

Analytical Prediction of Leaf Spring Bushing Loads Using MSC/NASTRAN and MDI/ADAMS

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ABSTRACT

Analytical loads in leaf spring bushing can be used to perform finite element analysis on brackets that connect the leaf spring to a truck frame. Two models of leaf spring in MSC/NASTRAN and MDI/ADAMS were created to compare the bushing loads predicted by each model. Geometric non-linear capability of MSC/NASTRAN (SOL 106) was used to predict the bushing loads in MSC/NASTRAN model. The quasi-static simulation capability of MDI/ADAMS was used to predict the bushing loads in MDI/ADAMS model. The analyses simulated the standard jounce and roll tests at The University of Michigan Transportation Research Institute (UMTRI). An accurate prediction of loads in MSC/NASTRAN model provides the benefit of integration that allows us to include the leaf spring model in a full vehicle model to simulate full vehicle lab tests as well as proving ground durability events. Good correlation was obtained between the two models in jounce condition. More effort is underway to establish satisfactory correlation for roll condition.

1. Introduction

Large displacements cause geometric non-linear behavior in leaf spring suspensions of a truck. A typical front suspension system of a truck is shown in Figure 1. The finite element model of a front suspension is shown in Figure 2. When the loads are applied at the tire patch or spindle point, they are transmitted through the suspension components to the rest of the structure. The distribution of spindle load through the leaf spring generates bushing forces that are applied to spring hanger and shackle brackets. The brackets connect the leaf spring to the truck frame. Analytically predicted bushing loads can be used to perform finite element (FE) analysis of the bracket before the availability of the first prototype.

The purpose of this study was to compare the predicted bushing loads of the front suspension of a heavy truck under standard University of Michigan Transportation Research Institute (UMTRI) bounce and roll tests from MSC/NASTRAN and MDI/ADAMS models.

2. Model Description

Two models of a typical heavy truck leaf spring were created for this study. The first model was created using Hypermesh which is the preprocessor used for MSC/NASTRAN. The second model was created in MDI/ADAMS.

2.1 Leaf Spring Description of MSC/NASTRAN Model

A model of single leaf spring was created in MSC/NASTRAN (Figure 3). Each element of the leaf spring is made of general purpose beam elements with constant rectangular cross section. The cross sections of the beam elements are decreased from the spring seat to the spring eyes in order to represent the thickness. Ten elements were created along the front end of the leaf spring. Similarly, ten elements were created along the rear end of the leaf spring. The general purpose beam element of MSC/NASTRAN has a total of 14 degrees of freedom and can be used to build suspension mechanism. The spring and the shackle eyes are represented by pin joints in the FE model. The strain free rotation of the pin joints is also represented to simulate the large displacement and pin-joint mechanisms of the leaf spring.

2.2 MDI/ADAMS MODEL

In the MDI/ADAMS model, the beam elements are of constant cross section similar to the FE model created in MSC/NASTRAN. A total of 20 elements were used to create the single leaf spring model. The shackle is modeled as a rigid part. The pin joints are represented by revolute joints with one degree of freedom along the global y-axis. The forces and moments are applied at the axle seat. A model of the MDI/ADAMS single leaf spring is shown in Figure 4. It should be noted that the corresponding beam elements created in both the MSC/NASTRAN and MDI/ADAMS models were of equal length and equal inertia properties. Maximum efforts were made in order to create similar models in both software in order to prevent errors due to modeling discrepancies.

3. UMTRI Testing Facility

A facility for the measurement of heavy truck suspension properties exists at the University of Michigan Transportation Research Institute (UMTRI) [2]. The UMTRI facility has three major mechanical systems including a static structure, a movable table, and four wheel pad assemblies. The facility is also equipped with a computerized data acquisition and control electronics for primary data collection and display. Figure 5 shows a schematic of the heavy vehicle suspension test facility.

The load cases in this study simulated the UMTRI heavy vehicle suspension testing. In a jounce test, the axle is forced to move in the vertical direction with no roll component (relative to the vehicle frame). The force-deflection data is collected for the vertical spring rate. This data is further reduced to a vertical force-deflection curve for each individual spring to calculate the vertical stiffness.

