Deformable Body Kinematics

Development of a Mathematical Model to Predict Accelerations Within a Motor Coach

Presenter: Graham Leverick Supervisor: Dr. Christine Wu

Background

Testing the durability and performance of public transit vehicles is a costly, but very important stage in the design process. Component-wise accelerated durability testing is a time and cost effective way to test a part's performance. In order to perform an accelerated durability test, acceleration data that's representative of what the part experiences in service is required. This is typically acquired by collected part-specific data from a field test. It is costly to collect data for every part that is to be tested.

Objectives

This project has two objectives:

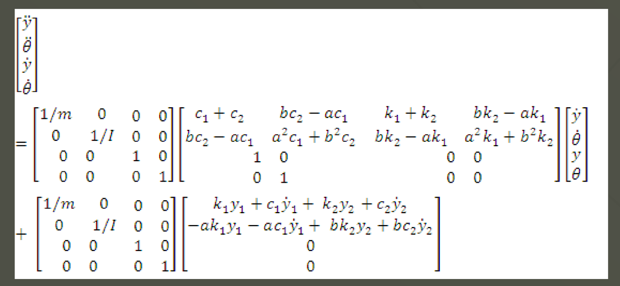
- To obtain a model which can accurately interpolate the acceleration data for any component on a motor coach
- To investigate the impact of body deformation on response of the motor coach

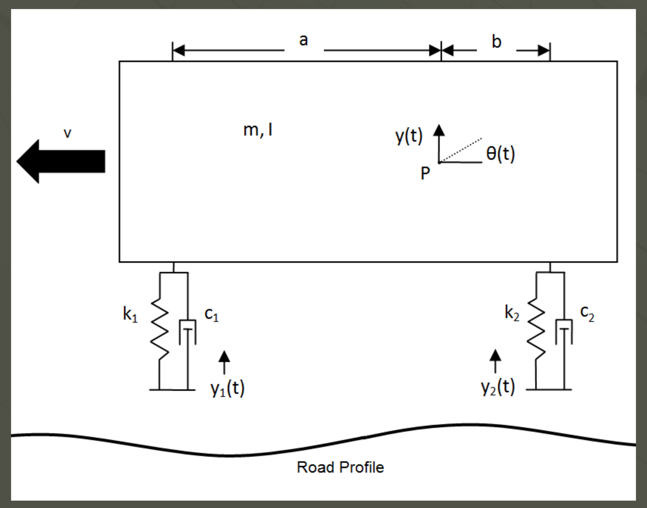
Methodology

Two different models will be developed: a rigid body model and a deformable body model. These models can be compared to investigate the effect of body deformations on the response.

Two Degree-of-Freedom Rigid Body Model

Two independent bases (which represent the front and rear axles) excite a rigid body through two spring-damper elements. The vertical and angular response is calculated numerically at the center of mass. Through rigid body kinematics, the response at any point can be calculated.

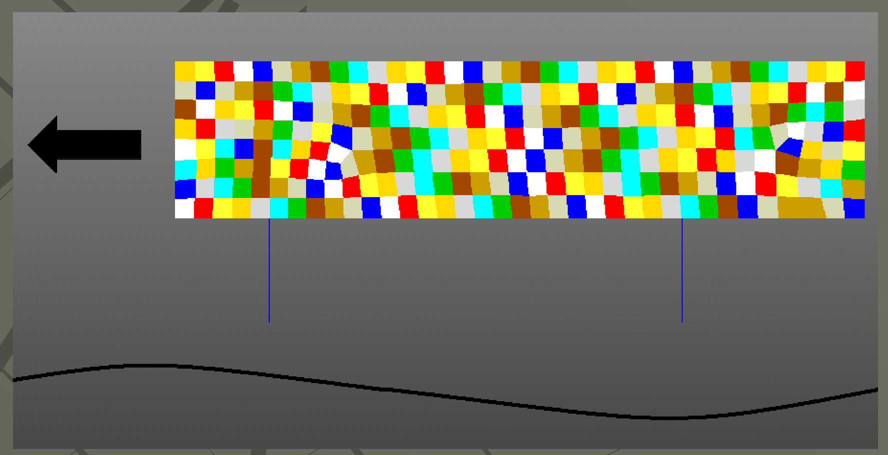




Two Degree-of-Freedom Deformable Body Model

Similar to the Two DOF Rigid Body Model, but now deformations within the body are considered. A solution is found through finite element method (FEM). In FEM, a continuous body is quantized into discrete elements and nodes. The equations pertaining to the solution are solved at the nodes and interpolated to solve values within the elements. The FEM Analysis was conducted in ANSYS.

