A BRIEF DESCRIPTION OF THE UMTRI TIRE/WHEEL UNIFORMITY MACHINE

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16. Abstract

This document provides a concise description of a laboratory device for measuring nonuniformities and imbalances in truck tires and wheels. With the addition of a dedicated data-acquisition and data-processing system, the device is now ready for performing tests. (The development and evolution of this machine has been supported by the Motor Vehicle Manufacturers Association (MVMA).)

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Introduction

The Tire/Wheel Uniformity Test Machine described in this report has evolved from experience gained during projects conducted over the last several years at The University of Michigan Transportation Research Institute (UMTRI). The latest improvement to the machine has been the development of a dedicated instrumentation-data reduction system, completed in the fall of 1987.

The purpose of this document is to describe the current capabilities of the machine. Results for a low aspect ratio tire are presented to illustrate measurements of forces and moments due to tire nonuniformities and imbalances.

Purpose and Capabilities

The UMTRI Tire/Wheel Uniformity Machine is a special device developed to measure tire and/or tire and wheel imbalances and nonuniformities as they affect vertical, longitudinal, and lateral forces and aligning and overturning moments of truck tires. Time histories of tire forces and moments are reduced to harmonics of the wheel rotation rate. The amplitudes and phases of these harmonics are computed, displayed, and tabulated at the end of each test run.

(The machine can also be used to measure free radial runout at various locations across the tire, for example, left shoulder, centerline, and right shoulder.)

A major challenge in building a machine of this type is to prevent machine resonances from interacting with the tire data. The UMTRI machine is unique with regard to the mounting and load cell arrangements used to provide results that are valid at high frequencies. Resonances in the machine are seen at 48 Hz for the radial force, F_z; 38 Hz for the longitudinal force, F_x; 30 to 40 Hz for lateral force, F_y; and 35 Hz for both aligning moment, M_z, and overturning moment, M_x. In terms of wheel rotation rates, the fundamental (first harmonic) of a typical truck tire traveling at 60 mph is approximately 8.6 Hz. Hence, for example, the machine produces useful results through the fifth harmonic of the radial force nonuniformity at 60 mph. At 30 mph, the validity of the results for the first 10 harmonics of F_z is not limited by machine resonances.

Description of the UMTRI Tire/Wheel Test Machine

The Tire/Wheel Uniformity Test machine (see Figure 1) consists of a road wheel, a tire carriage/transducer system, a linear variable displacement transformer (LVDT), and computer-based instrumentation. These components are briefly described below.

Road Wheel/Drive System - The road wheel is a drum that is 62.23 inches in diameter. The drum is 24 inches wide so that dual wheel assemblies can be tested. The road wheel is driven by a 75 hp-d.c. electric motor with a closed-loop control system to maintain the desired speed over the range of 0 to 60 mph.

Carriage/Transducer System - The carriage/transducer system is a fabricated structure built by UMTRI. A lathe bed is installed to provide a rigid guideway for the carriage. To increase its lateral stiffness, outriggers are added to the bed. The carriage holds the tire/wheel assembly supported by six load cells and loads the tire/wheel

