Automation of Coach Rollover Simulation

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Abstract

Through the use of HyperMesh and Process Manager, Plaxton has successfully implemented a methodology to automate the process of setting up and pre-conditioning a vehicle FEA model in order to simulate a vehicle rollover in RADIOSS to demonstrate compliance of the structure to the requirements of UN ECE R66.

UN ECE R66 is an international rollover protection standard for coaches. The R66 standard prescribes a clearly defined set of parameters and procedures for setting up a physical rollover test and the FEA model build up for simulation of the R66 test mimics those physical test requirements. As such, a number of tasks must be performed during model set up that can be somewhat repetitive and laborious, but also complex enough that they are easy to forget if one is not performing the rollover model setup task regularly. It is important to perform the set up steps consistently and correctly in order to ensure accurate, repeatable and consistent results. Through the use of Process Manager in HyperMesh, the process of setting up the analysis of a rollover test for solution in RADIOSS has been largely automated. The benefits are a significant reduction in the time the user must spend manually performing model set up tasks and the assurance of a consistent and repeatable model build procedure every time an analysis is performed, even if the task is being performed by a different analyst.

Keywords: rollover, process manager, RADIOSS, R66
1.0 Introduction

In 1986 strength of superstructure validation became a mandatory requirement for all coach vehicles, now categorised as M3 class III or B.

With respect to large passenger carrying vehicles, M3 class III, there has been a requirement since 1986 to fulfil a structural compliance with ECE regulation 66, “strength of superstructure”, the setup for an ECE R66 test is shown in Figure 1.

![Figure 1: ECE R66 Test Setup diagram](image)

Compliance can be demonstrated using: a full vehicle rollover test, a rollover or pendulum test on a body section, or by calculation to the satisfaction of the approval authorities.

In partnership with the approval authority, VCA, and Cranfield impact centre, the business adopted a quasi-static analysis approach using a calculation method based on coefficients derived from physical testing. This method evolved until the mid-1990s after which it remained relatively unchanged.

More recently, recognising a need to reduce weight and develop a more optimised structure, it became apparent that we required a more versatile R66 approach. We therefore embarked on a project to realise a new way to demonstrate compliance with ECE R66 which would suit our industry, our method of manufacture and our available skill set. This resulted in the implementation of Altair HyperMesh and the development of an R66 process manager template.

2.0 Process Manager Template development

The starting point for the project was an existing simple rollover template which was made available by Altair. This template completed the basic tasks of loading the model and integrating the survival space, creating a platform to roll from and the impact floor.

To assess the suitability of the existing rollover template and fully understand how it interacted with a vehicle analysis model, a RADIOSS model of a full coach structure was created in HyperMesh.

From initial appraisals it was evident that the existing template would require modification to incorporate more preconditioning features in order to allow an accurate rollover simulation.
meeting the ECE R66 requirements. Therefore the template was fundamentally overhauled to improve its suitability to carry out ECE R66 rollover simulation.

This template development was carried out in partnership with Altair who acted as technical experts in tcl and RADIOSS.

Key areas developed within the template were:

1. Orientation of axis with relation to the vehicle coordinate system.
   a. The use of multiple coordinate standards was considered and the template allows the user to select which is appropriate. This is limited to the direction of the X coordinate with respect to the model as right hand rule is assumed for Y and Z.
   b. The direction of roll for the vehicle is defined with respect to the driver/co-driver, including swapping the reference in the original template from Left Hand Drive to Right Hand Drive as standard (for use in the UK).

2. Correctly reporting the C of G of the vehicle.
   a. During the early development of the template it was apparent that the C of G being reported by the template did not always correspond to that of the model. An option was added to allow user determined coordinates and mass to be entered.

3. Allowing variability of the stopper height on the tilting platform.
   a. Regulation 66 requires that the height of the stopper against the vehicles wheels should be no more than 80mm or 2/3 the tyre sidewall height whichever is the smaller. Therefore the option to vary the stopper height was incorporated into the template.

4. Rationalising the steady state conditions of the vehicle prior to initiating rollover.
   a. There are three steady state conditions of a vehicle which were recognised.
      i. The tipping point at which a vehicle is in steady state on a flat plain.
      ii. The tipping point at which a vehicle is in steady state on an inclined plain with a stopper.
      iii. The tipping point at which a vehicle is in steady state on an inclined plain with a stopper including overcoming friction and reaction loads.

5. Reconciling the start conditions to allow free fall to initiate from the point of rollover stability.
   a. The three steady state tipping points are calculated and presented as the zero velocity start point of the rollover. As this is a steady state condition, the option to select an unstable angle was introduced which also applies the required angular velocity associated with this unstable condition.