In a roll test, the total suspension load is brought to the desired level. Then, while the load is held constant, the table is rolled in order to apply a roll moment to the suspension and the data is recorded. The moment-rotation angle is then plotted in order to calculate the rotational stiffness of the suspension.

4. Analysis Discussion

Large displacements of leaf spring lead to geometric non-linear behavior. Therefore, SOL 106 [3] of MSC/NASTRAN was used to account for geometric non-linearity. The quasi-static simulation [4] of MDI/ADAMS was used for the ADAMS model. The forces and moments were applied gradually at the center of the spring seat location for numerical stability reasons. Jounce load was applied in several steps. In the roll test simulation, the leaf spring was subjected to a moment to simulate a 10 degree roll

of the vehicle. Since our model only included a single leaf spring, an equivalent roll moment was applied at the spring seat location to simulate the roll test case.

5. Results and Conclusions

The reaction forces and moments in the front spring eye and in the shackle joints from MSC/NASTRAN model were compared to those from MDI/ADAMS model. The displacement of the seat location was also used for comparison. Tables 1-5 show the ratio of the results from MSC/NASTRAN model to those from MDI/ADAMS model. The results are discussed in the following sections.

5.1 Jounce Test Simulation

The Jounce test simulation results shown in Table 1 indicate a good correlation between MSC/NASTRAN and MDI/ADAMS forces. The forces are compared in two locations, in the front eye and, in the frame/shackle location. Displacements are compared at spring seat location and the results have good correlation (Table 2). The accuracy of jounce results is within 5% and indicates the predicted forces from MSC/NASTRAN can be used for component level stress analyses. Figure 6 shows the graphical representation of the Jounce test simulation results.

5.2 Roll Test Simulation

In the Roll test simulation, there is a variation of up to 11% in forces (Table 3), and up to 34% variation in moments (Table 4). The displacements and rotations also show no correlation. It can be seen from Tables 3 through 5 that when the pin joints are locked in the models, the behavior of the system is altered dramatically as reflected by the ratio of forces, moments, and displacements. The correlation of the results in the roll test were very poor and unacceptable. The cause of this is under investigation. Figures 7 and 8 show the graphical representation of the Roll test simulation results.

6. References

1. Norman A. and Scharff R., "Heavy-Duty Truck Systems", Delmar Publishers Inc., 1991.
2. Winkler, C.B., Hagan, M, "A Test Facility for the Measurement of Heavy Vehicle Suspension Parameters", SAE Paper No. 800906, 1981.
3. MSC/NASTRAN Handbook for Non-Linear Analysis, Version 67, The MacNeal-Schwendler Corporation, Los Angeles, CA, March 1992.
4. MDI/ADAMS Solver Reference Manual, Version 8, Mechanical Dynamics, Ann Arbor, MI.

Table 1. Ratio of NASTRAN to ADAMS forces in Jounce simulation

Location	Fx	Fy	Fz
Shackle/Body	1.01	0.0	1.01
Front Eye	1.01	0.0	0.95

Table 2. Ratio of NASTRAN to ADAMS Displacements in Jounce simulation

Location	X	Y	Z
Spring Seat	1.04	0.0	1.0

Table 3. Ratio of NASTRAN to ADAMS Forces in Roll simulation

Location	Free Shackle/Frame Joint			Locked Shackle/Frame Joint		
	Fx	Fy	Fz	Fx	Fy	Fz
Shackle/Frame	0.0	1.0	0.0	1.11	1.0	1.11
Front Eye	0.0	1.09	0.0	1.11	1.0	1.09

Table 4. Ratio of NASTRAN to ADAMS Moments in Roll simulation

Location	Free Shackle/Frame Joint			Locked Shackle/Frame Joint		
	Mx	My	Mz	Mx	My	Mz
Shackle/Frame	1.00	0.0	0.92	1.17	0.9	0.85
Front Eye	1.00	0.0	0.9	0.96	0.0	0.66