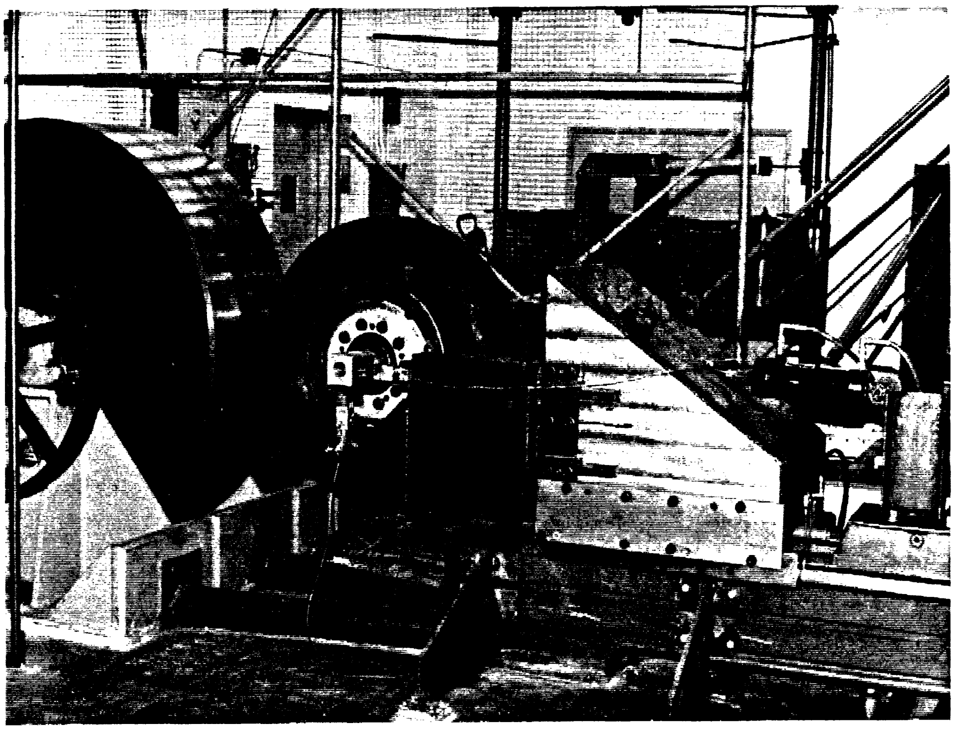


Figure 1a. UMTRI Tire/Wheel Uniformity Test Machine.

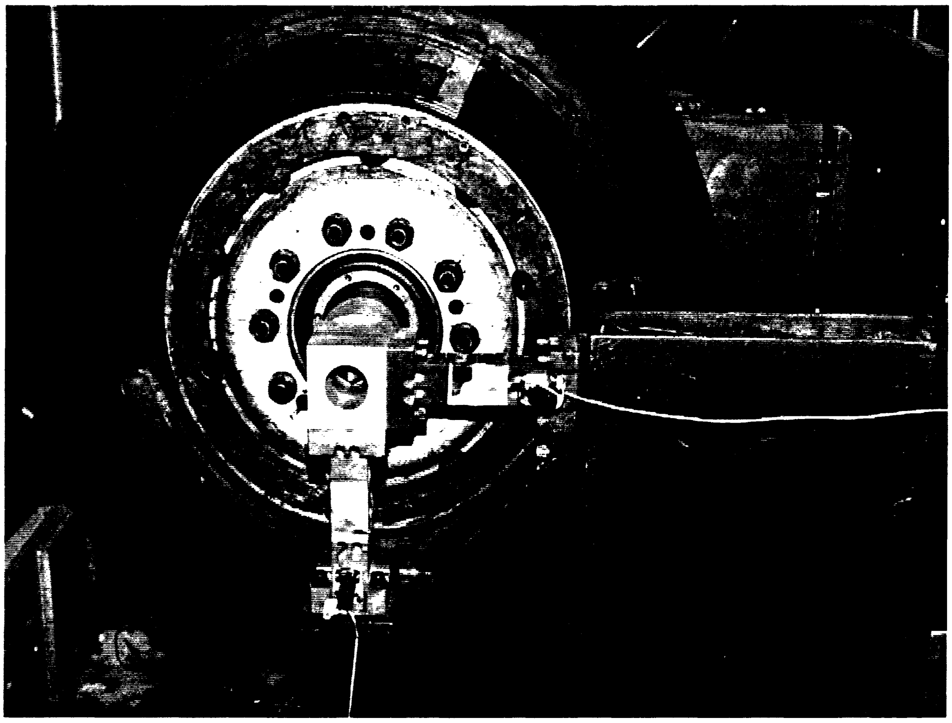


Figure 1b. Close-Up of Force and Moment Transducer.

assembly. The carriage is designed to accept both single and dual tire/wheel configurations. Out of the six force transducers (load cells), one is to measure the lateral force (F_y), two for the tractive force (F_x), and three for the radial force (F_z). All force transducers are based upon shear strain elements measured by four Kulite semiconductor strain gauges on each cell.

A seventh transducer is used to measure the wheel rotational speed. This is an optical photo-detector which produces one pulse per revolution.

Linear Variable Displacement Transformer (LVDT) - There is one LVDT that is used to measure the free radial runout properties of tires. The LVDT was constructed at UMTRI.

Instrumentation - The signals coming from the six force transducers, the LVDT, and the wheel rotation signal, are connected to a digital data-acquisition system. The signals from the transducers enter UMTRI's signal-conditioning unit where they are processed for offset, gain, and filtering. A Metrabyte 16 single-ended channel or 8 differential-ended channel analog-to-digital converter (DASH 16) is used to feed the signals into an IBM PC-XT with a 10 MB hard drive, single-sided drive, 640 KB of RAM, a MATH coprocessor, and a Hercules graphics card. The differential configuration on the DASH 16 board has been selected to eliminate a.c. noise, thus providing better resolution in the incoming signals.

Data is sampled at 250 Hz and written into the computer memory to be analyzed by a built-in computer program.