6. Allowing a choice of different gravity units.
   a. The option to use m/sec^2 or mm/sec^2 depending on your model units was added.

7. Understanding the contact interface required to allow accurate departure from the tilting platform.
   a. The contact between the wheel/tyres of the vehicle and the stopper platform is automatically created and utilises both RADIOSS type 7 and 11 interfaces to ensure correct departure of the model.

8. Adding friction to the impact surface.
   a. From the second stage validation the effects of friction during impact was realised. Therefore the use of variable friction was added to the template.
9. Exporting a pre-process status report.
   a. Because of the number of variables and model conditions a text file is
      automatically saved indicating the setup of the model.

10. Implementing rigid on/off methods to improve the analysis time.
    a. When utilising the full free fall of the model, a significant amount of process
       time is used before the model contacts the ground. To reduce this
       computation time the use of RIGID ON/OFF was introduced in order to
       rigidise the model up to the point of impact, before switching back to
       deformable at that point.

11. Exporting a simple display model to speed up post processing.
    a. The method of using a two stage rollover analysis via RIGID ON/OFF speeds
       up the initial free fall analysis however his approach has a significant hit in
       terms of model loading time for displaying results due to the presence of a
       large rigid body over the whole coach. Therefore a display model is saved
       which has the rigid elements removed.

3.0 Validation

In order to satisfy both our own internal requirements and those of the approval authorities
as to the validity of this process, a validation programme has been undertaken.

Initial validation concerned the use of explicit FEA analysis and centred on the comparison
of a physical test with that of the same test generated in HyperMesh and solved in
RADIOSS (Figure 2).

![Figure 2: Single Joint Validation Against Test](image)

The next area of validation centred on the rollover process template and resulted in the
addition of new features, removing anomalies, and checking the output reflected our
understanding of reality. This was achieved using a commissioned full vehicle analysis
model (Figure 3) which allowed us to repeatedly test the model pre conditioning during the
template development and compare the outputs with expected values.
During this development the rollover template was formalised to ensure the correct sequence of pre-processing of the FEA model to ensure due care and allow accurate physical representation by offering precondition variables to be set.

Figure 5: Orientation of FEA model coordinate system can be set with respect to X

Figure 6: The position of the centre of gravity and mass can be calculated or manually entered depending on the FEA model setup i.e. the use of ADMAS and the effects this can have on the calculated centre of gravity
Figure 7: The initial stable condition of the vehicle and the desired unstable starting angle can be selected

Figure 8: The distance to the ground and its friction value can be set

Once sufficient confidence in the process manager rollover template was gained, validation was progressed to physical comparisons. To this end a physical single bay vehicle test coupon was constructed along with a rolling platform, so controlled and repeatable testing in accordance to the requirements of ECER66 could be carried out. This physical testing was paralleled via simulating the same scenario using an independently constructed RADIOSS FEA model of the test coupon (Figure 9). This model was both pre-processed via the developed process manager template and by hand setup. The validity was reconciled on the final plastic deflections and deformed shape of the physical tests. The use of varying start conditions was also considered so the variation in FEA model results could be compared with reality.

Figure 9: RADIOSS FEA model and the physical test coupon
4.0 Results

Initial comparison of the RADIOSS FEA runs and physical testing show good correlation in both the physical motion and post impact deformation shapes.

There is good correlation in the variance of ground friction with respect to the models behaviour and the physical testing.

When using the correct ground friction the analysis shows higher deflection, conservative worst case.

5.0 Conclusion

The rollover template allows preconditioning of a RADIOSS FEA model with respect to simulating ECE R66 vehicle rollover.

The rollover template allows rapid and repeatable preconditioning of a suitable vehicle FEA model with little interaction from the operator.

The rollover template allows the user to set key variables during the pre-process creation to optimise the FEA model to ECE R66 and aid in vehicle development.

The unstable initial angular velocity applied to the FEA model uses a conservative worst case approach which trades reduced computational times against higher impact speeds.

6.0 Next Steps

Further physical coupon testing is planned to improve the statistical significance of the results used to validate the rollover analysis.

A full and accurate RADIOSS FEA model is to be built of a current vehicle which will be rolled using the process template.

Accurate measurements of the x,y,z CoG and mass of a vehicle are to be made in accordance with ECE R66 (Figure 10) and will be set as the stable condition of the FEA model.

![Figure 10: Physical Methodology to determine Vehicle CoG](image)
7.0 References

[1] ECE R66-00, 01 & 02


[3] ‘Rollover Crash Worthiness of Bus Model as Per ECE R66’ Altair India HTC09 Ramkrishna Shekhar, Narayan Pansekar