Data preparation for the Euro NCAP far-side ISO/TS 18571 rating calculation with tools from the DYNAmore Eco System

Alexander Schif, Venkata Krishna, Yupeng Huang, Sebastian Stahlschmidt

DYNAmore GmbH, an Ansys Company

1 Abstract

In 2024 the Euro NCAP Virtual Testing far-side protocol was introduced with a monitoring phase. The protocol defines all the requirements in precise detail. To obtain an assessment for the virtual testing, the OEM needs to pass two validation load cases. The assessment is conducted using ISO/TS 18571 ratings. Euro NCAP is responsible for the ISO/TS 18571 rating calculations. The OEM must provide the simulation and test data in a predefined ISO MME data format. If the ratings meet the defined criterion, the virtual testing assessment is deemed successful.
This paper presents a straightforward workflow for preparing ISO MME data, illustrated by a case study of a far-side test involving the open-source Toyota Yaris car and the DYNAmore WorldSID 50th dummy model in LS-DYNA. The DYNAmore Eco System tool DM.binout2isomme is used to create the required ISO MME files for sharing with Euro NCAP. Furthermore, the ISO/TS 18571 scores are calculated with a Python script with the same procedure as defined by Euro NCAP.

2 Introduction

All the requirements for the Euro NCAP far-side virtual testing simulations are precisely defined in the official protocol [1]. In Figure 1 the flow chart of the protocol is shown. This paper will focus on the data preparation of the simulation (blue). Additionally, a way to calculate the ISO/TS 18571 [2] ratings and injury criteria (green) is shown in chapter 5.

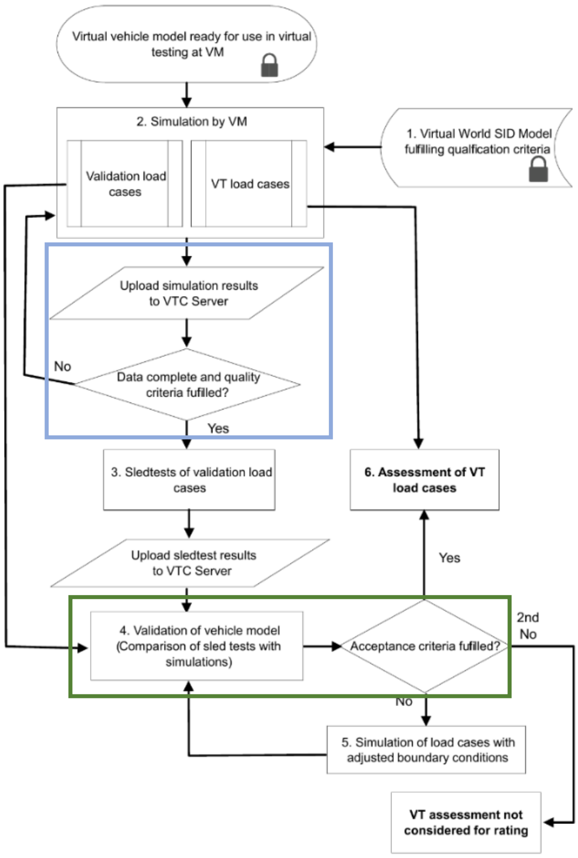

Figure 1: Flow chart of the Virtual Far Side Simulation & Assessment Protocol [1]

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For the data upload of the simulation and the test results Euro NCAP requires zipped ISO MME files. ISO MME files are a simple way to exchange multimedia data of impact tests between different laboratories. The format defines a directory structure with the exchange information available as ASCII files. The ISO MME format is described in ISO/TS 13499:2019. [3]
ISO MME files are usually already available for tests. For the simulations the ISO MME files need to be created out of the available binouts from LS-DYNA.

In the Euro NCAP virtual testing far-side protocol 115 required channel outputs are defined for the simulations. In Figure 2 the output channels are shown. They include coordinates, velocities, accelerations, forces, moments, displacements, energies and added mass.