Software - The program for processing the data is written in FORTRAN. The program allows the test operator to control the gathering and processing of data using commands displayed in a menu. These commands provide means for configuring the hardware, editing previous configurations, calibrating transducers, setting gains and offsets, and collecting data. The software also has provisions for troubleshooting the system.

The software computes the harmonic content of time histories (FFT's), corrects for tire/wheel imbalance in order to separate uniformity effects from those due to imbalance, and "locates" nonuniformities with respect to a reference mark on the wheel.

Example Results

Preparations for tire testing are as follows:

1) Install the tire, orient with SN (DOT) at precision wheel position 1.

2) Inflate tire to 100 psi, load to 5,000 lb, and run at 50 mph for 15 minutes.

3) Check tire pressure and reset to 100 psi.

A typical test sequence might be as follows:

1) Imbalance test - Run the tire to 60 mph, retract and run an imbalance test. Reduce data to harmonics and save.

2) Force and moment test - Conduct force and moment variation tests at 5 and 60 mph with loads of 5,650 lb (100% load), 4,250 lb (75% load). Reduce to harmonic magnitudes and phases, correct for imbalance, and save.

3) Repeats - Repeat test 1 and 2 with the tire (DOT) oriented to positions 6, 11, and 16 on the precision wheel. (Repeats will be done only for some tires (selected randomly) to verify the performance of the machine.)

4) Free radial runout - Rotate the tire at low speed (1 to 3 mph) and measure the free radial runout on the left and right shoulders and on the centerline of the tread. Reduce to harmonic magnitudes and phases, and save.

The forces and moments measured in an imbalance test are listed in Table 1. Only the entries corresponding to the first harmonic are meaningful in this case. These entries were obtained by processing "raw" data such as that displayed in Figure 2. Confidence in the imbalance results can be obtained by noting that the F_x and F_z signals are of equal amplitude and 90 deg out of phase (see Figure 3).

The next figure (Figure 4) shows "raw" data for a force and moment test. These data include the influences of both imbalance and nonuniformity. Note that the signal for F_z (the radial force) is superimposed on an average normal load of 5,638 lb. In this case, the wheel is rotating at 8.62 Hz, corresponding to 60 mph, that is, the period of one wheel revolution is 0.116 sec. Table 2 presents the reduced data for all the forces and moments. These data are corrected for imbalance so that they provide uniformity results.

The magnitudes of the harmonics for F_z are shown in Figure 5. The data in Figure 5 and Table 2 are not valid for the sixth harmonic and above at 60 mph. (All 10 harmonics are only valid at speeds below 30 mph and below the resonant frequencies of the machine.)

Concluding Remarks

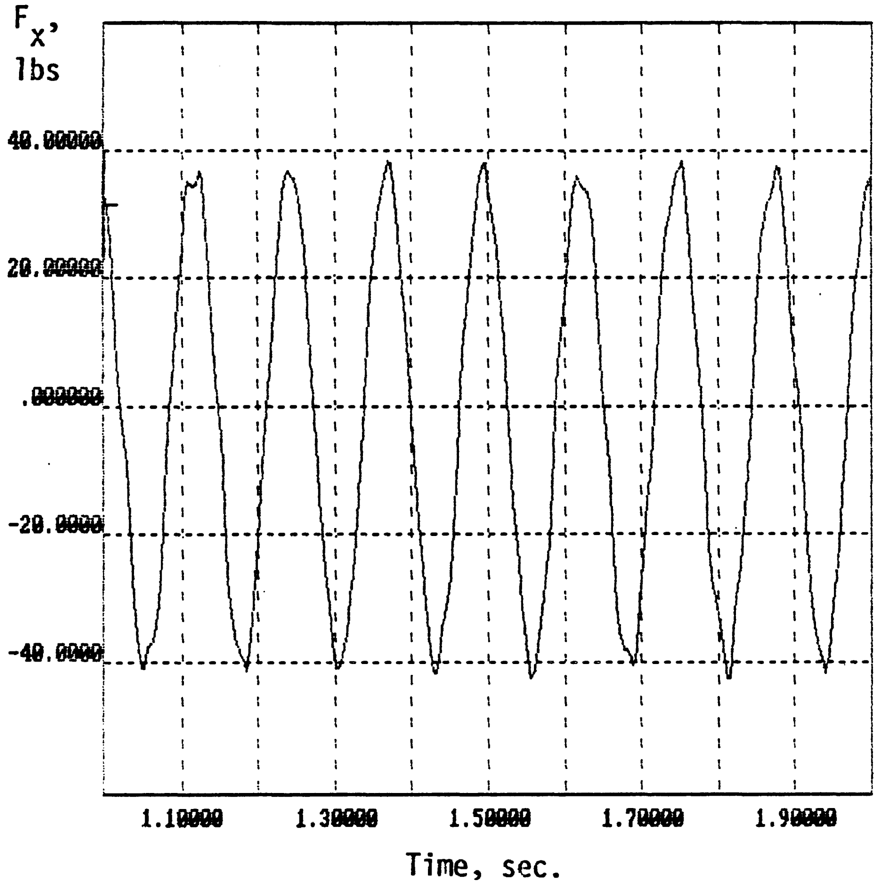
As indicated by the results presented in this short document, a working tire/wheel uniformity machine is now available for further research on the measurement of truck-tire uniformity. The development of this machine has been made possible through support from the Motor Vehicle Manufacturers Association.

