Stability of a Trailer During a Lane Change Maneuver

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Abstract

The purpose of this project is to use computer simulation to study the stability of a trailer during a lane change maneuver as defined by ISO standard 3888-2 [1]. A multi-body dynamics model of the trailer was built and its hitch was kinematically constrained to follow a path according to the ISO standard. A beam was used to model the compliance of the trailer. The stiffness of this beam was varied and the paths taken by the centers of gravity of the trailers were compared.

Introduction

The model described in this report represents a trailer performing an obstacle avoidance maneuver as defined in IS0 388-2 Passenger Cars –Test Track for a Severe Lane-Change Maneuver [1]. A description of the course defined by that standard is reproduced in Figure 1and Table 1.

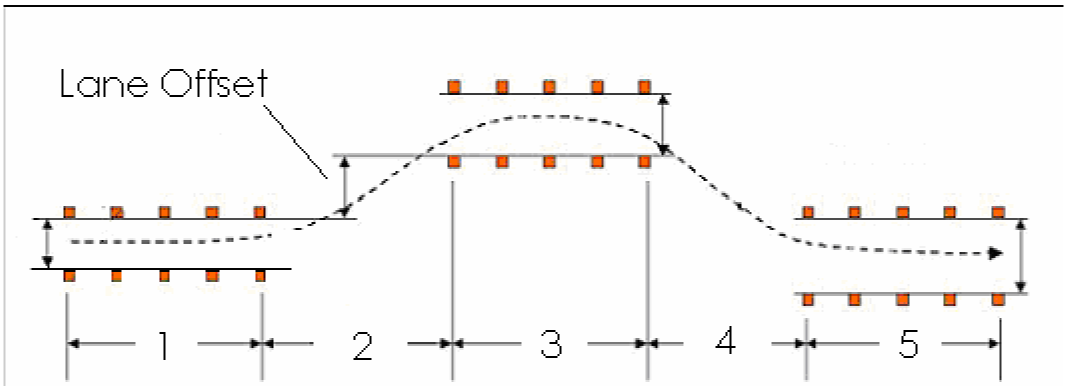

Figure 1 Obstacle Avoidance Track with Designation of Sections [1]

Dimensions in Meters

Section	Length	Lane Offset	Width (b)
1	12	-	1.1 x Vehicle Width + 0.25
2	13.5	-	-
3	11	1	Vehicle Width + 1
4*	12.5	-	-
5	12	-	1.3 x vehicle Width + 0.25, but not less than 3 m

* To ensure high lateral accelerations at the end of the track, section 4 is 1 m shorter than section 2.

Table 1 Obstacle Avoidance Track Dimensions [1]

The trailer's hitch was constrained to stay within the course. Its weight was kept constant as were the tire properties. The stiffness of the beam which defined the compliance of the trailer was set at a high and then a low value and the paths taken by the high stiffness trailer was compared to the path taken by the low stiffness trailer.

Model Description

The model was built using Blended MBDyn an open source graphical user interface for ,MBDyn an open source MultiBody Dynamics application [2]. A picture, illustrating all of the components of the model is shown in Figure 2. A sketch of the trailer is shown in Figure 3. The dimensions are shown in Table 2