Parameter	Value
Total Number of Nodes	887
Total Number of Elements	267
Body Element Type	PLANE82 (8 Point Planer Quadrilateral Elements)
Number of Body Elements	265
Spring-Damper Element Type	COMBIN14 (Combined Spring-Damper Elements)
Number of Spring-Damper Elements	2



The response of the motor coach is made up of two components: the rigid body component and component caused by deformation within the body.

$$y = y_{rigid} + y_{deformable}$$

Results and Discussion

In order to investigate the effects of deformation, the responses calculated by the rigid body and deformable body models are compared for different road profiles.

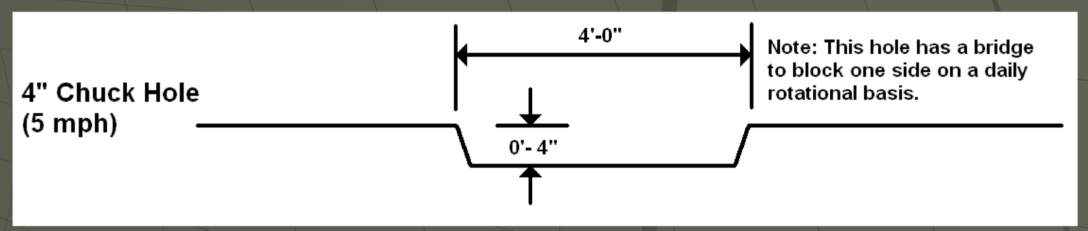
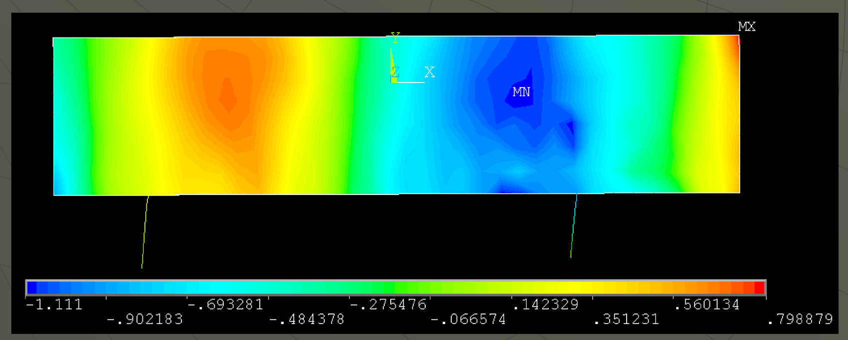
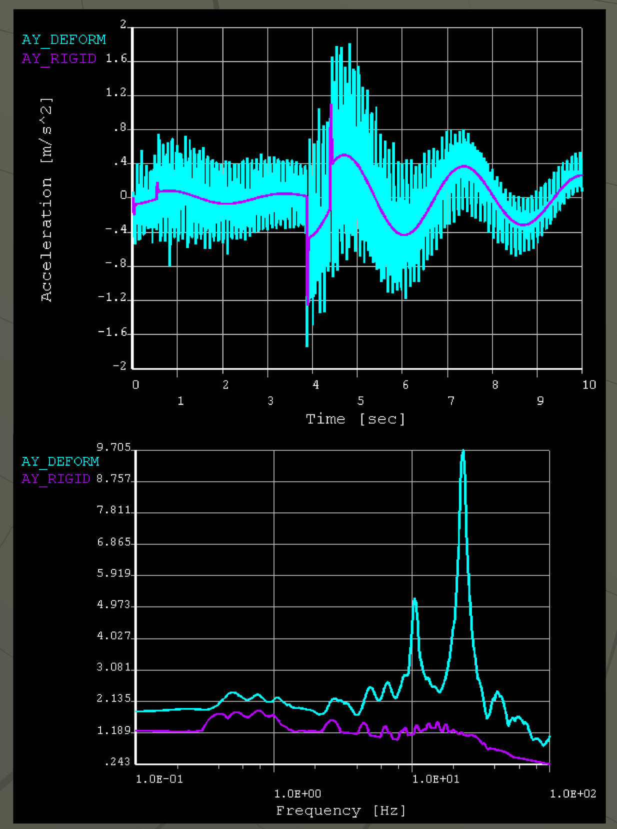


Figure 1 – Road Profile #1 – Four Inch Chuck Hole



A contour plot showing the vertical accelerations calculated by the deformable body model is shown above. A point from the body is then selected for further investigation. A comparison of the response calculated by the two models shows very distinct differences between the responses. A spectral analysis (shown below it) shows large amounts of very specific high frequency content.