Table 1. Imbalance

DATE 9-15-1987 14:26:50
TYPE OF TEST:Imbalance Test
CUSTOMER:
OPERATOR:LUIS
FILE NAME:MXZA1P-1
COMMENT:TIRE #3 MICHELIN PILOT XZA-1 RADIAL 275/80R22.5 DOT 1
****
TIRE AND WHEEL INFORMATION
TIRE IDENTIFICATION:XZA-1 RADIAL
WHEEL IDENTIFICATION:TEST WHEEL
HUB IDENTIFICATION:
TIRE INFLATION PRESSURE: 100.00
TIRE ORIENTATION: 1.00
WHEEL ORIENTATION: 1.00
DIRECTION OF TIRE ROTATION(CW OR CCW FROM OUTSIDE):CCW
SPEED(MPH): 60.00
LOAD AGAINST TIRE(LB): 5.58
FREQUENCY(HZ): 250.00
DATA CORRECTED FOR IMBALANCE: NO
RADIUS OF TIRE(IN.): 20.84
ROTATIONAL FREQUENCY: 8.065 HZ
IMBALANCE : 91.801 in-oz

Imbalance Test V =60.0 mph Load = 5.58 Lbs Rotation = 8.06 HZ

Harmonic	Fx(lb)	Fy(lb)	Fz(lb)	Mx(in-lb)	My(in-lb)	Mz(in-lb)
1	37.999	.061	37.488	123.84	.00	129.43
	(63.87)	(51.83)	(-205.23)	(-18.79)	(-60.01)	(-110.00)
2	.125	.325	.583	9.60	.00	5.59
	(-115.92)	(176.44)	(-29.84)	(-31.15)	(60.01)	(108.58)
3	.335	.339	.269	14.54	.00	16.12
	(107.66)	(-59.70)	(-137.06)	(-5.00)	(60.01)	(106.77)
4	.202	.253	.425	7.76	.00	1.98
	(113.98)	(-187.85)	(-102.51)	(282.25)	(60.01)	(190.04)
5	1.987	.067	.468	22.71	.00	2.98
	(25.11)	(-47.76)	(30.35)	(-23.33)	(60.01)	(-86.01)
6	.344	.054	1.089	14.85	.00	3.99
	(-136.87)	(-101.48)	(99.27)	(-44.88)	(60.01)	(122.64)
7	.426	.147	.787	14.70	.00	2.65
	(-263.66)	(32.08)	(135.69)	(-85.72)	(60.01)	(-249.37)
8	.282	.178	.990	15.84	.00	2.63
	(-121.53)	(-132.32)	(-3.92)	(194.68)	(60.01)	(-72.47)
9	.161	.299	1.352	12.70	.00	3.17
	(174.42)	(42.78)	(-57.41)	(145.73)	(60.01)	(153.42)
10	.390	.398	1.436	27.65	.00	9.30
	(135.86)	(-127.12)	(-76.59)	(22.82)	(60.01)	(-67.66)