Table 5. Ratio of NASTRAN to ADAMS Displacements in Roll simulation at Spring Seat Location

Displacement	Free Shackle/Frame Joint			Locked Shackle/Frame Joint		
	X	Y	Z	X	Y	Z
Displacement	1.04	0.91	1.07	1.27	2.87	1.43
Rotation	1.22	0.71	1.14	1.28	1.13	1.27

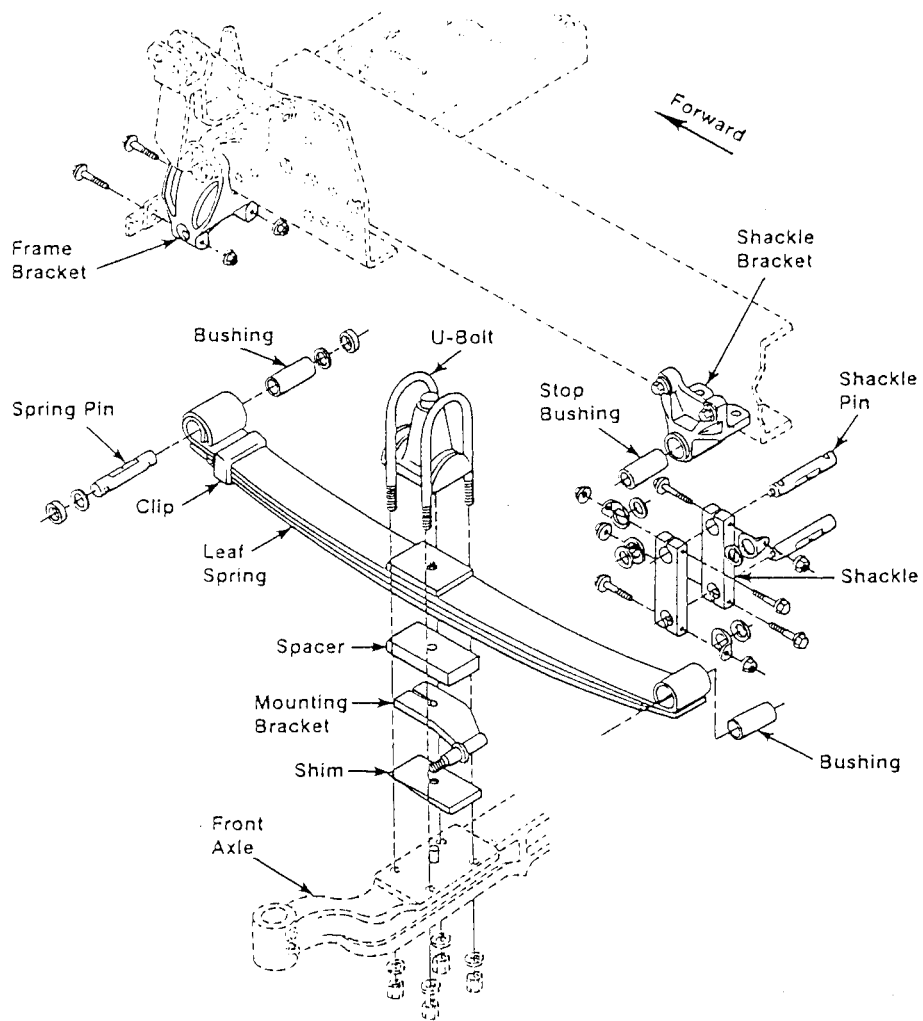


Figure 1. Front Suspension (Spring) Arrangement on a Heavy-Duty Truck (From Reference [1]).