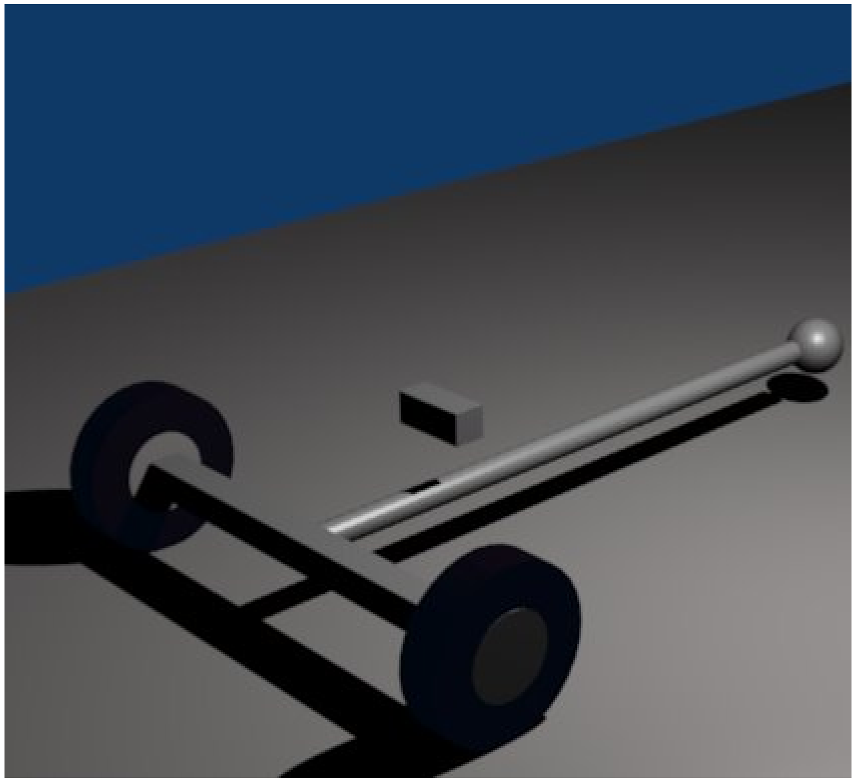

Figure 2 Trailer Model

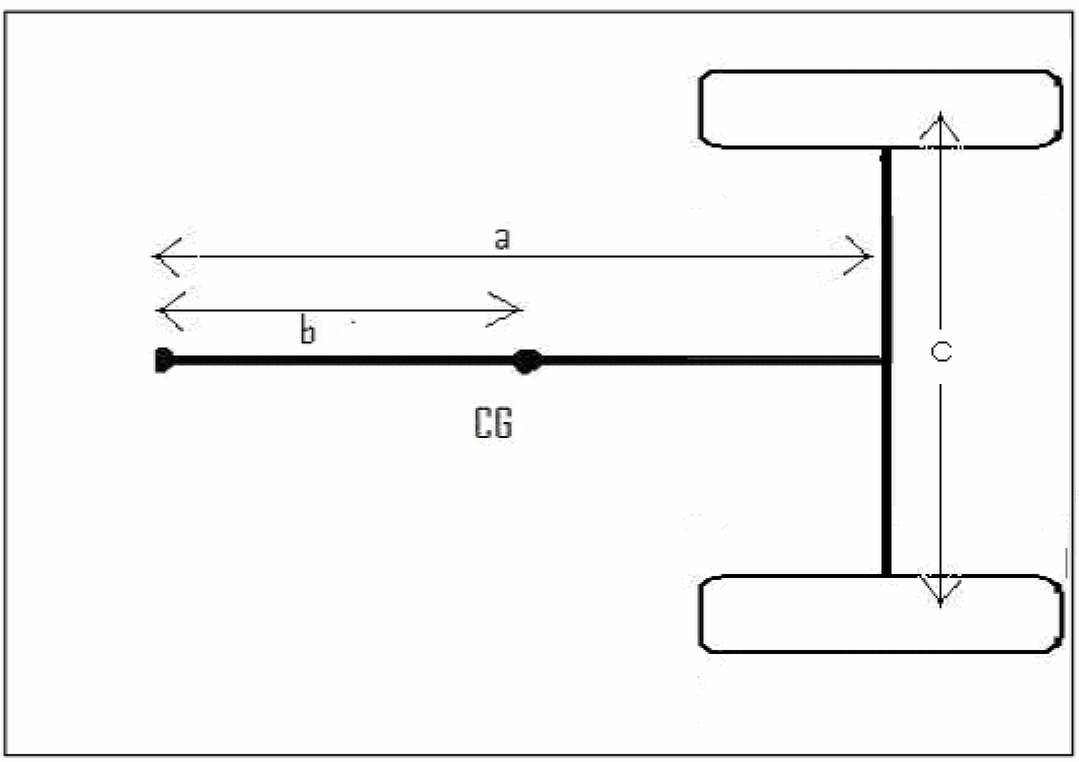

Figure 3 Top View and Dimensions

Dimension	Value
a	4.5
b	3.5
c	3
Tire Radius	0.5
CG Height	1

Table 2 Dimensions in meters

A sixth order polynomial which followed the course described above was used to constrain the position of the trailer hitch and it kept a constant forward velocity of 15 meters per second.

Bodies

The model contains 4 moving rigid bodies:

1. Trailer Hitch (The Sphere of Figure 2)
2. Trailer axle which represents the axle and the load on the trailer. The solver recognizes this as only one rigid body, but it is depicted in Figure 2 as two, the long cube between the two tires and the small cube (which contains most of the mass) suspended above the trailer.
3. Left Tire
4. Right Tire

The mass of the trailer hitch is inconsequential because its motion is constrained and it's inertia was negligible. The weight of the wheels and the axle are shown in Table 3.