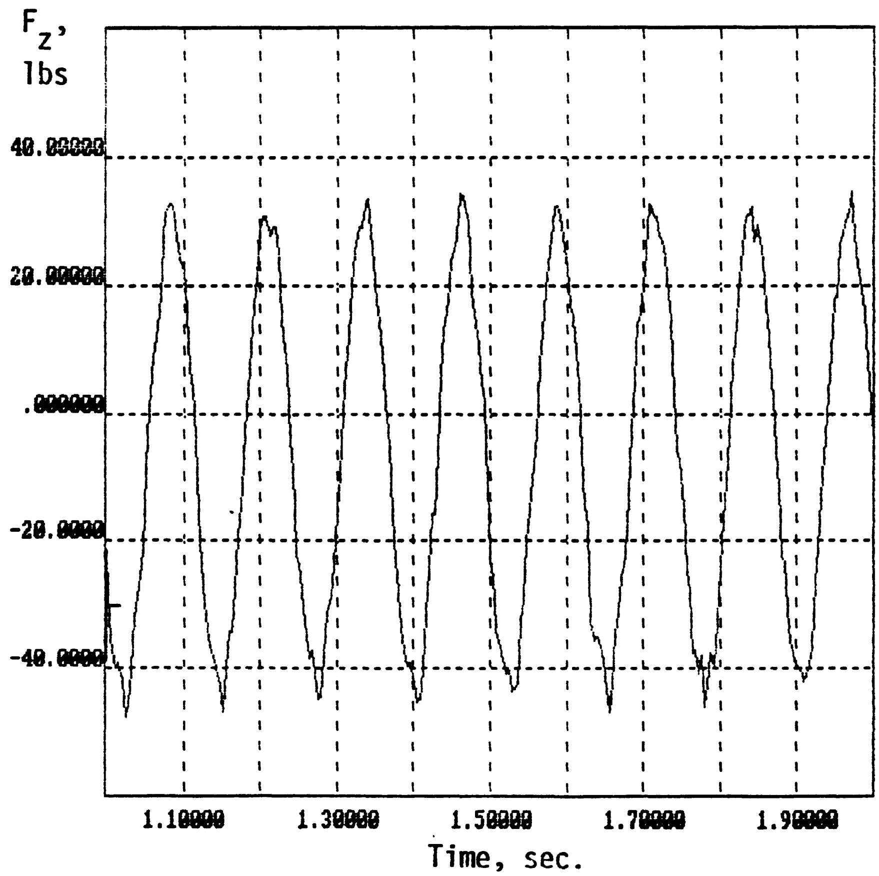


Figure 2. "Raw" data from the imbalance test.