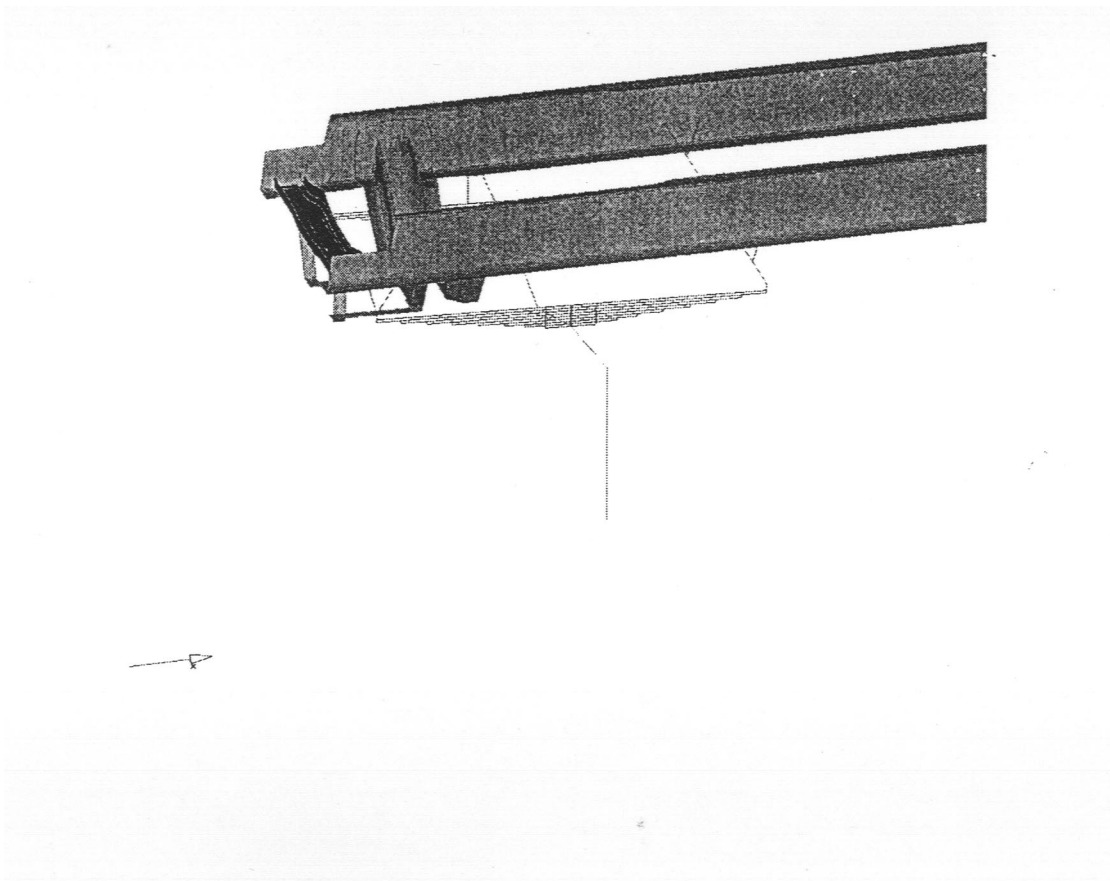


Figure 2. A Typical MSC/NASTRAN Model of a Front Leaf Spring Suspension.

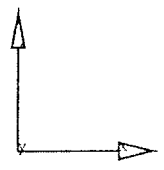
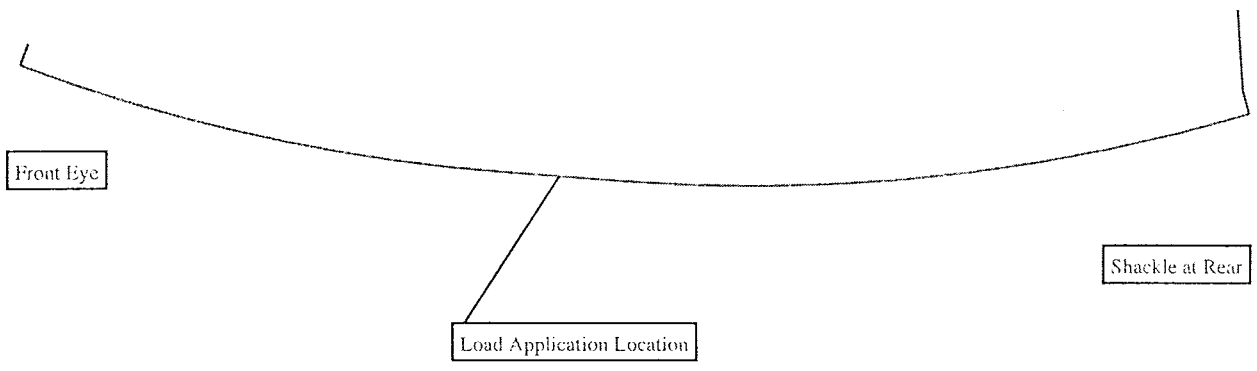


Figure 3. Single Leaf Spring with Shackle at Rear.



