Traction Loss of a Suspended Tire on a Sinusoidal Road

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ABSTRACT

It has been known for some time that automobiles lose a significant percentage of their traction when exposed to a sinusoidal road input, that is, a washboard road, above certain speeds. Similarly, when an automobile is on a four post shaker, it is common practice to use an approximately 10-Hz shaker frequency, and then push the automobile by hand to position it on the shaker. Early studies of a laboratory test with a fixed axle showed that there is significant loss in traction at higher amplitudes or higher frequencies (shorter wavelengths or high speeds), or at a combination of the two. Presented in this paper are the results of a study on the effects of sinusoidal roads on the traction of the right front quarter-car assembly of a 1968 Oldsmobile Toronado using the circular track apparatus at the Pennsylvania Transportation Institute. The results show that as much as 30 percent of the automobile's traction is lost at frequencies of 11 Hz (as compared to a flat track), and that the rate of decay increases rapidly by this frequency. Furthermore, the loss of traction increases for larger input amplitudes; 11 Hz is comparable to a vehicle traveling at 55 mph on a road with roughness at a 7.3-ft wavelength.

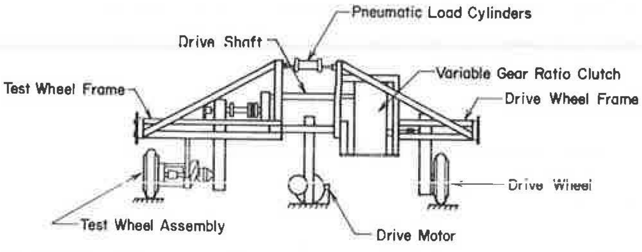
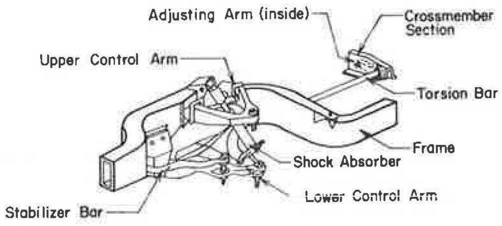


FIGURE 1 Circular track apparatus.



Quantity	Description
1	15-inch-diameter Wheel
1	Right Front Drive Axle Assembly
1	Shock Absorber
1	Front Wheel Ball Bearing
2	Hub Assembly O-Rings
4	Upper and Lower Control Arm Bushings
1	Right Front Output Shaft
1	Bearing Seal

FIGURE 2 Toronado suspension system.

It has long been known that, when an automobile attempts to stop on a washboard road, the braking traction is greatly reduced in comparison to the traction on a flat road. Preliminary work by Ingram (1) produced test data showing this loss of traction as a function of the input roadway frequency and amplitude. Ingram's work was done with a mounted tire that was allowed to slip on a flat plate to simulate braking while the plate was moved sinusoidally up and down to generate the road input. The effect of traction loss on cornering has been demonstrated by Quinn (2).

The purpose of the present study was to examine the effects of road roughness in the range from 1 to 12 Hz on the coefficient of friction between automobile tires and the road by using a more realistic quarter-car model. To accomplish the testing segment of the study, the Circular Track Apparatus (3), located at the Pennsylvania Transportation Institute of Pennsylvania State University, was used (see Figure 1). The circular track consists of a 14-ft-diameter test track on which a test suspension can be operated at various speeds and percent braking slip. For this set of tests, the right front suspension system from a 1968 Oldsmobile Toronado was used (see Figure 2). A special track surface was fabricated using sets of 16 concrete slabs (4). The slabs were cast with computer-generated, banked, sinusoidal surfaces so as to react with the tire like a straight road with sinusoidal bumps. Five sets of slabs were made: two different wavelengths, $\lambda = 16$ in. and $\lambda = 32$ in., at two different amplitudes, 0.25 in. and 0.5 in., peak-to-peak; and one set of flat blocks, $\lambda = \infty$. The first four complete track sets permitted continuous testing over the frequency range from 1 to 12 Hz at two different amplitudes. The flat track set was used to collect reference data for comparison with the sinusoidal tests. The slabs were painted with an antiskid paint to ensure that all surfaces were the same and that any changes of the tire/track coefficient of friction thus would be due only to the variations of test parameters and not to any variation in the track surface.

THEORETICAL CONSIDERATION

The principles of the tests are straightforward and will be discussed in this section. First, the static and dynamic simulation of the quarter-car model will

TABLE 2 Overview of Key Variables

Experience	Panel	Number	Sites	Vehicle	Speeds	Null Hypothesis
Panel regionality	21 Pennsylvania	1-a	Florida	K-car[a]	1 per site	No difference between the mean ratings for regionally different panels
	21 Florida	1-b	Florida	K-car[a]	1 per site	
Vehicle size	21 Pennsylvania	1-a	Pennsylvania	K-car[a]	1 per site	No difference between the mean ratings obtained from either vehicle
	21 Pennsylvania	2	Pennsylvania	Subcompact[b]	1 per site	
Vehicle speed	21 Pennsylvania	1-a	Pennsylvania	K-car[a]	1 per site	Different speeds have no effect on subjective appraisal of ride quality
	21 Pennsylvania	3	Pennsylvania	K-car[a]	1 per site but 6-8 site speeds changed	
Expert/laymen	21 Pennsylvania	1-a	Pennsylvania	K-car[a]	1 per site	No difference between the mean ratings made by expert and laymen panels
	22 experts	4	Pennsylvania	K-car[a]	1 per site	

[a] All K-cars were as identical as possible (age, mileage, tires, tire pressure).
[b] Front wheel drive.

DATA ANALYSIS

The analysis of the effect of vehicle size, vehicle speed, expert versus untrained raters and panel residence (regionality) on mean panel ratings is summarized in Table 3.

TABLE 3 Data Analysis

Analysis	Effect
Vehicle size	Mean panel ratings are unchanged when vehicle size is changed (compact versus subcompact).
Vehicle speed	Mean panel ratings are unchanged by normal changes in vehicle speed (extreme changes can cause some effect on panel ratings).
Experts versus untrained raters	Both types of panel members subjectively rate pavement sections the same
Panel regionality	Regionality has no effect on smooth roads but has a small, statistically significant effect on rougher roads. The average difference is about 0.5 scale units.

In each case, a two-way analysis of variance was used to test the hypothesis that there was no effect of the primary variable (vehicle size, vehicle speed, expert versus untrained or panel residence) on mean panel ratings.

CONCLUSIONS

The major results of this experiment can be summarized as follows:

1. There is a small, but significant effect of panel regionality (i.e., area of residence) on subjective ratings of rough roads but no effect on smooth roads.
2. There is no significant effect of vehicle size (intermediate-compact and subcompact) on subjective ratings.
3. There is no effect of vehicle speed on subjective ratings (at least for speeds within a normal driving range).
4. There is no significant difference between subjective ratings provided by "experts" and subjective ratings provided by untrained (in road evaluation) laymen. (However, highly critical, regionally diverse experts will provide statistically different ratings.)

ACKNOWLEDGMENT

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REFERENCE

1. M. S. Janoff, et al. Pavement Roughness and Rideability. Final Report. NCHRP Project 1-23, TRB, National Research Council, Washington, D.C., in preparation.