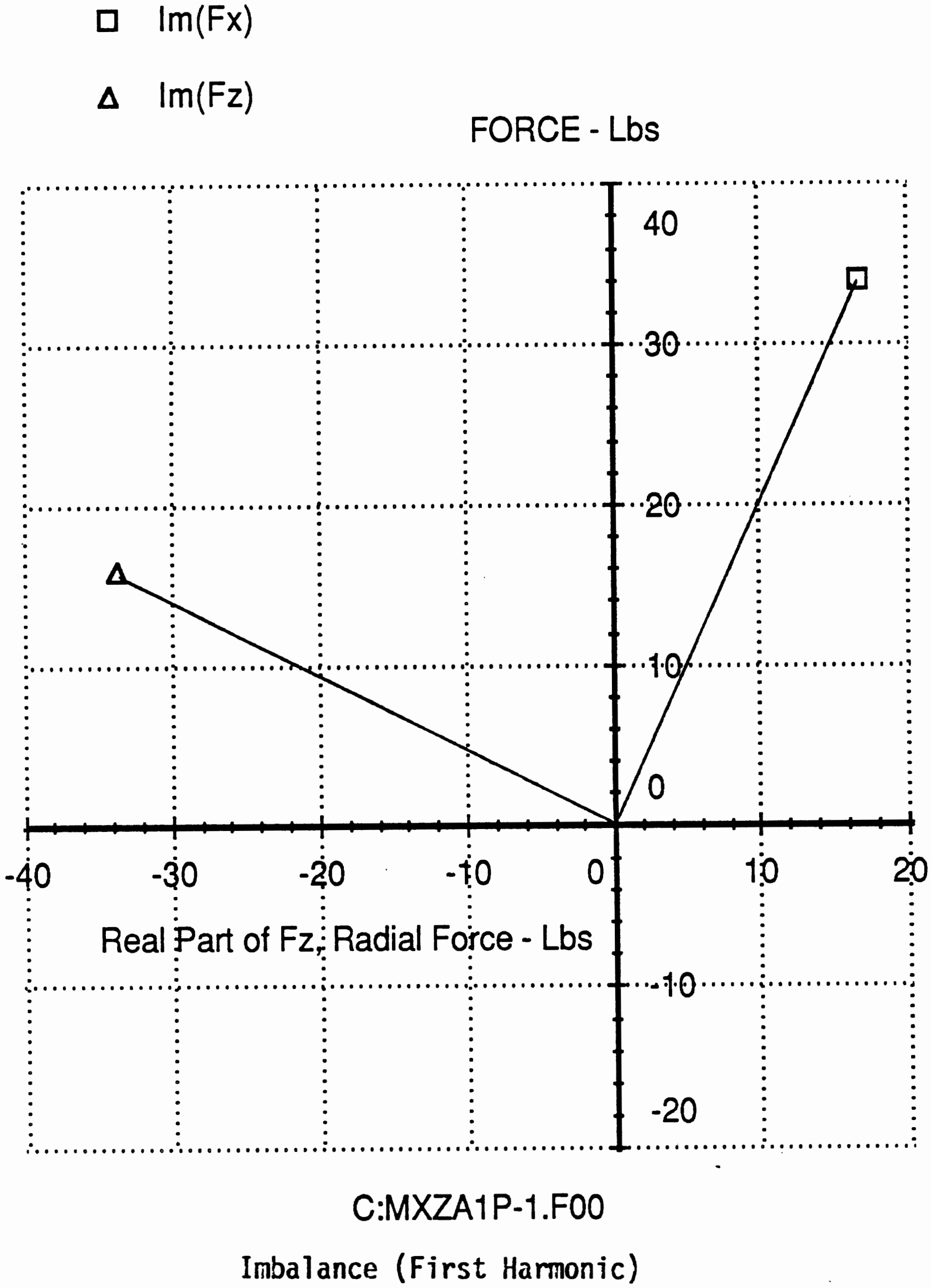
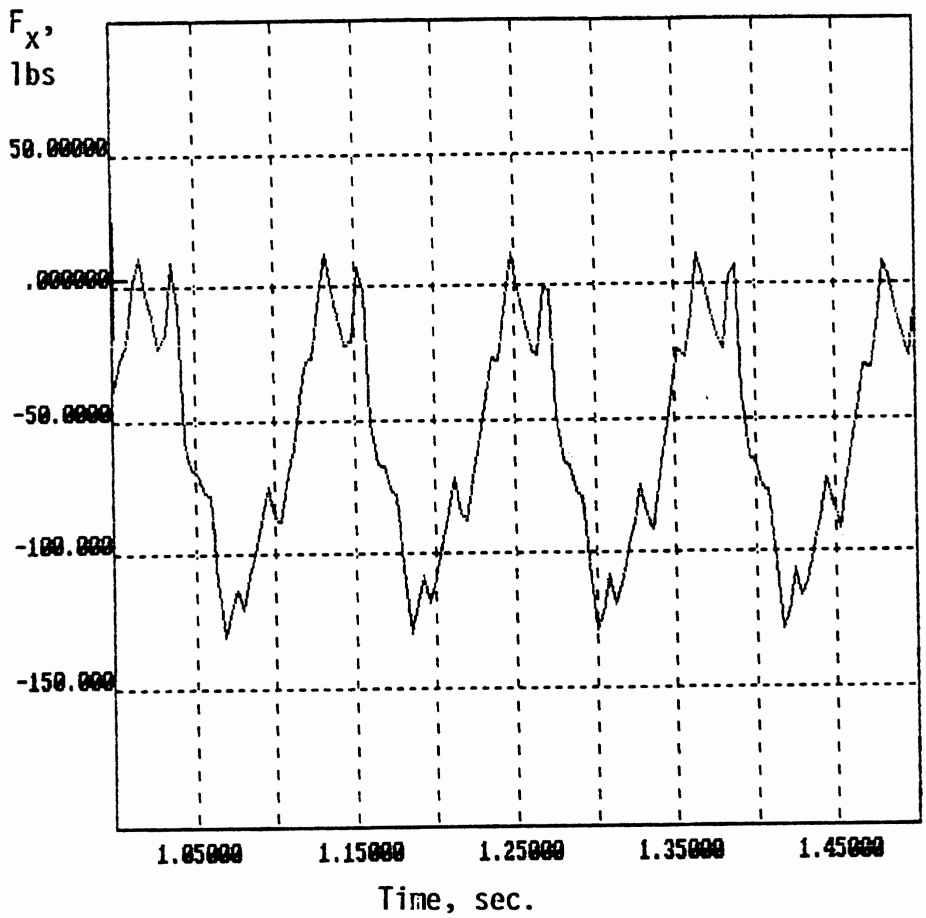


Figure 3. Verification of the imbalance results.

