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REPRESENTATION OF TRUCK TIRE PROPERTIES IN BRAKING AND HANDLING STUDIES: THE INFLUENCE OF PAVEMENT AND TIRE CONDITIONS ON FRICTIONAL CHARACTERISTICS

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Zeev Bareket
Paul Fancher

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16. Abstract

This study addresses the influences of frictional properties between tire tread and pavement. A semi-empirical model of the shear force properties of truck tires is used to illustrate the influences of tread groove depth, roadway skid number, and the mean texture depth of the pavement on the lateral and longitudinal forces generated by truck tires.

An existing tire model is described; additions to the model providing an enhanced representation of frictional properties are also discussed. Empirical formulas based on information published in the literature are used to represent the frictional characteristics of "poor wet roads." The influences of vertical load, forward velocity, slip angle, and longitudinal slip are included in the analyses.

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traction fields for truck tires, tire shear force, tire-road friction, modeling truck tires	UNLIMITED

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NOMENCLATURE

Symbol	Definition
a	Length of the increasing and decreasing pressure zones (see Figure 2)
α	Slip angle, degrees
C	General symbol used in representing any tire parameter (see page 5)
C_α	Cornering stiffness, lb/deg
C_y	Lateral deflection stiffness, lb/in
C_S	Longitudinal stiffness, lb/unit slip
E	Denotes scientific notation
GD	Tire groove depth, inch
MD	Mean pavement texture depth, inch
SN_V	Skid number at speed V
μ_{xs}	Sliding longitudinal frictional coupling
μ_{xp}	Peak longitudinal frictional coupling
μ_0	Combined frictional coupling value
μ	Frictional coupling
a/l or a/L	Pressure distribution parameter

L or l	Length of the contact patch
X_P	Pneumatic trail, inches
S_x	Longitudinal slip
F_Z	Vertical tire load, lb
F_{Z0}	Nominal tire load, lb
V	Test velocity, mph
V_0	Nominal tire velocity, mph
W	Width of the contact patch
x_s	Longitudinal location of the sliding boundary
P_{max}	Maximum pressure value in the contact patch
F_X	Longitudinal tire braking force, lb
F_Y	Lateral tire force, lb
A_T	Aligning torque, in-lbs

1.0 INTRODUCTION

Frictional characteristics between the tire and the road depend on both vehicle and roadway properties. In order to represent the properties of truck tires in braking and handling studies, an investigation of those characteristics has been carried out as part of a research program supported by the Motor Vehicle Manufacturers Association. An objective of the program is to develop a comprehensive model, capable of predicting tire traction performance during combined braking and steering, while taking into account the operating conditions at the tire/road interface. A block diagram describing the comprehensive model is shown in Figure 1.

During the work performed in FY 87/88, we addressed the traction characteristics from the perspective of the influence of the vertical load–that is, from the vehicle aspect. UMTRI's tire model has been revised and improved to predict more accurately influences of vertical load on side force characteristics [1]. A semi-empirical tire model was derived and then employed to study measured data of radial truck tires. Calculations to predict traction fields were also performed using the model under conditions of combined braking and steering (longitudinal and lateral slip).

The objectives of the work done during 1989 were to continue the study of the previous year's model and to investigate and incorporate within it operational conditions pertinent to roads and tires.

Tread wear and pavement texture have major influences on tire/road friction levels. In the past, based on information available in the literature, UMTRI estimated the influence of those factors on friction levels while braking on wet roads [2]. This year we have addressed the factors influencing friction levels between the tire and the road, and extended the previous model to include those factors. Several tire and friction models were investigated and compared in order to achieve a more accurate estimation of shear forces. The comprehensive model includes friction parameters, and is capable of predicting traction on both wet and dry roads.