Body	Mass	Ixx	Iyy	Izz
Axle	500	400	400	400
Wheels	1	1.2	1	1

Table 3 Body Masses (kg)

Beam

The beam representing the compliance of the vehicle is depicted in Figure 2 as a cylinder. It is a force element in MBDyn connecting the mass of the trailer's axle (which includes the weight of the load) to the trailer hitch, effectively creating a lumped mass beam. Mathematically the beam is a 6x6 stiffness matrix and a 6x6 damping matrix. The generalized coordinates of the beam are shown in Figure 4 and the stiffness matrix in Figure 5. The damping matrix is similar to the stiffness matrix in form, but is 10% of the magnitude.

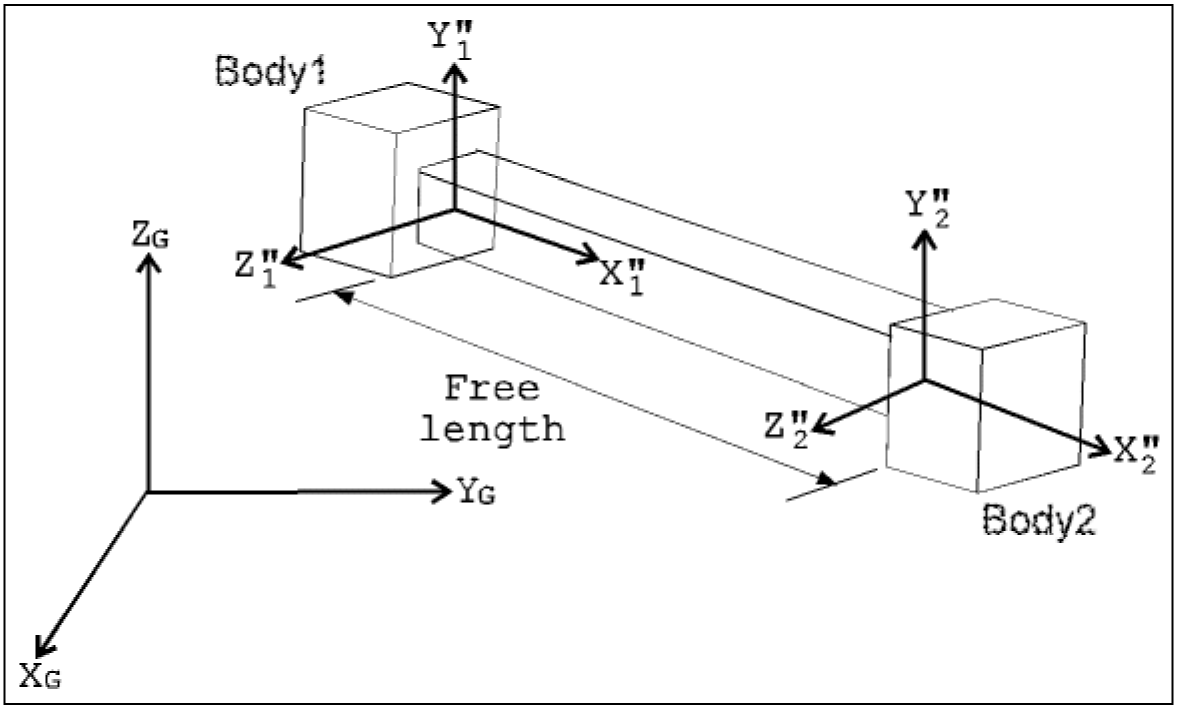

Figure 4 Beam Element Generalized Coordinates [3]

$$\begin{bmatrix} \frac{EA}{l} & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{12EI_z}{l^3} & 0 & 0 & 0 & \frac{-6EI_z}{l^2} \\ 0 & 0 & \frac{12EI_y}{l^3} & 0 & \frac{6EI_y}{l^2} & 0 \\ 0 & 0 & 0 & \frac{GI_x}{l} & 0 & 0 \\ 0 & 0 & \frac{6EI_y}{l^2} & 0 & \frac{4EI_y}{l} & 0 \\ 0 & \frac{-6EI_z}{l^2} & 0 & 0 & 0 & \frac{4EI_z}{l} \end{bmatrix}$$

Figure 5 Beam Stiffness Matrix [3]

Where

E	= Young's Modulus
l	= Undeformed beam length
G	= Shear modulus $\left(\frac{E}{2(1+\nu)}\right)$ where ν is Poisson's ratio
I_x	= Moment of inertia where the subscript is the axis

There were two analyses done. The only parameter changed was the beam diameter. The properties of the beams are shown in Table 4.