Location	Parameter	Axis
Head CoG accelerometer	Global coordinates	x, y, z
	Angular velocities	x, y, z
	Velocities	x, y, z
	Accelerations	x, y, z
Upper neck loadcell	Forces	x, y, z
	Moments	x, y, z
Lower neck loadcell	Forces	x, y, z
	Moments	x, y, z
Spine – T4 accelerometer	Global coordinates	x, y, z
	Accelerations	x, y, z
	Velocities	x, y, z
Spine – T12 accelerometer	Global coordinates	x, y, z
	Accelerations	x, y, z
	Velocities	x, y, z
Lumbar spine loadcell	Forces	x, y, z
	Moments	x, y, z
Shoulder joint	Forces	x, y, z
Shoulder – rib facing centre console	lateral displacement	1D
Thorax - Upper rib facing centre console	lateral displacement	1D
Thorax - Mid rib facing centre console	lateral displacement	1D
Thorax - Lower rib facing centre console	lateral displacement	1D
Abdomen – Upper rib facing centre console	lateral displacement	1D
Abdomen – Lower rib facing centre console	lateral displacement	1D
Pelvis accelerometer	Global coordinates	x, y, z
	Velocities	x, y, z

Location	Parameter	Axis
	Accelerations	x, y, z
Pubic Symphysis Loadcell	Force	1D
B-Pillar (non-struck side)	Global coordinates	x, y, z
	Global velocities	x, y, z
	Accelerations	x, y, z
Lap Belt (B6)	Force	1D
Shoulder Belt (B3)	Force	1D
Contact Dummy – Centre Console	Force	x, y, z
Contact Dummy – Seat	Force	x, y, z
Contact Dummy – Seatbelt	Force	x, y, z
Contact Dummy – Airbag[6]	*Force*	*x, y, z*
Total Setup	Global Kinetic Energy	-
	Global Internal Energy	-
	Global Hourglass Energy	-
	Global External Work	-
	Total Energy	-
	Added Mass (absolute)	-
Dummy	Kinetic Energy	-
	Internal Energy	-
	Hourglass Energy	-
	Added Mass (absolute)	-
Driver Seat	Kinetic Energy	-
	Internal Energy	-
	Hourglass Energy	-
	Added Mass (absolute)	-
Sled[7]	Kinetic Energy	-
	Internal Energy	-
	Hourglass Energy	-
	Added Mass (absolute)	-
Centre Console	Kinetic Energy	-
	Internal Energy	-
	Hourglass Energy	-
	Added Mass (absolute)	
Airbag[6]	*Kinetic Energy*	-
	Internal Energy	-
	Hourglass Energy	-
Total number of requested channels:		115

Figure 2: Required output channels defined in the Euro NCAP virtual testing far-side protocol [1]

Additionally, the protocol defines which information needs to be available in the ISO MME headers. If any of the required channels are missing or if there is any difference to the defined standard format defined by Euro NCAP, the data will be declined by the server.

Building up the whole process from the initial sled test model with all the required outputs to the final data upload to the Euro NCAP server requires a lot of work. With a clearly defined procedure and some helpful tools, the required work can be reduced to only three required main steps as shown in Figure 3.

Figure 3: DYNAmore workflow to receive Euro NCAP ISO/TS 18571 ratings and injury criteria

First, the model needs to be set up with all the required output definitions available. Second, tools like DM.binout2isomme can be used to create ISO MME files out of the available binouts from LS-DYNA. Third, the ISO MME files can be uploaded to the Euro NCAP VTC server or a DYNAmore Python script can be used for a fast checking of all the ratings and criteria without uploading it to any server.

3 Showcase model

As a showcase model the open-source Toyota Yaris [4] model is used together with the DYNAmore WorldSID 50th far-side sled test model from the certification report [5].
These models are merged into a sled model and modified so that the showcase sled model has all the required outputs defined by Euro NCAP available in the binouts. Figure 4 illustrates the process of the model merging and how the final sled model looks like.