This report starts with background information on the tire model, emphasizing the properties needed to be measured. Following that it presents the traction algorithm as discussed. This algorithm describes the operational conditions and evaluates the frictional parameters which are used later to predict traction fields. Results which were obtained from a simulation run of the comprehensive model, are then compared with an actual test

Comprehensive Tire Model — Block Diagram

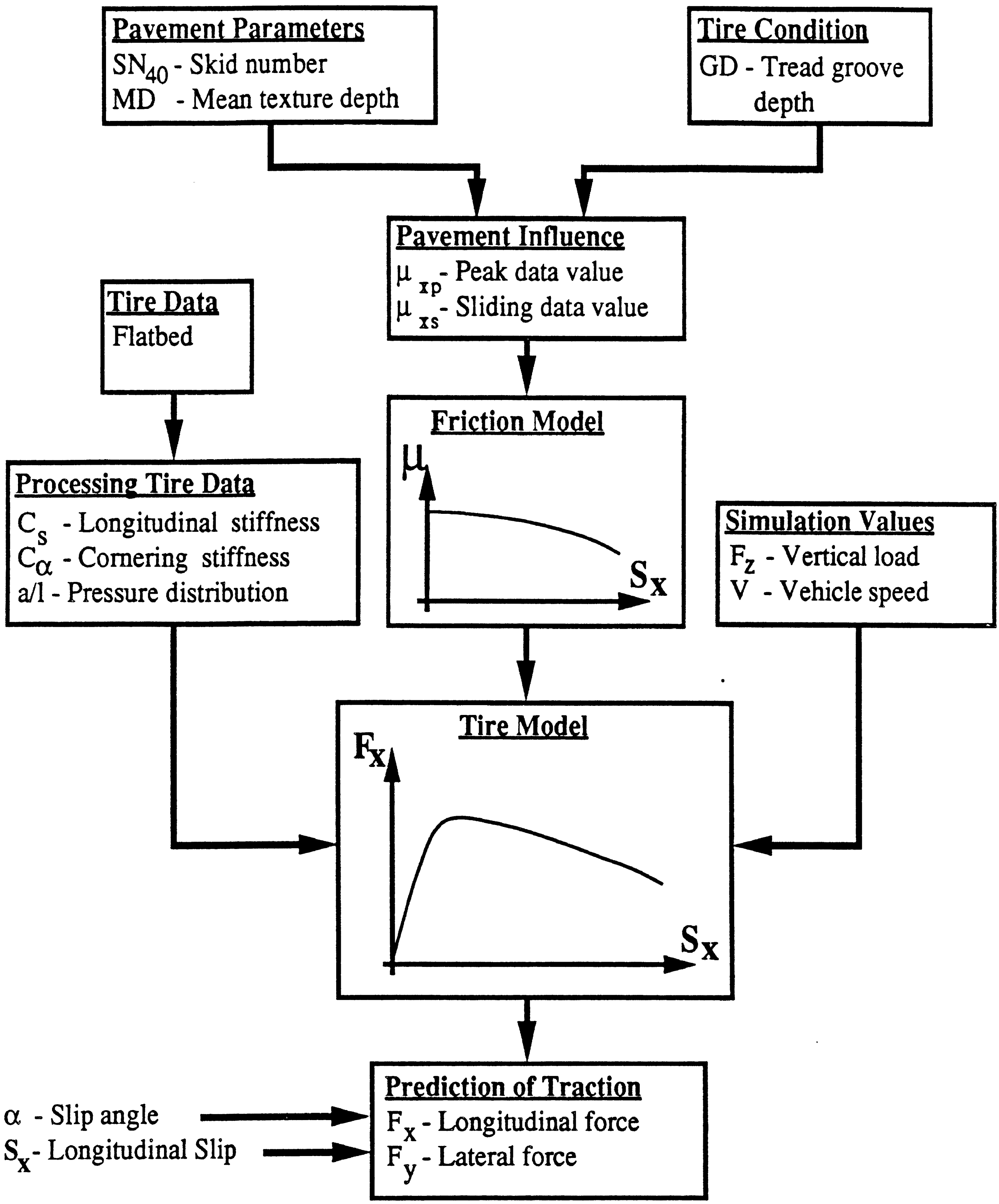


Figure 1

data set as a sample model verification. A sensitivity study is then presented to demonstrate the influences of parametric variations from a set of baseline operating conditions. The concluding section summarizes the findings and presents recommendations concerning the utility of the tire model as part of accident avoidance studies. Three concluding appendices present (a) the equations for the tire model, (b) the equations representing the frictional effects, and (c) the results computed in the sensitivity study.