Figure 4. MDI/ADAMS Model of a Single Taper Leaf with Shackle in the Rear.

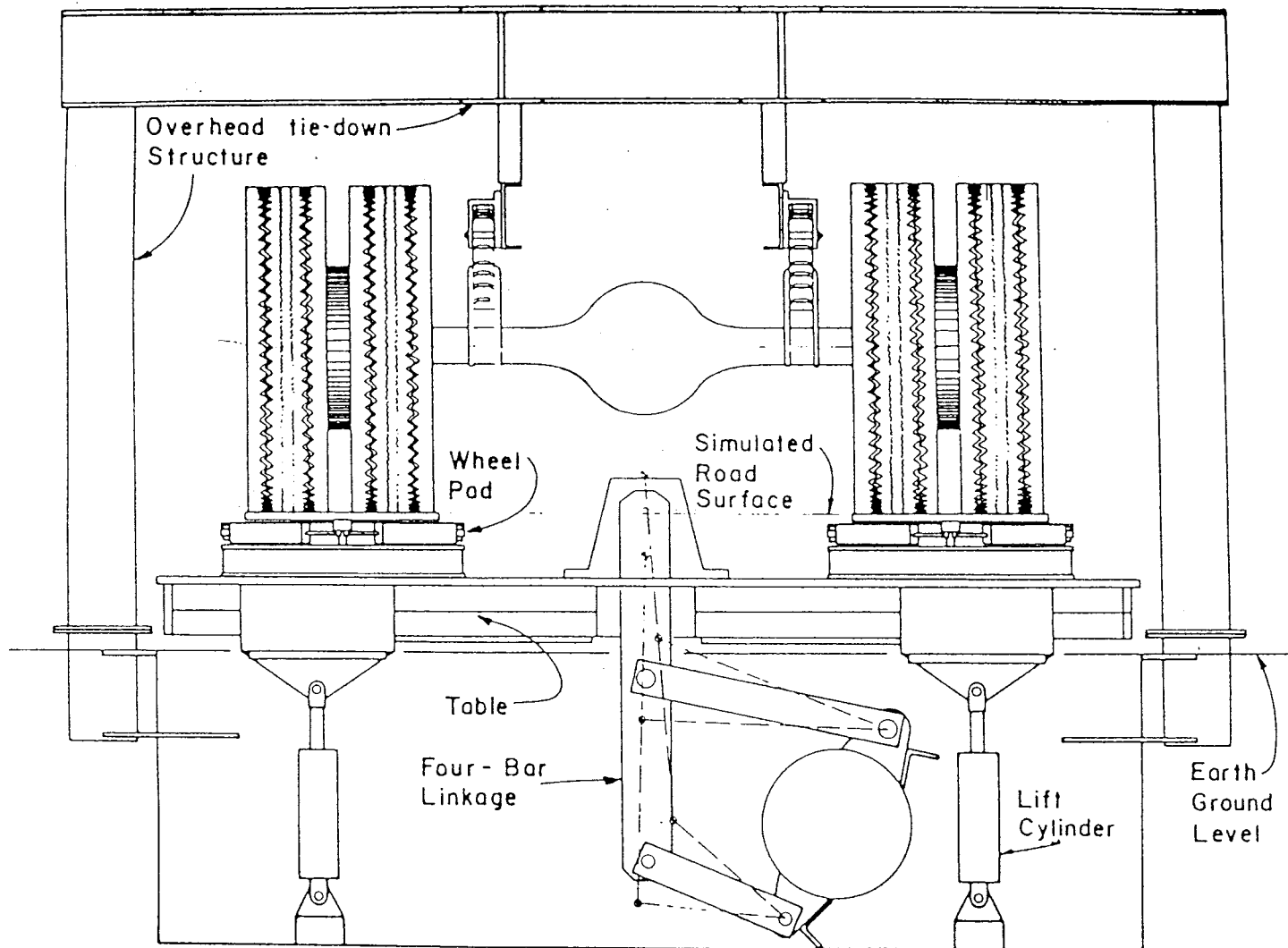
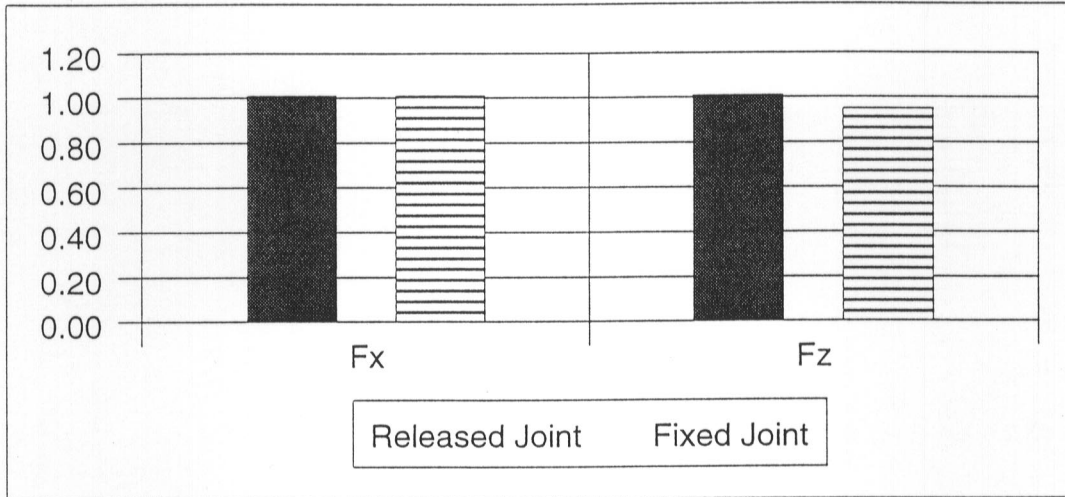