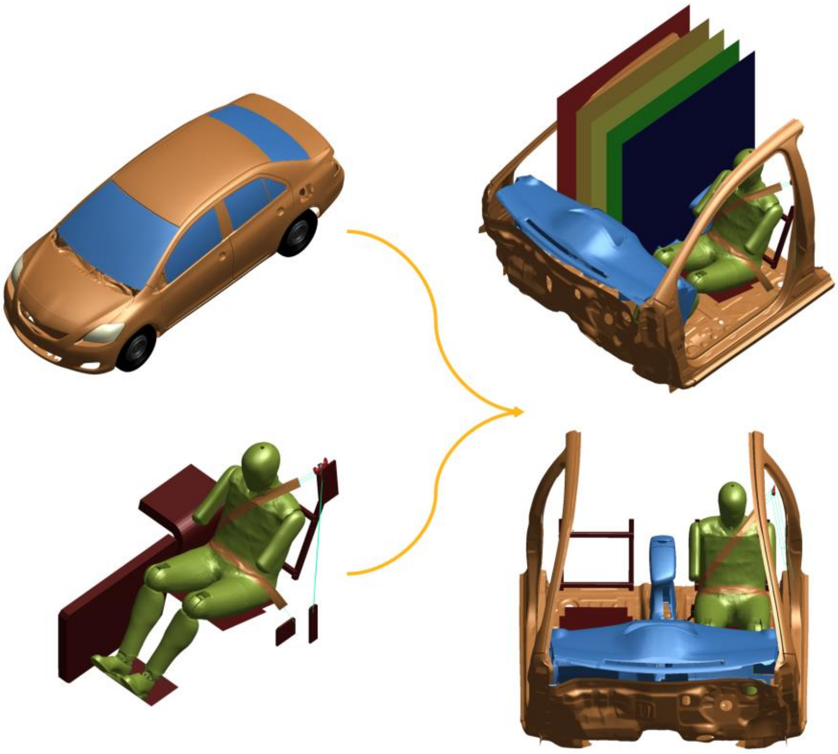

Figure 4: Showcase sled model (right) out of Toyota Yaris and DYNAmore WorldSID 50th far-side sled

The Toyota Yaris model is reduced to a simplified sled test model. Besides the reduced sled geometry, the instrumentation panel and the center console from the Toyota Yaris model are used. All these parts are defined as rigid bodies. To connect the center console to the sled, a tied contact is defined.
From the DYNAmore WorldSID 50th far-side sled test model the center console is removed. Dummy, rigid seat and belt system are then merged into the previously reduced Toyota Yaris sled test model. As the passenger seat a copy of the rigid driver seat is used. The seats are connected to the sled by discrete beams.
To mark the head excursion lines, several planes are defined as described in the Euro NCAP far-side occupant test and assessment protocol. These planes can be used to visualize and calculate the intrusion of the dummy head into the defined zones of the protocol. [6] One node of each plane will be added to the history nodes as backup for later calculations.

67 out of the required 115 outputs are already defined in the DYNAmore WorldSID 50th dummy model. Outputs for belt forces, b-pillar and contact forces can be defined with *DATABASE_CROSS_SECTION, *DATABASE_HISTORY_NODE and *CONTACT_FORCE_TRANSDUCER_PENALTY (23 outputs).
With *DATABASE_GLSTAT the total setup energy outputs are tracked (6 outputs). For the energies and added masses of the subsystems of dummy, driver seat, sled, center console and airbag *DATABASE_EXTENT_SSSTAT_MASS_PROPERTIES is used (19 outputs).
The output frequency for all outputs is defined as 10 kHz.

In Figure 5 the simulation state of the maximum head excursion of the run is shown. The dummy head crossed the 3rd plane from the right. The 3rd plane is the yellow plane, meaning the head is inside the orange zone.

After running the simulation the binout files with all the outputs are available for further processing. For the showcase, the test results were created with the simulation model by simply scaling the used pulse by a factor of 1.1.

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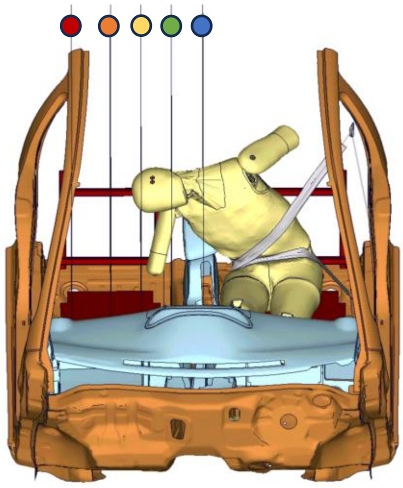

Figure 5: Showcase sled model maximum head excursion

4 DM.binout2isomme for ISO MME file creation

The DYNAmore tool DM.binout2isomme is a no GUI post-processing tool available for many years. With the tool it is possible to create ISO MME files (ISO/TS 13499) [3] out of LS-DYNA binout files. To control the tool a config file is read including all the user requested outputs to be extracted out of the binout files. The tool runs in batch mode, has cluster support and is available for Linux and Windows.
Besides standard extraction of the results from the binouts it is also possible to scale, offset, differentiate, integrate, change unit system or CFC filter the results. Additionally, there is an option to directly calculate channels out of previously extracted channels by mathematical expressions.

