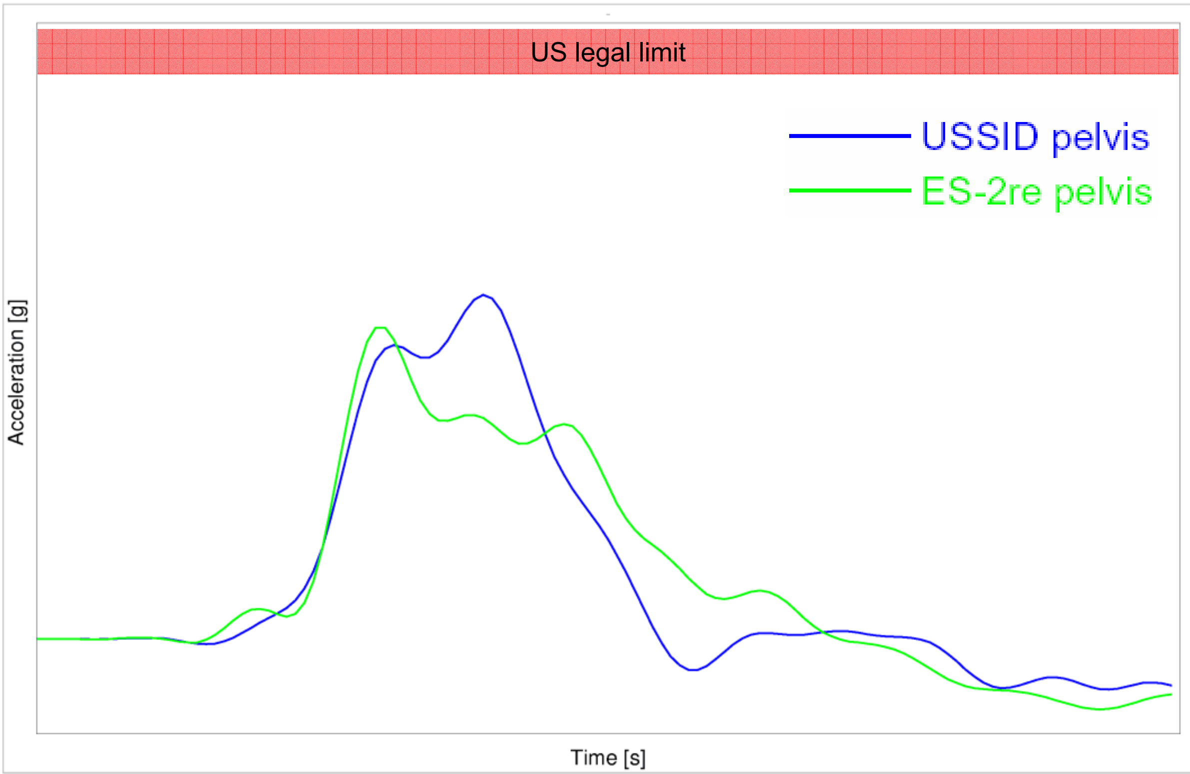

Figure 24 Comparison of the simulated pelvis accelerations for USSID (fir100) and ES-2re (SAE180) in SINCAP load case.