100% Load @ 60 mph



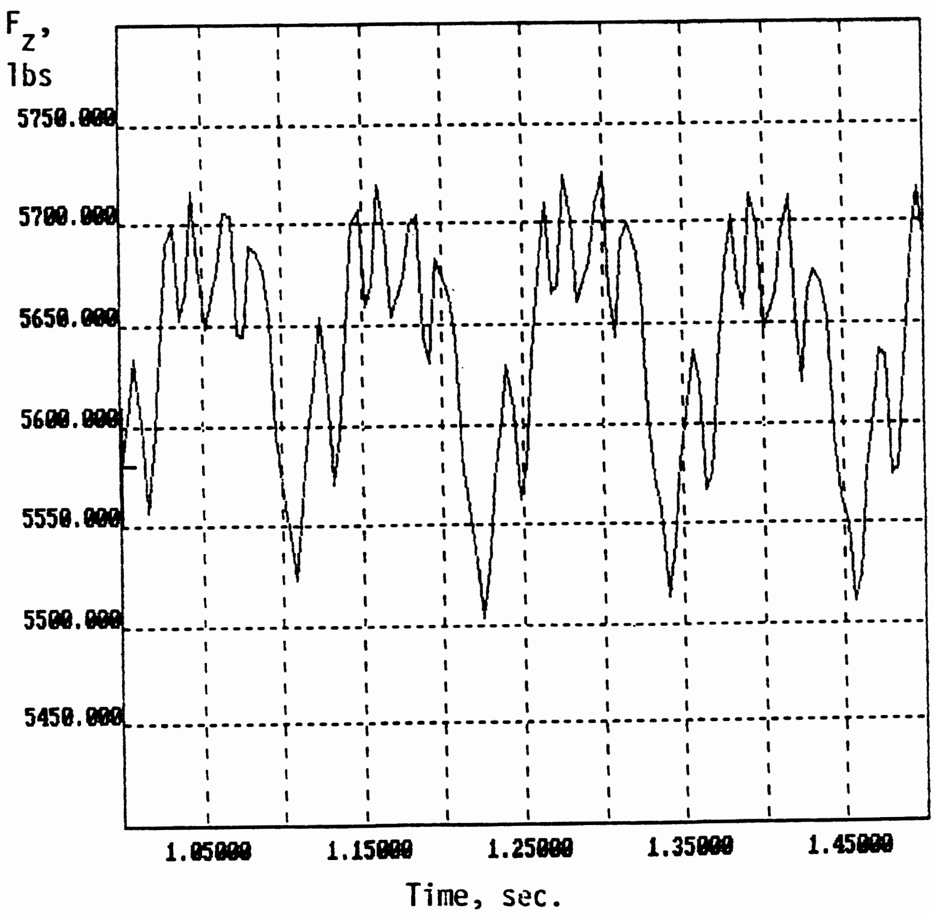


Figure 4. "Raw" data for a force and moment test.

Table 2. Forces and Moments

DATE 9-15-1987 15:10: 4
TYPE OF TEST:Force and Moment
CUSTOMER:
OPERATOR:LUIS
FILE NAME:MXZA1P-1
COMMENT:TIRE #3 MICHELIN PILOT XZA-1 RADIAL 275/80R22.5 DOT 1
****
TIRE AND WHEEL INFORMATION
TIRE IDENTIFICATION:XZA-1 RADIAL
WHEEL IDENTIFICATION:TEST WHEEL
HUB IDENTIFICATION:
TIRE INFLATION PRESSURE: 100.00
TIRE ORIENTATION: 1.00
WHEEL ORIENTATION: 1.00
DIRECTION OF TIRE ROTATION(CW OR CCW FROM OUTSIDE):CCW
SPEED(MPH): 60.00
LOAD AGAINST TIRE(LB):5638.10
FREQUENCY(HZ): 250.00
DATA CORRECTED FOR IMBALANCE: YES
RADIUS OF TIRE(IN.): 19.50
ROTATIONAL FREQUENCY: 8.621 HZ