Figure 6 shows a basic example config file. The unit system of the binout files used for this example is kg-mm-ms. Euro NCAP requires SI unit system kg-m-s. All output will be transferred to the required unit system with DM.binout2isomme. Keeping the unit system in kg-mm-ms would also work for uploading the results to the Euro NCAP server. The server will automatically transfer the results into SI unit system kg-m-s.

```
*SCALES
$   name,     unit,    scaling value
    time,        s,            0.001

*NODOUT
$ ID or name,  LS-DYNA component,  scale factor,  target unit,          ISO-CODE,          description,  offset,  derivation
      10001,      x_acceleration,        1000.0,     m/(s*s),  11HEAD0000WSACX0,  head x-acceleration,     0.0,           0
      10001,          y_velocity,           1.0,     m/(s*s),  11HEAD0000WSACYA,  head y-acceleration,     0.0,           1
      10001,      z_displacement,         0.001,     m/(s*s),  11HEAD0000WSACZB,  head z-acceleration,     0.0,           2
```

Figure 6: DM.binout2isomme config file example

Usually the first definition of the config file is the *SCALES keyword. With this keyword the time unit and time scaling are defined. In the example the original time of the simulation is scaled from milliseconds to seconds by a scaling of 0.001. The time scaling is the same for all channel outputs.

The *NODOUT keyword defines the start of node extractions. Each line after the *NODOUT keyword starting with either a node ID or a node name defines one channel output for the ISO MME extraction. In the example the node ID 10001 is extracted three times.

In the first extraction the *x_acceleration* component of node 10001 of the LS-DYNA binout is extracted. It will be scaled with factor 1000.0 from mm/ms^2 to m/s^2. The ISO-CODE is 11HEAD0000WSACX0. The last character of the ISO-CODE defines the CFC filter to be applied. Here no filtering (0) is applied. The description of the channel is defined as *head x-acceleration*. There is no offset or derivation to be considered for this channel.

For the second channel *y_velocity* is extracted from the LS-DYNA binout. The scaling factor from mm/ms to m/s is 1.0. The target unit is defined as m/s^2, this is because the derivation value is defined as 1, meaning the derivative of the y_velocity (m/s) will be taken, resulting in the *head y-acceleration* (m/s^2). The ISO-CODE ends with an “A”, thus a CFC1000 filter will be applied.

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For the third channel the z_displacement is evaluated and converted into the head z-acceleration with the 2nd derivative. The channel will be filtered with CFC600 (B). Additional available filters are CFC180 (C) and CFC60 (D).

For most of the required channel outputs the config file definitions are very straightforward. DM.binout2isomme offers help options to look up which keywords are available and which LS-DYNA components can be extracted.
To be compliant with the Euro NCAP requirements, no filtering should be applied to the channels to be uploaded to Euro NCAP. The units should be defined without any special characters (use m/(s*s), not m/s^2).
A full list of all outputs is not shown in this paper, only for some special outputs the config file definitions are shown. The full config file can be requested from DYNAmore.

The Protocol requires lateral rib displacements calculated with the formula of the Technical Bulletin TB 021. [7] For the calculation of the corrected rib displacements the filtered sensor length (DC) and the filtered sensor rotation (ANZ) are required. In the DYNAmore WorldSID 50th dummy model these outputs can be extracted from available joints. In Figure 7 the required config definitions for the extraction of these outputs with DM.binout2isomme is shown.

```
*JNTFORC_TYPE0
$ ID or name,    LS-DYNA component,  scale factor,  target unit,          ISO-CODE,          description,  offset,  derivation
        1057,          theta_degrees,        0.001,            m,  11SHRIRI00WSDC0C,  Shoulder IR-TRAC DC,     0.0,           0
*JNTFORC_TYPE1
$ ID or name,    LS-DYNA component,  scale factor,  target unit,          ISO-CODE,          description,  offset,  derivation
        1063,           beta_degrees,          1.0,       degree,  11SHRIRI00WSANZC,  Shoulder IR-TRAC ANZ,    0.0,           0
*EXPRESSION
channels = {
"11SHRIRI00WSDC0C" : "x",
"11SHRIRI00WSANZC" : "y",
}
card.isocode = "11SHRIRI00WSDS00"
card.unit = "m„
card.scale = 1.0
card.description = "shoulder rib lateral displacement"
card.expr = " (x-x[0])*cos(y/57.2958) "
```

Figure 7: DM.binout2isomme config file JNTFORC and EXPRESSION

Two channels are extracted with JNTFORC keywords and are directly filtered with CFC 180 according to TB 021. The required lateral rib displacement (DS) is calculated with the expression from the TB 021 using the previously extracted and filtered channels.
Cosine instead of sine is taken, because the simulation dummy model comes with an initial ANZ angle of 0 degrees and not 90 degrees as assumed in the TB 021 formula.