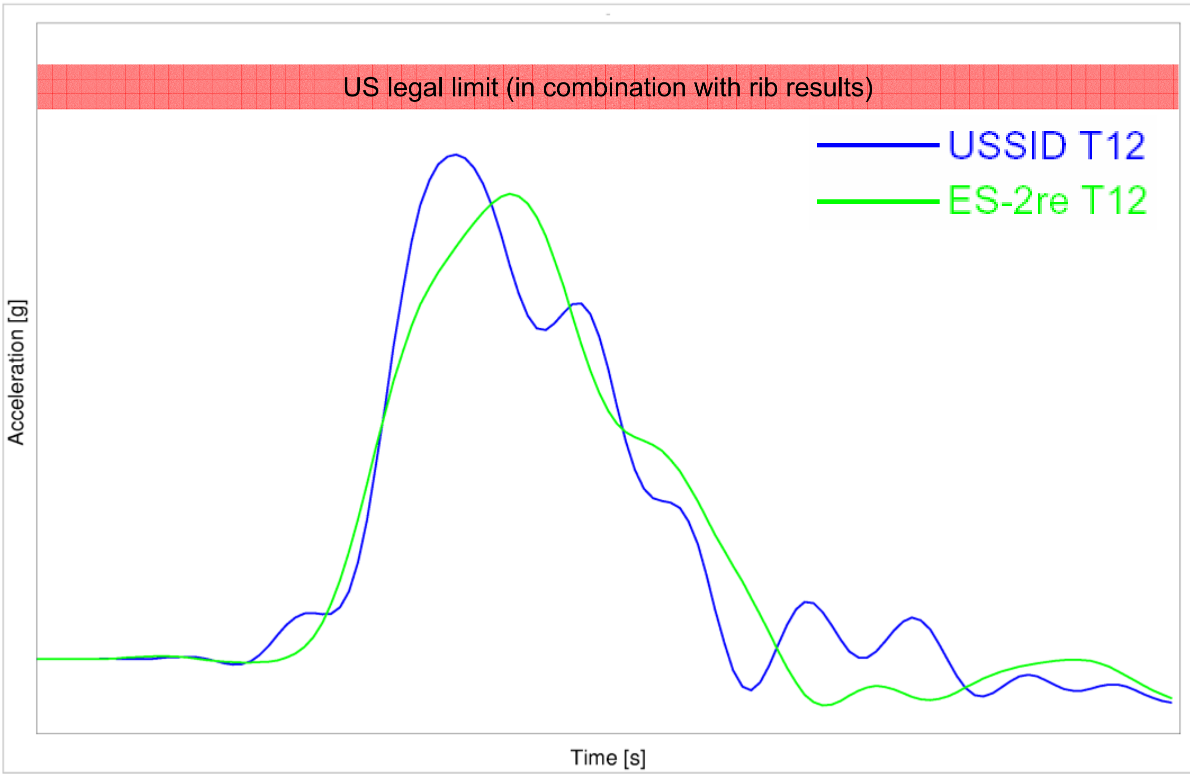

Figure 25 Comparison of the simulated T12 accelerations for USSID (fir100)and ES-2re (SAE180) in SINCAP load case.