Figure 5. Heavy Vehicle Suspension Test Facility Schematic (From Reference [2]).

Ratio of Predicted Force (ADAMS to NASTRAN) for Jounce Simulation



Ratio of Predicted Displacements (ADAMS to NASTRAN) for Jounce

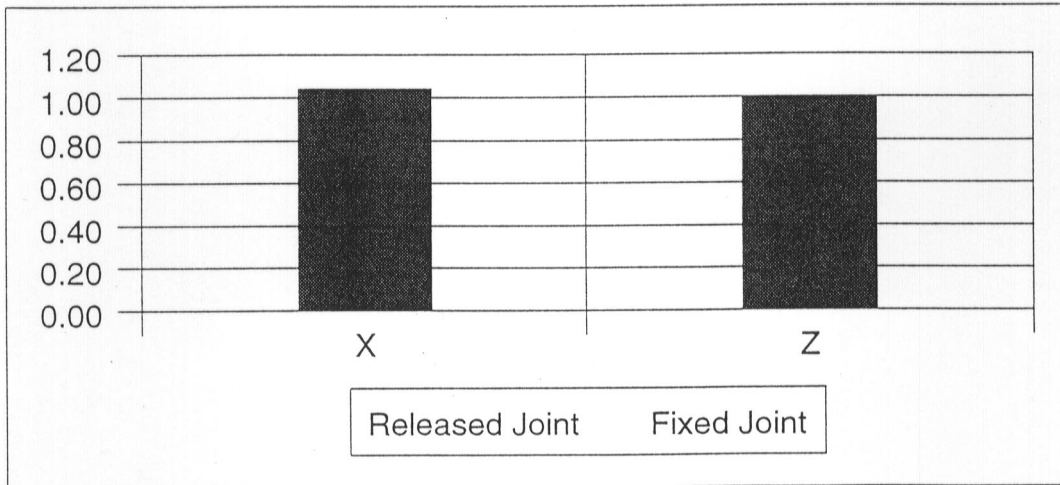
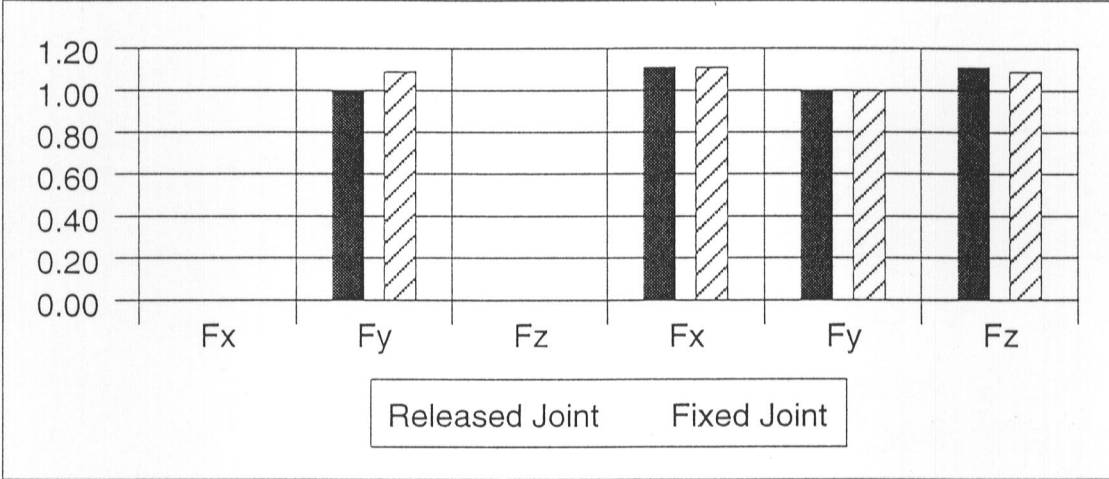


Figure 6. Graphical Representation of the Jounce Test Simulation Results.

