2010 Toyota Yaris Finite Element Model Validation
The original Finite Element model was developed under a contract with the Federal Highway Administration through the process of reverse engineering. The work was done by the National Crash Analysis Center of the George Washington University and later at Center for Collision Safety and Analysis at George Mason University.
2010 TOYOTA YARIS PASSENGER SEDAN MODEL

The original Finite Element model was developed in LS-Dyna format. The model and details about its development can be found here, [https://www.ccsa.gmu.edu/models/2010-toyota-yaris/](https://www.ccsa.gmu.edu/models/2010-toyota-yaris/).

Version 2j of the model was converted to Radioss using Altair HyperCrash with a few minor changes to property and contact options.

<table>
<thead>
<tr>
<th>Unit: Ton-mm-s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of nodes</td>
</tr>
<tr>
<td>Number of elements</td>
</tr>
<tr>
<td>Number of parts</td>
</tr>
</tbody>
</table>
2010 TOYOTA YARIS PASSENGER SEDAN MODEL

In general, Radioss best practices are used for property, material, and contact settings.

Note that due to the translation from LS-Dyna to Radioss, not all details of the model would be considered best practice if the model was created for Radioss from the beginning.

For example, the model contains a shell skin elements on many solid elements. These elements are needed in LS-Dyna for contact. In Radioss, the contact works without these extra shell skin elements. However they are left in model to have the correct model mass.
2010 TOYOTA YARIS PASSENGER SEDAN MODEL

Connections

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Spot-weld</td>
<td>816</td>
</tr>
<tr>
<td>Number of Rigid body</td>
<td>3994</td>
</tr>
</tbody>
</table>
2010 TOYOTA YARIS PASSENGER SEDAN MODEL

Accelerometers

5000001, Left Rear Seat
5000002, Right Rear Seat
5000003, Vehicle C.G.
5000004, Engine Top
5000004, Engine Bottom
# 2010 TOYOTA YARIS PASSENGER SEDAN MODEL

## Weight and CG Comparisons

<table>
<thead>
<tr>
<th></th>
<th>Actual Vehicle (in test 5677)</th>
<th>FE Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight [kg]</td>
<td>1277</td>
<td>1252</td>
</tr>
<tr>
<td>Vehicle CG X [mm] (aft of front axle)</td>
<td>1046</td>
<td>1068</td>
</tr>
<tr>
<td>Vehicle CG Y [mm]</td>
<td>-8.3</td>
<td>-4.0</td>
</tr>
<tr>
<td>Vehicle CG Z [mm]</td>
<td>558</td>
<td>546</td>
</tr>
</tbody>
</table>
Finite Element Modelling

• The CAD geometry of the Model is imported into HyperMesh

• Any continuous object/geometry has infinite degrees of freedom and it’s just not possible to solve the problem in this format

• Finite Element Method reduces the degrees of freedom from infinite to finite with the help of discretization or meshing (nodes and elements)

• The meshing is done by following certain quality criteria’s

• The necessary connections like spot weld, bolts, adhesives, springs etc are defined during meshing
Material Definition

- All the meshed components of the model are assigned with suitable materials.
- Choosing the right material and providing the reliable material data in performing a simulation is very important.
- RADIOSS provides one of the most comprehensive material and rupture libraries in the industry. The material laws and rupture criteria span across definitions for concrete, foam, rubber, steel, composites, biomaterials, and more.
Property Definition

- The components are then assigned with the properties.
- Property entities are used to define and store 1D, 2D, and 3D property definitions for a model.
- Properties are created, edited, deleted, and shown under the Property folder within the Model browser.
- RADIOSS (Block Format) has many properties and most of them are supported. In addition RADIOSS allows you to program your own properties (mostly for springs) that can be used in a simulation.
Material curves

- Material curves are created and assigned with the suitable material
- Normally it will be a Stress-Strain curve
- The relationship between the stress and strain that a particular material displays is known as that particular material's stress–strain curve
- It is unique for each material and is found by recording the amount of deformation (strain) at distinct intervals of tensile or compressive loading (stress)
- These curves reveal many of the properties of a material
Creating Rigid Walls

- Rigid walls required for the simulation are defined under the groups category.

- A rigid wall is a non-yielding retaining wall which is defined by the user defined ground Node and a group of Slave Nodes.

- Rigid Walls allows the user an easy way to define an interface between a rigid surface and nodes of a deformable body.
Creating Contacts

- Contact definition is an important part of many complex nonlinear problems.