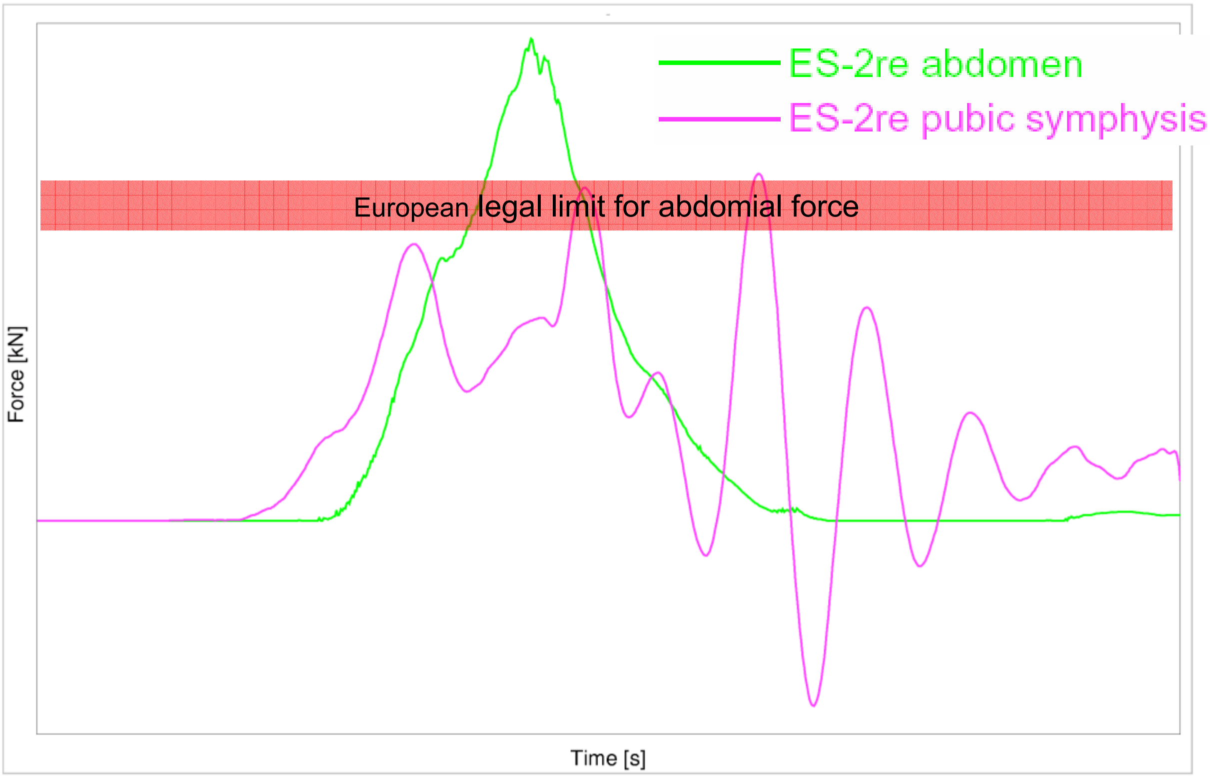

Figure 26 Abdominal and pubic force for the ES-2re in SINCAP load case.

5.1 Discussion of Vehicle Simulation

The geometrical differences between the torso and arm of the USSID and the ES-2re result in significant different airbag volumes during deployment of the airbag. Due to the different dummy designs the injury criteria can not be compared directly. For instance the rib accelerations of the ES-2 are likely to be much higher than the rib acceleration of the USSSID since the mass of the ribs differ significantly. Likewise, the rib intrusions of the ES-2re can not be compared with the rib intrusions of the USSID. The rib intrusion of the USSID is affected by the rotation of the thorax in regard to the spine. The ES-2re design does not allow this artificial rotation. Hence, it seems more reasonable to compare the signals with respect to the legal limits given in the different regulations. For the ES-2re the legal limits of the EUROSID-1 are chosen.

The considered load gives a more severe load for the ES-2re than for the USSID model. Furthermore, the higher instrumentation of the dummy allows more options to assess the safety of a vehicle. Although the acceleration of the lumbar spine at T12 is comparable for both dummy models a high abdominal force is observed in the ES-2re. This quantity can not be extracted from the USSID.

Hence, the FMVSS 214 regulation with an increased barrier speed of 62km/h leads to injury values of the ES-2re that exceed several legal limits, if we apply the European assessment for the EUROSID-1. Contrarily, the USSID shows a decent load in respect to the SINCAP assessment. The fact that the airbag system is adapted to the USSID might also amplify that the crash seems to be less severe if it is measured by the USSID than with the ES-2re.

6 Conclusion

The ES-2re is likely to substitute the USSID in the moving deformable barrier side impact test in the FMVSS 214. Since the ES-2re provides much more opportunities for load measurements an increasing effort to build cars for FMVSS 214 is likely. The additional pole test in the new FMVSS is not considered in this paper.

Detailed finite element models of the ES-2, ES-2re and USSID are described. The models are an outcome of a development project between the German automotive industry and DYNAmore GmbH. The models are very detailed and show a good correlation with tests. In simple tests the ES-2re dummy model behaves very similar to the ES-2 dummy model, but with increasing complexity of the environment the differences occur.

The detailed and highly validated vehicle models from MAGNA STEYR Fahrzeugtechnik AG allowed investigating the different behavior of the dummy models. Modeling techniques regarding the seat turned out to be more important for the ES-2re than it is for other side impact models. The rib intrusion and the VC-criterion of the lower rib show a strong dependency on the seat geometry.

The fact that NHTSA will introduce a dummy that is similar to the ES-2 used in EURO-NCAP does not necessarily lead to a harmonization of side impact restraint systems since the load cases are still different. The ES-2re seems to be a more sensitive measurement device than the USSID; in particular local loads are measured more precisely. A comparison of the USSID and the ES-2re in a full vehicle simulation of a SINCAP load case illustrates the increased demands. The injury criteria for the USSID were in a mid range whereas the ribs of the ES-2re were highly loaded locally.

7 References

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