Development of a special version of the FAT ES-2/ES-2re for rapid prototyping

Rapid Analysis Model (RAM)

Reuben D'Souza

Sebastian Stahlschmidt , Yupeng Huang

DYNAmore GmbH, Germany

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- Overview of the ES-2_v5.0 model
- Comparison to previous releases / Motivation for development of the '**R**apid **A**nalysis **M**odel' (RAM)
- EuroSID 2 Version 5.0 '**R**apid **A**nalysis **M**odel' (RAM)
- CORA (**COR**relation and **A**nalysis)
- Comparison of Results
- Conclusion

ES-2 Release v5.0

- Released in Spring 2011.
- Initiated by the PDB
  (Partnership for Dummy Technology and Biomechanics)
  in 2009.
- The model has been improved in nearly all body regions like:
  - Shoulder
  - Abdomen
  - Lumbar spine
- New material tests have led to new material data being used
- New component and sled tests were carried out.
- Geometry of internal parts has been captured accurately.

Model comparison for ES-2

	ES-2_v4.5	ES-2_v5.0
Discrete	**15**	**16**
Beams	**335**	**486**
Shells	**87850**	**142608**
Solids	**174163**	**194438**
TOTAL	**262363**	**337548**

Model comparison for ES-2

	ES-2_v4.5	ES-2_v5.0
Tetrahedron	**136462**	**147292**
Hexahedron	**37701**	**47146**

*MAT_SIMPLIFIED_RUBBER (*MAT 181) and *MAT_SIMPLIFIED_RUBBER_WITH_DAMAGE (*MAT 183) are computationally expensive materials.

Following are the number of parts using the above 2 materials in the various versions of the ES-2 model:

ES2_v4.5 : **15**

ES2_v5.0 : **43**

Comparison of simulation times in PDB Barrier tests:

LS-DYNA Version : mpp971_s_R5.1.1-69996_Intel_linux86-64_hpmpi

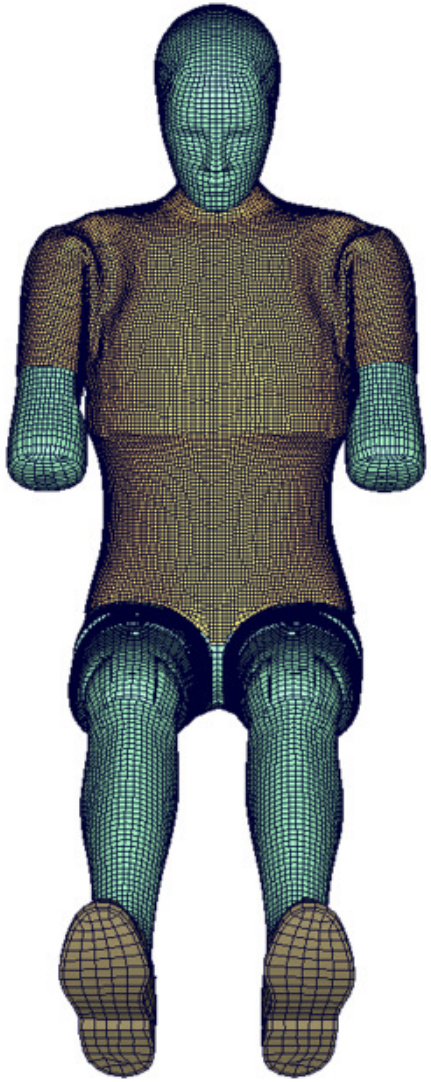
Number of processors : 8

Simulation run time : 101ms

	ES-2_v4.5	ES-2_v5.0
Barrier D1	**4h 37m**	**8h 05m**
Barrier D3	**4h 34m**	**7h 32m**
Barrier D4	**4h 29m**	**8h 05m**

ES-2 Release v5.0 'Rapid Analysis Model' (RAM)

- Model remains unchanged in geometry. Only material definitions have been changed
- The accurate material models of the version v5.0 like MAT_181 and MAT_183 are replace by simple and quicker material models.
- The materials have been validated only by using the component, pendulum and sled tests
- All other definitions are exactly the same as in the original ES-2 v5.0 model
- Shall be released by end of 2012.