Beam	Diameter	Young's Modulus	Poisons Ratio	Undeformed Length
1	0.2	2.00E+11	0.28	4.5
2	0.1	2.00E+11	0.28	4.5

Table 4 Beam Properties

Tires

The tires are represented with a vertical stiffness, a vertical damping, a slip angle curve and slip curve shown in Figure 6 and Figure 7 respectively. A description of this type of tire model can be found in Gillespie [4].

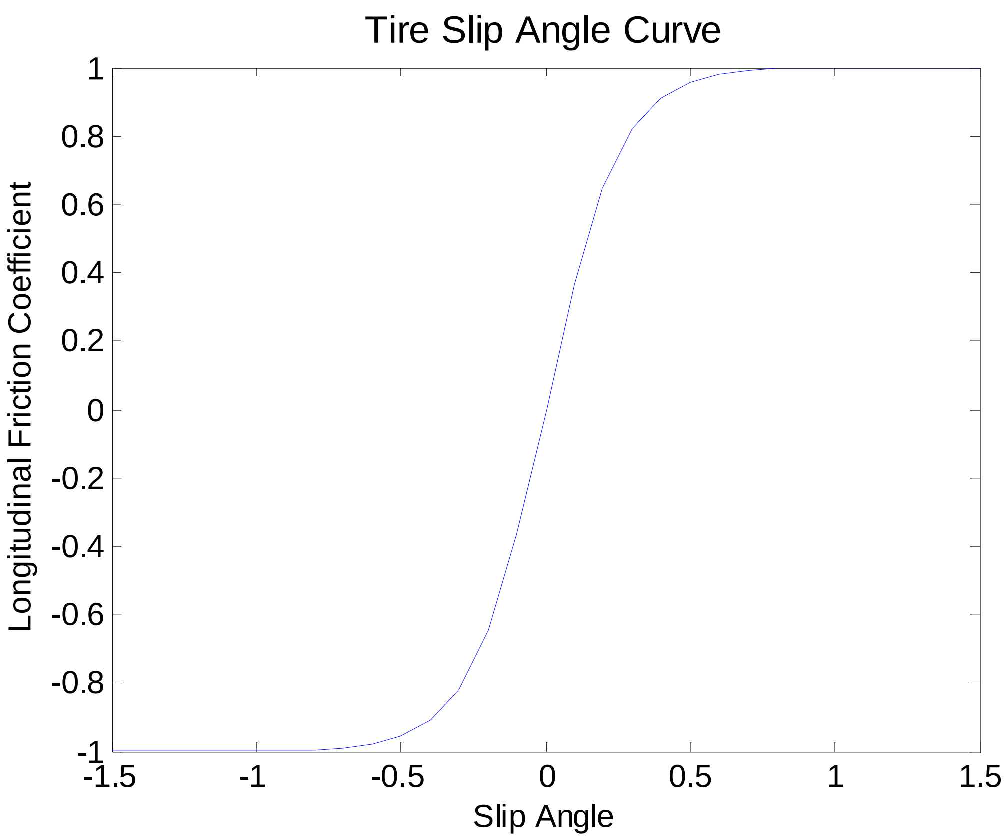

Figure 6 Tire Angle Slip Curve

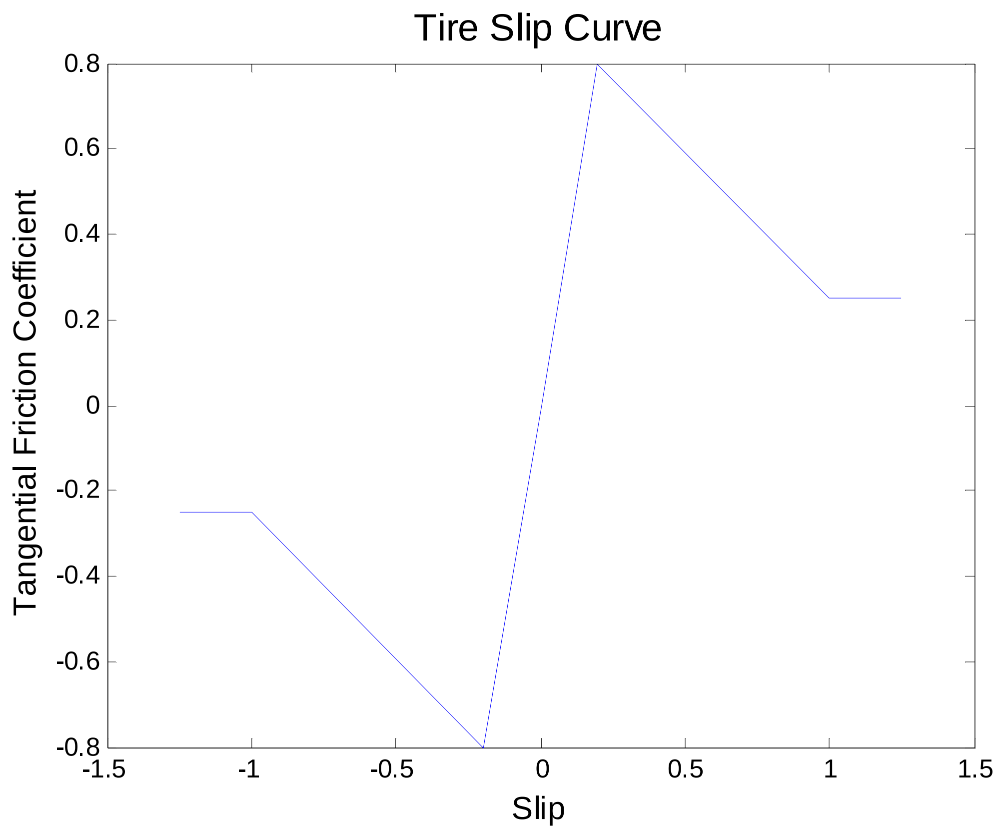

Figure 7 Tire Slip Curve

Results and Conclusions

Figure 8 and Figure 9 (a close up of the end of the course) show the path taken by the center of gravity of the two trailers. The less stiff trailer deviates further from the prescribed path then does the stiffer trailer, but both fall within the boundary of the course.