Ratio of Predicted MDI/ADAMS to MSC/NASTRAN Roll Simulation Forces



Ratio of Predicted MDI/ADAMS to MSC/NASTRAN Roll Simulation Moments

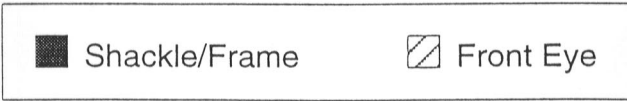
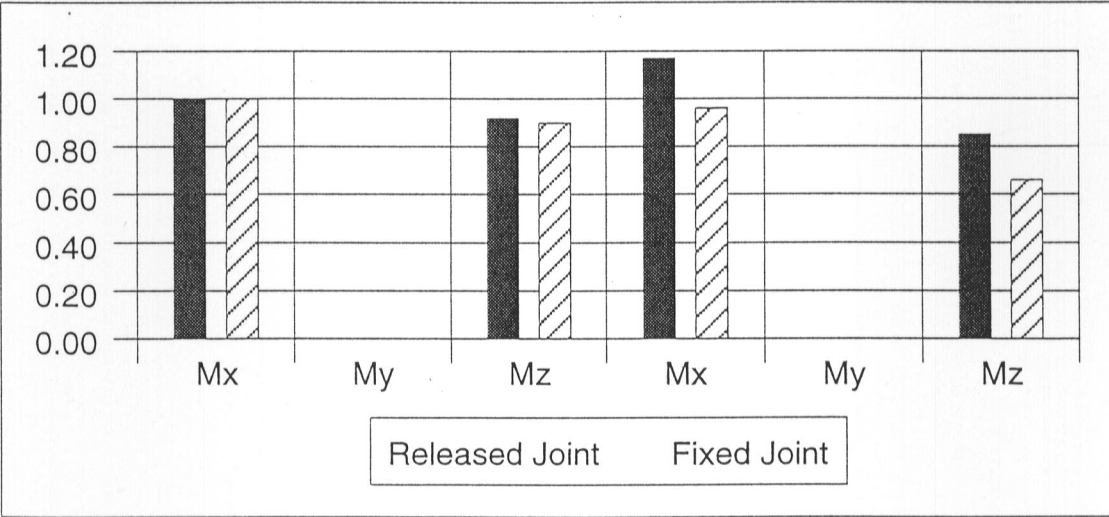
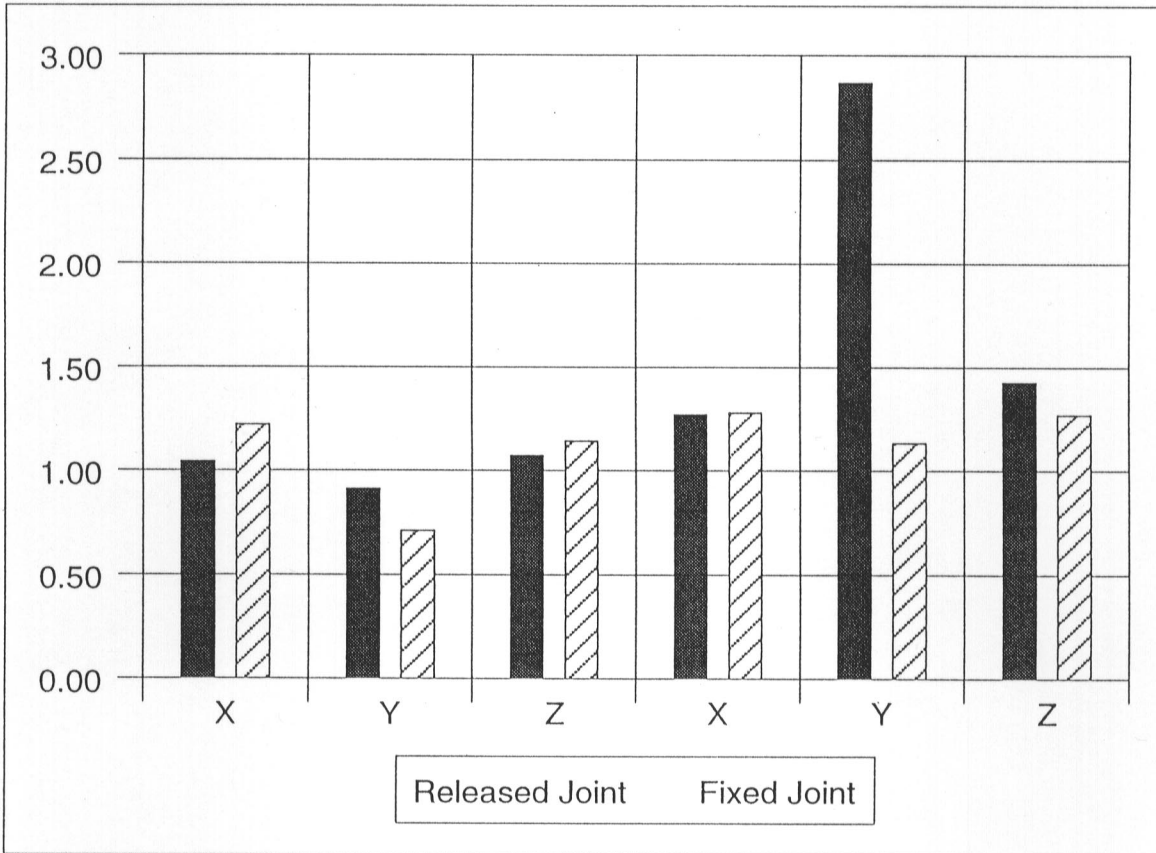


Figure 7. Graphical Representation of the Roll Test Simulation Results.

Ratio of Predicted Roll Simulation Displacements at Spring Seat Location



■ Displacement ▨ Rotation

Figure 8. Graphical Representation of the Roll Test Simulation Results of the Spring Seat Location.