- Component tests, certification tests and sled tests carried out for the '**R**apid **A**nalysis **M**odel' (RAM)
- Results of the various tests compared for the following versions:

  ES2_v5.0

  ES2_v5.0 '<u>R</u>apid <u>A</u>nalysis <u>M</u>odel' (RAM)
- Results were evaluated by means of CORA (CORrelation and Analysis) developed by PDB (Partnership for Dummy Technology and Biomechanics)

CORA (CORrelation and Analysis)

- Provides an objective evaluation of signals
- Combines 2 independent sub-methods:
  - Corridor rating (Evaluates the fitting of a response curve into user-defined or automatically calculated corridors)
  - Cross-correlation rating (Evaluates phase shift, shape and area below curves)
- Possible to tune the evaluation to the specific needs of the application.

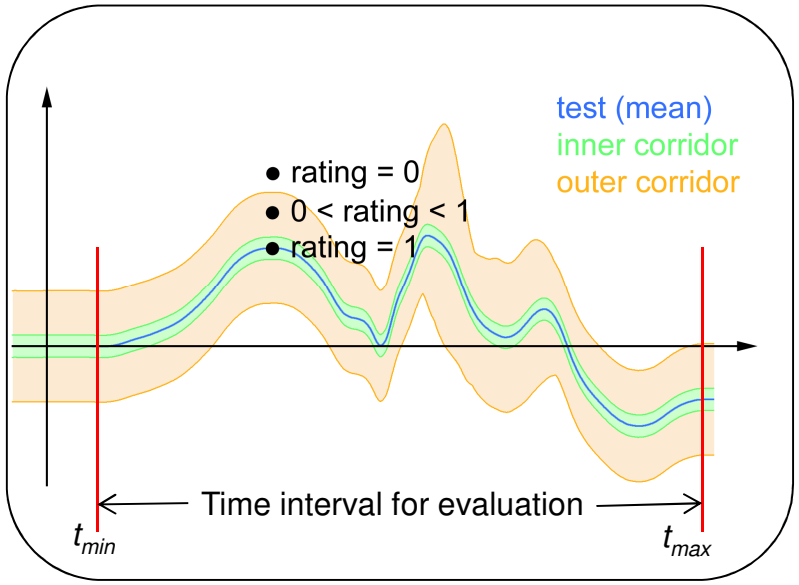
CORA : Corridor method

- An evaluation interval needs to be specified
- Inner and outer corridors are defined around the reference curve (eg. from physical test).
- The simulation curve is evaluated with the help of these corridors. The following cases exist for the rating of a given curve:

  (a) Curve lies outside outer corridor – Rating is 0

  (b) Curve lies inside inner corridor – Rating is 1

  (c) Curve lies between the 2 corridors – Rating lies between 1 and 0 (an interpolation is performed).



Courtesy CORA Manual

CORA : Cross-correlation method

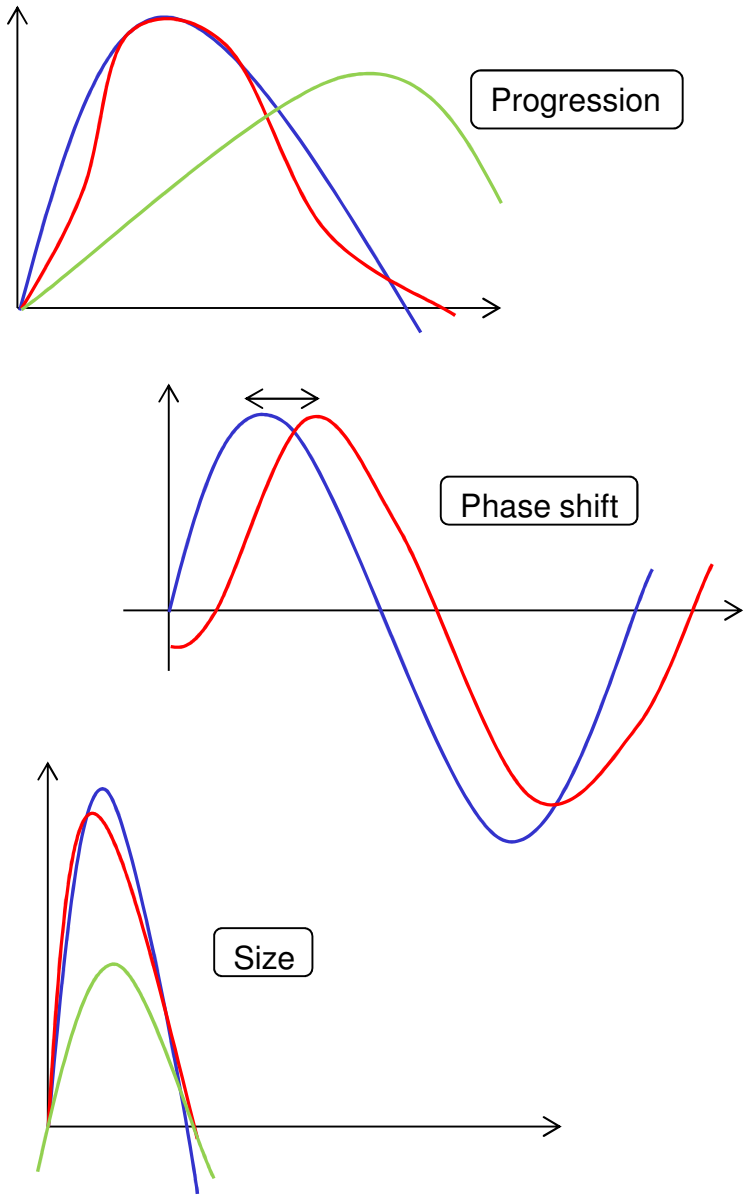
- Method rates the following 3 curve characteristics:

  (1) Progression (V)

  (2) Phase shift (P)

  (3) Size (G)

- An evaluation interval needs to be specified
- A curve is assigned a rating between 0 and 1 depending on how well it correlates to the reference signal in regard with the 3 characteristics mentioned above.
- Weighted sum of V,P and G gives us the cross-correlation rating for a curve.



Certification Test Results:

	ES2_v5.0 'RAM'	ES2_v5.0
Shoulder	0.693	0.852
Thorax	0.906	0.911
Rib	--------	0.806
Abdomen	0.729	0.774
Lumbar spine	0.380	0.568
Pelvis	0.709	0.785
Head drop	0.815	0.899
Neck	0.581	0.638

Component Test Results:

	ES2_v5.0 'RAM'	ES2_v5.0
Clavicle	0.705	0.750
Clavicle Box	0.577	0.634
Rib	--------	0.855
Abdomen	0.797	0.776
Abdomen Slab	0.612	0.619
Lumbar spine	0.542	0.731
Arm	0.558	0.728
Femur	0.701	0.774
Iliac Wings	0.388	0.563

➢ Sled Test Results:

Green > White > Blue

- PDB Sled Tests

	ES2_v4.5	ES2_v5.0 'RAM'	ES2_v5.0
$D1_P$ barrier	0.522	0.504	0.617
$D3_P$ barrier	0.609	0.492	0.724
$D4_P$ barrier	0.564	0.527	0.657

- FAT Sled Tests

	ES2_v4.5	ES2_v5.0 'RAM'	ES2_v5.0
PDB tests	0.565	0.508	0.666
FAT tests	0.556	0.565	0.668

	ES2_v4.5	ES2_v5.0 'RAM'	ES2_v5.0
$D1_F$ barrier, v1	0.607	0.620	0.775
$D1_F$ barrier, v2	0.511	0.507	0.587
$D3_F$ barrier, v1	0.573	0.548	0.695
$D3_F$ barrier, v2	0.647	0.580	0.697
$D4_F$ barrier	0.529	0.646	0.667
$D5_F$ barrier	0.535	0.524	0.657
$D6_F$ barrier, v1	0.594	0.610	0.640
$D6_F$ barrier, v2	0.775	0.704	0.794
$D7_F$ barrier	0.419	0.434	0.497

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	ES-2_v4.5	ES-2_v5.0	ES-2_v5.0 ‚RAM'
Barrier D1	**4h 37m**	**8h 05m**	**3h 22**
Barrier D3	**4h 34m**	**7h 32m**	**3h 08m**
Barrier D4	**4h 29m**	**8h 05m**	**3h 20m**

Conclusion:

- ES-2 v5.0 ‘RAM’ model is about 60% faster than the accurate model in the sled tests.
- In a full-car environment, difference in simulation time would be minimal.
- CORA results show that the loss in accuracy is only very small.

Thank you!