- Based on the applications RADIOSS has a large number of contact types. In RADIOSS an interface is created by defining the master segment and slave set.

- Once these master slave sets are identified the algorithm will check these locations for potential penetration of a slave node through a master segment, and this check is done in every time step.
Creating load definitions

- Loading conditions are defined in the model under different load collectors

- Gravity - It defines an acceleration on a group of nodes. The gravity versus time is defined by a function /FUNCT

- Initial Velocity about an Axis - Initial Velocity about an Axis initializes translational and/or rotational velocities on a group of nodes in a given coordinate system

- A local frame can be used if the rotation is not around a global axis
creating accelerometers

- describes the sensors which are used to activate or deactivated an object according to the defined characteristics

- sensors can be used to activate airbags, imposed forces, pressures, and fixed velocities

- the sensors shown in screenshot are actually accelerometers. in 2019, they have there own entity in hm.
TOYOTA YARIS PASSENGER SEDAN: PRE-PROCESSING

Creating output requests

- The output requests are defined using various control cards/engine keywords

- Animation output control cards generates animation files containing results according to the keywords specified

- The request is defined in the engine file. Output is written to runnameA01, runnameA02…runnameAnn file at a frequency of Tfreq defined by the user

- The time history contains the results of the analysis at sequential output intervals for a subset of elements, groups, parts, materials..etc

NOTE: In the model, used the new native /H3D output instead of /ANIM. Right now /H3D cannot be defined in HM. The /ANIM output is in the engine but commented out.
Model Warnings / Issues

Intersections from original LS-Dyna model were not removed. (Ideally the model should not have intersections)

Initial penetrations caused by discretization

Both Issues handled by /INTER/TYP7 contact options Fpenmax=0.8, Inacti=6
Model Warnings / Issues

--- ELEMENT INITIALIZATION 8 WARNING(S) |
|--- 1 WARNING ID : 325 |
| ** WARNING : BAD SPRING FRAME DEFINITION (NULL LE |
|--- 7 WARNING ID : 432 |
| ** WARNING IN SPRING ELEMENT SEEMS TO BE MASS AND LENGTH INCONSISTENT |
| ( REFERENCE INERTIA = MASS*LENGTH^2 ) |

Both Warnings can be ignored
Model Warnings / Issues

--- KINEMATIC CONDITIONS

| 3 WARNING(S) |
|--- 1 WARNING ID : 312 |
| ** INCOMPATIBLE KINEMATIC CONDITIONS IN MODEL |
|--- 2 WARNING ID : 446 |
| ** WARNING IN RIGID WALL |

Both Warnings can be ignored.

Rigid wall slave nodes in other kinematic conditions are automatically removed from the rigid wall.
TEST DATA

NHTSA test number 5677 – vehicle: 2007 Toyota Yaris Sedan
US-NCAP Full frontal impact @ 56 km/h

Test results and data available at
TOYOTA YARIS NCAP 56.3 KM/H

Deformation at 70 ms
TOYOTA YARIS NCAP 56.3 KM/H

Mass scaling was used to impose a constant time step of 1e-6.
Total mass added = 0.88%
TOYOTA YARIS NCAP 56.3 KM/H
TOYOTA YARIS NCAP 56.3 KM/H

Right Rear Seat Acceleration SAE60
TOYOTA YARIS NCAP 56.3 KM/H

Engine Top Acceleration SAE60

- Test 5677 SAE60
- Radioss - 5000004 Engine top TYPE7

Accelration x-axis (g)

Time (s)
TOYOTA YARIS NCAP 56.3 KM/H
TOYOTA YARIS NCAP 56.3 KM/H

Left Rear Seat Velocity

- Test 56??
- Radisson TYPE?
TOYOTA YARIS NCAP 56.3 KM/H

Right Rear Seat Velocity

- Test 56??
- Radioss TYPE?
Wall Force SAE60

- Test 5077 SAE60
- Rigidless Wall TYPE7

TOYOTA YARIS NCAP 56.3 KM/H
TOYOTA YARIS NCAP 56.3 KM/H

Force Displacement SAE60

- Test 5877 SAE60
- Radioss TYPE7

Displacement (mm) vs. Force (kN) graph.
Deviation between test curves and CAE results for engine accelerations & wall force can be due to the difference between real & FE motor block. The original model had similar differences in the results when compared to test.
SUMMARY

The Altair Radioss simulation of the 2010 Toyota Yaris in a US-NCAP Full frontal impact @ 56 km/h was verified against NHTSA test number 5677.

The results from the Altair Radioss simulation show good correlation to the test results.