For the ISO MME headers Euro NCAP requires several information about the simulation to be available. These information can be directly added by DM.binout2isomme with definitions in the config file. With the keyword *MME_INFO inputs for the ISO MME header can be given as shown in Figure 8.

DM.binout2isomme will write these entries into the ISO MME main header. The required information can be taken from the protocol, dummy manual and d3hsp. The masses and distances can be determined with any pre-processor. If the materials are fully encrypted, the masses of the subsystems have to be manually added after running DM.binout2isomme by checking the total mass channel files.

After running DM.binout2isomme the received ISO MME files should be ready to upload to the Euro NCAP servers. DM.binout2isomme also offers an option to directly create a zip archive for the ISO MME data. The Euro NCAP server will only accept zipped ISO MME files.
For an easier rating and injury criteria calculation tools like the DYNAmore tool described in chapter 5 can be used from within the shell without uploading any data. This is helpful especially during the car development process.

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```
*MME_INFO
Customer name                                          :Euro NCAP
Customer test ref. number                              :1234
Customer project ref. number                           :1234
Type of the test                                       :Side Impact
Subtype of the test                                    :Pole 75 degree
Virtual Testing reference ID                           :FS_Pole_75_x-ref_z-ref_50M_Sim_1
Regulation                                             :VIRTUAL FAR SIDE SIMULATION AND ASSESSMENT PROTOCOL – Version 1.0
Date of the test                                       :2024-08-30
Name of test object 1                                  :Showcase Yaris Sled
Ref. Number of test object 1                           :NOVALUE
Velocity test object 1 lon.                            :NOVALUE
Velocity test object 1 lat.                            :NOVALUE
Driver position object 1                               :1
Impact side test object 1                              :RI
Type of data source                                    :Simulation
Dummy Simulation Model Specification                   :WorldSID 50M version 8.1 DYNAmore
Reference to Dummy Model Qualification Documentation:Wsid50_pdb_v8.1_manual_VTC_Validation_Report.pdf
Solver Name                                            :LS-DYNA
Solver Version                                         :mpp s R12.2-180
Solver Precision                                       :SP
Platform Name                                          :Platform MPI 8.1.2 x86-64
Number of CPUs                                         :48
Time step setting                                      :5.0E-7
Contact Type between dummy and seat                    :S2S SOFT2 nu=0.2
Contact Type between dummy and seatbelt                :S2S SOFT2 nu=0.2
Number of contacts used in the overall simulation setup :32
Number of elements                                     :930123
Mass of total setup                                    :205.88
Mass of dummy in kg                                    :73.97
Mass of seat in kg                                     :5.54
Mass of sled in kg                                     :106.20
Mass of centre console in kg                           :16.82
Distance between head CoG and green line               :0.510
Distance between head CoG and yellow line              :0.635
Distance between head CoG and orange line              :0.760
Distance between head CoG and red line                 :0.920
```

Figure 8: DM.binout2isomme config file MME_INFO

5 DYNAmore Euro NCAP ISO/TS 18571 and injury criteria script

The DYNAmore Euro NCAP ISO/TS 18571 and injury criteria script is currently under development and may be available soon. The script provides ISO/TS 18571 and injury criteria evaluation according to Euro NCAP. It requires the ISO MME files of test and simulation as input. The ISO MME channels required are the same as defined in the Euro NCAP virtual testing far-side protocol.
The script will run within the shell and has only two required arguments as an input. The arguments are the test and simulation ISO MME file paths. As result a short overview will be shown in the shell and all results will be available in a written Excel file.

To make sure that the ratings and injury criteria are the same as if uploaded to the official Euro NCAP server, the preparation of the data and used methods are very important. Therefor the DYNAmore script uses some of the Python packages also used by Euro NCAP like *Objective Rating Metric ISO 18571* [8] and *Head Trajectory Calculation* [9].