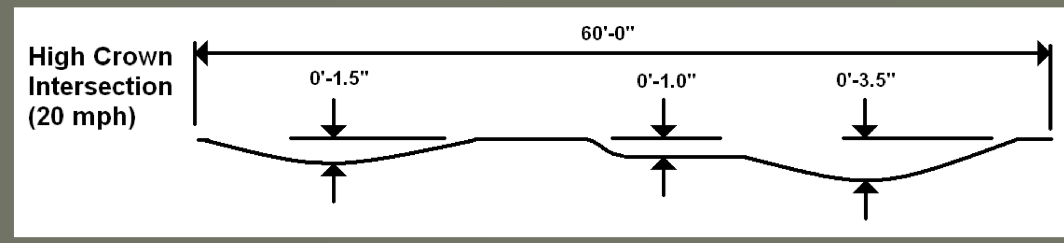
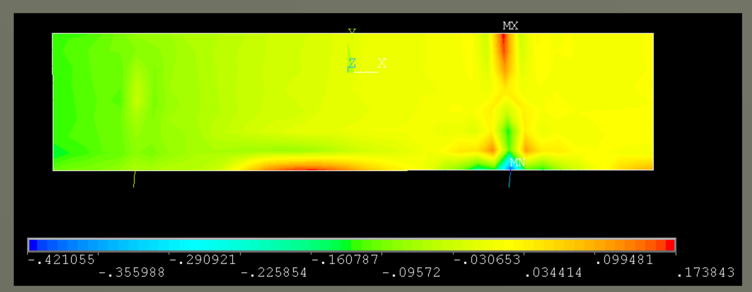
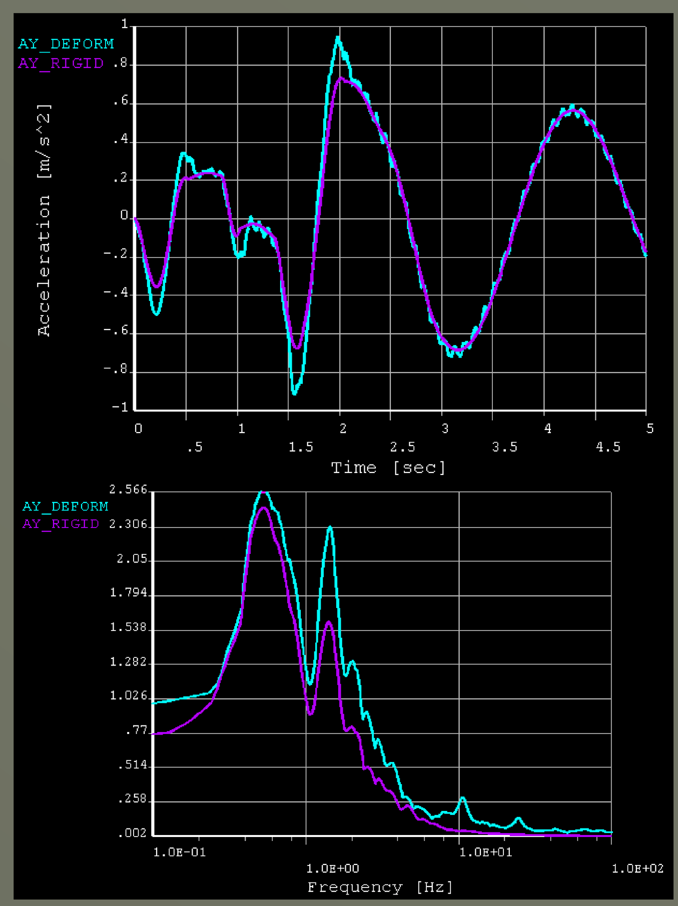


Figure 2 – Road Profile #2 – High Crown Intersection



A similar comparison was undertaken for a different road profile, the high crown intersection. Although this comparison is noticeably different than the chuck hole, similar trends emerge. As before, the peaks of the deformable body model are accentuated. In addition to this, there is also high frequency content present in the deformable body model, which does not exist in the rigid body model.



Conclusions

The effect of deformation on the overall response of the body is clearly dependent upon the road profile. Less severe road events tend to have responses more closely aligned with the rigid body response. Higher impact events led to responses which were dominated by body deformations. Deformations within the body caused high frequency content to appear in the response which wasn't present in the rigid body response. These frequencies are likely associated with deformation modes and resonant frequencies of the body of the motor coach. In addition, deformations strongly effected acceleration peaks. Although further investigation into this phenomenon is required, one explanation could be the release and absorption of strain energy by the body of the motor coach.

Although the models developed in this project are simplified, they still capture the overall trend of the motor coach's response. The trends and observations made during the creation of these models can serve as valuable resources for the creation of future, more complex models.