Force & Moment Test V =60.0 mph Load = 5638.10 Lbs Rotation = 8.62 HZ

Harmonic	Fx(lb)	Fy(lb)	Fz(lb)	Mx(in-lb)	My(in-lb)	Mz(in-lb)
1	13.886	13.300	105.153	170.09	.00	14.16
	(31.91)	(21.16)	(-38.19)	(45.74)	(-8.56)	(26.16)
2	6.616	3.653	22.086	65.20	.00	1.96
	(45.16)	(218.81)	(90.32)	(-157.10)	(8.56)	(210.57)
3	7.327	2.829	17.493	50.26	.00	71.73
	(266.13)	(198.61)	(314.89)	(134.04)	(8.56)	(186.17)
4	5.507	4.382	26.763	46.10	.00	79.47
	(43.11)	(46.00)	(84.44)	(77.20)	(8.56)	(139.60)
5	6.335	.798	8.187	67.35	.00	53.66
	(27.13)	(91.52)	(227.66)	(236.86)	(8.56)	(135.93)
6	16.853	.826	33.750	83.16	.00	35.06
	(58.32)	(-205.26)	(-106.58)	(266.48)	(8.56)	(114.20)
7	6.189	3.325	20.901	89.99	.00	16.71
	(19.18)	(-115.68)	(-125.30)	(-101.11)	(8.56)	(-218.62)
8	1.694	1.403	10.480	25.40	.00	27.10
	(-246.14)	(-175.82)	(-53.32)	(27.01)	(8.56)	(21.81)
9	13.668	7.850	16.500	60.33	.00	22.55
	(52.35)	(-156.99)	(-86.64)	(-69.17)	(8.56)	(1.33)
10	51.548	12.744	112.912	395.20	.00	199.52
	(10.39)	(10.15)	(180.98)	(-171.79)	(8.56)	(15.85)

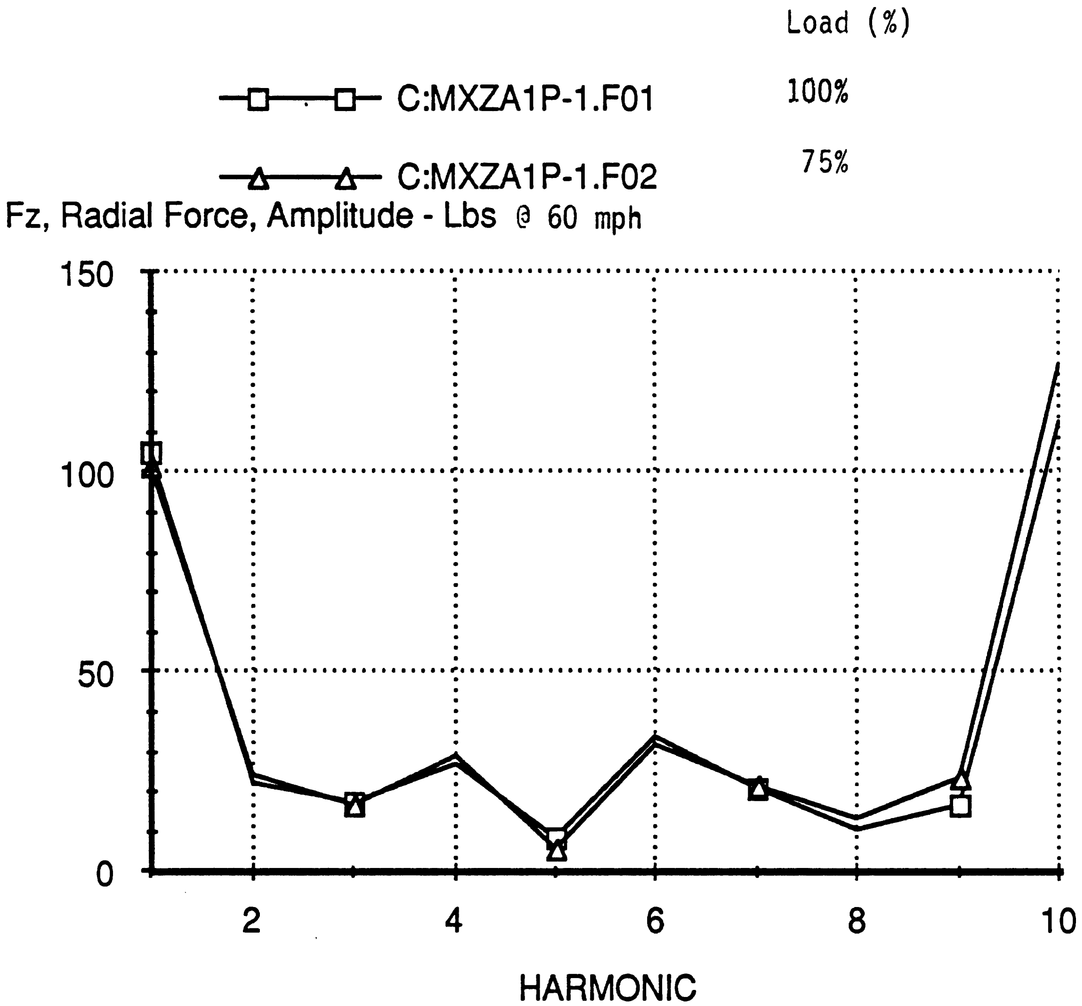


Figure 5. Harmonic content from a force and moment test.