With the correctly defined input the script creates an Excel file with all the ISO/TS 18571 ratings and injury criteria. In the Excel file all the simulation and test curves and their values for the ISO/TS 18571 ratings are shown with the ratings, sub ratings and weightings for each curve. Additionally, the head excursion curves for simulation and test are available. This makes it very easy to check the results without having to upload the data to the Euro NCAP server. By following the same procedure as Euro NCAP, the results are the same.

In Figure 9 the overview page of the showcase evaluation is depicted. On the upper left the validation criteria 1 and 2 are shown with the injury criteria values. On the bottom left the head excursion curves with the distances to the different planes are visible. On the right side the overview of all ISO/TS 18571 ratings for all channels are shown with their weights. On the bottom (blue) all the detailed pages for the channels curves and sub ratings can be found.

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Figure 9: Overview page from the DYNAmore script evaluation

For the showcase model the ISO/TS 18571 ratings and injury criteria are shown in Figure 10. The ratings are very good, because the only difference between simulation and test data of the showcase is a different scaling of the pulse. Since no rating is below 0.5, the 1st validation criterion is passed.

	channel	rating	weight
HEAD_ANGULAR_VELOCITY	**HEAD0000WSAVX*	0.926	0.664
0.916	**HEAD0000WSAVY*	0.913	0.228
	**HEAD0000WSAVZ*	0.861	0.108
T4_ACCELERATION	**THSP0400WSACX*	0.825	0.171
0.825	**THSP0400WSACY*	0.832	0.646
	**THSP0400WSACZ*	0.8	0.183
T12_ACCELERATION	**THSP1200WSACX*	0.839	0.261
0.829	**THSP1200WSACY*	0.826	0.565
	**THSP1200WSACZ*	0.826	0.174
PELVIS_ACCELERATION	**PELV0000**ACX*	0.795	0.329
0.801	**PELV0000**ACY*	0.827	0.510
	PELV0000ACZ*	0.733	0.161
B-PILLAR_ACCELERATION	**BPILLO0000ACX*	0.975	0.211
0.975	**BPILLO0000ACY*	0.975	0.788
	**BPILLO0000ACZ*	1.0	0.001
B3_FORCE	**SEBE0003B3FO0*	0.949	1.0
0.949			

monitoring_rating	0.883
tend	0.1738 s
zone	orange

HEAD	sim values	test values
Maximum_Head_Displ [mm]	576.0	586.0
HIC15 [-]	68.3	122.55
a3ms [g]	32.08	42.95
NECK		
Upper_Fz [kN]	1.29	1.7
Upper_MxOC [Nm]	37.04	41.64
Upper_MyOC [Nm]	25.01	33.52
Lower_Fz [kN]	1.35	1.8
Lower_MxOC [Nm]	123.87	139.83
Lower_MyOC [Nm]	42.76	41.45
CHEST_ABDOMEN		
Upper_Thorax_Disp [mm]	2.78	3.13
Mid_Thorax_Disp [mm]	9.17	13.57
Lower_Thorax_Disp [mm]	13.27	15.01
Upper_Abdomen_Disp [mm]	52.16	53.62
Lower_Abdomen_Disp [mm]	38.88	46.66
PELVIS_LUMBAR		
Pubic_Fy [kN]	0.4	0.53
Lumbar_Fy [kN]	0.61	0.66
Lumbar_Fz [kN]	2.58	2.91
Lumbar_Mx [Nm]	35.8	35.58

Figure 10: ISO/TS 18571 ratings (left) and injury criteria (right) of showcase model

The 2nd validation criterion is also fulfilled. Some of the ratios between test values and defined limit values of the protocol exceed 50 percent. This triggers an additional checking of the difference between the ratios of simulation and test. If the absolute value of any of these differences exceeds 0.3 (d_{AC}), the validation criteria 2 would fail. For the showcase the maximum d_{AC} value is 0.17.

The calculated maximum dummy head excursion crosses the yellow line, resulting in the orange zone. The related evaluation interval end time is 173.8 milliseconds. The script is calculating the distances to the planes by reading the user given initial distances of the planes to the dummy center of gravity out of the ISO MME header. If the distances are not given, the script will calculate the distances out of the given history nodes of the planes defined earlier.

6 Summary and Outlook

With a clean model buildup and the usage of DM.binout2isomme it is quite easy to create the required ISO MME files ready to upload to the Euro NCAP server for the ISO/TS 18571 rating and injury criteria calculations. Only three main steps are necessary: proper model build up with all outputs defined, creation of the ISO MME files with DM.binout2isomme and finally the evaluation by uploading the ISO MME files to the Euro NCAP server or using the DYNAmore script from chapter 5. After the first build up, most of the process can easily be adapted to similar models.

With the DYNAmore tool for ISO/TS 18571 and injury criteria calculation an alternative way, as uploading the data to the Euro NCAP VTC, may be available soon. This can be helpful especially during the car development process.

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7 Literature

[1] Euro NCAP VTC Group: “VIRTUAL FAR SIDE SIMULATION & ASSESSMENT PROTOCOL”, Version 1.0, 2023

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