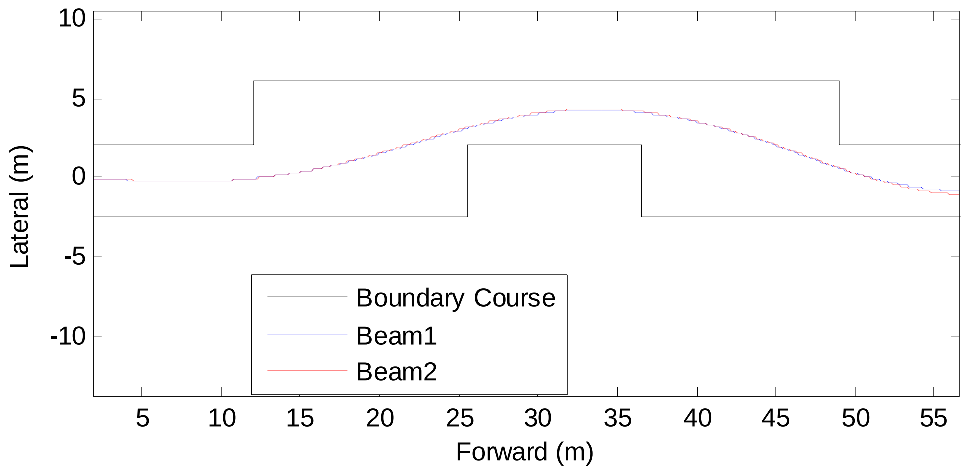

Figure 8 Trailer Tracking Comparison

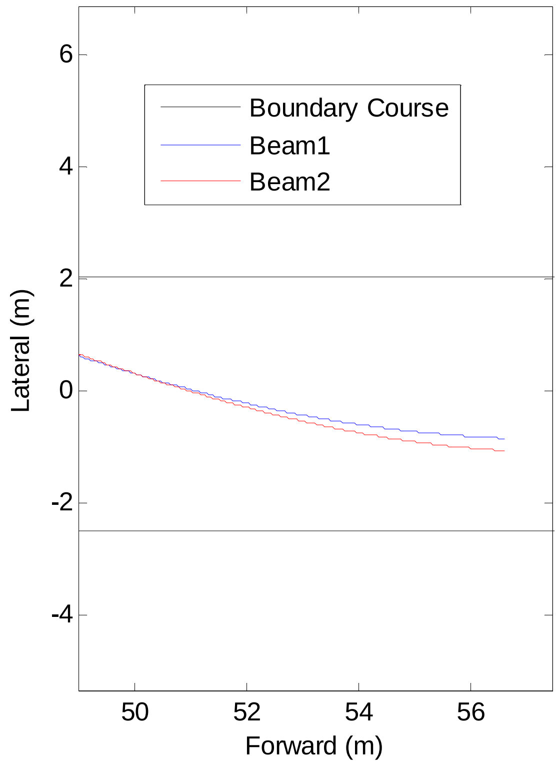

Figure 9 Trailer Tracking Comparison View 2

The lateral tire force is what keeps the trailer behind the hitch and it is a function of the weight on the wheels which is directly related to the height of the center of the tire off the ground. Figure 10 shows a comparison of the center height of the left wheel of both trailers. The oscillations are a function of the damping in both the tire and the beam. The wheel of the trailer with the less stiff beam is allowed to elevate more than that of the stiffer trailer which would reduce the tire's lateral force and decrease its ability to track.

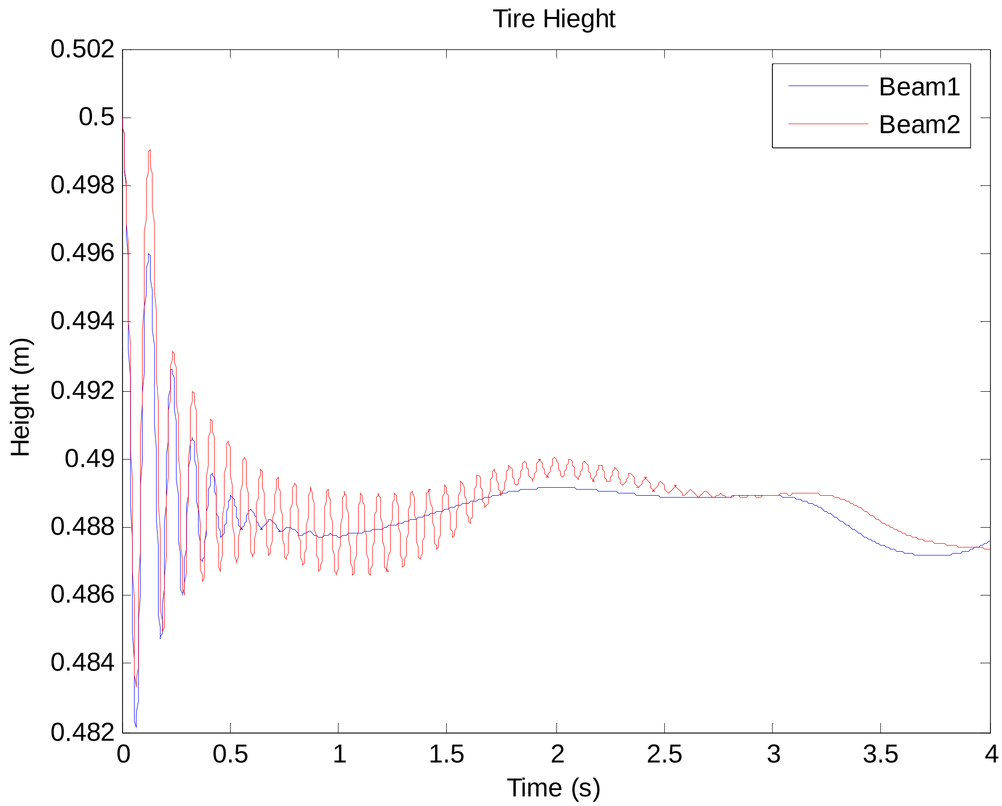

Figure 10 Tire Height Comparison

The dimensions and weights used here were not representative of any specific trailer. It would be interesting to find test data and correlated the simulation. This would take some time and effort particularly in gathering data for the tires and perhaps the tire model would have to be altered. Although the fact that this was an academic investigation in that there was no data with which to correlated, generally this was a successful test of the procedure and software.

Reference

1. Passenger Cars _ Test Track for a Severe Lane-Change Manuever First Edition 2002-11-15 © ISO 2002
2. MBDyn - MultiBody Dynamics Software http://www.aero.polimi.it/~mbdyn/
3. DADS Revision 9.6 Documentation Computer Aided Design Software Inc. © 1998
4. Fundamental of Vehicle Dynamics, Thomas D. Gillespie, © Society of Automotive Engineers 1992