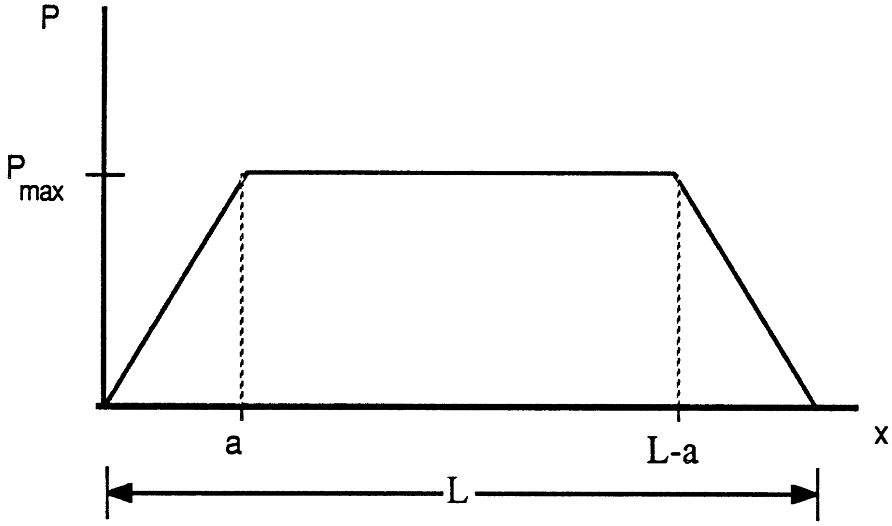
2.0 BACKGROUND ON THE TIRE MODEL

A Tire Model for Combined Steering and Braking

This study employs an extension of a previously developed semi-empirical model of the tire. Two major assumptions concerning the tire-ground contact patch were made while deriving the model.

1) The pressure distribution can be approximated by a trapezoidal shape along the length of the contact patch (see Figure 2). (Variations in pressure across the width of the contact patch are averaged together. Hence, the lateral distribution of pressure does not appear in the analysis.)
2) The contact patch can be divided into sliding and adhesive zones. (The boundary between the sliding and cornering zones is denoted by the symbol x_s.)

These assumptions are typical of those used in developing semi-empirical tire models. See References [4] and [5]. The new features of the previously developed model are the introductions of second-order polynomials to represent the changes in (the basic quantities describing the tire) a/L, C_α, and μ, as brought about by changes in vertical load. In particular, the notion that the form of the pressure distribution (as controlled by a/L) changes as vertical load changes is a new idea. In reference [1] quantitative results for the influences of vertical load on the tire's basic quantities (a/L, C_α, and μ) were derived using data from UMTRI's flatbed tire tester.



where:

$$P_{max} = \frac{|F_z|}{(L-a) * W}$$

L = length of the contact patch
W = width of the contact patch
a = length of the increasing and decreasing pressure zones

Figure 2: Approximation of the pressure distribution over the contact patch.

On the basis of these assumptions, the algorithm for calculating the stresses and forces incorporated the following principles:

1) The shear stresses in the adhesion zone of the contact patch are determined by the elastic properties of the tire. (The quantity C_α, the cornering stiffness, represents the influence of lateral elastic properties of the tire and C_s, the longitudinal (or circumferential) stiffness, represents the longitudinal elastic properties of the tire.)
2) The shear stresses in the sliding zone of the contact patch are determined by the frictional properties of the tire/road interface. (The friction level may vary with normal load, speed, and other factors.)

3) The longitudinal force, F_x, and the lateral force, F_y, are obtained by integrating the shear stress over both the adhesion and sliding zones of the contact patch. Because of the form of the pressure distribution, there are three different regions where the sliding zone may start. Using x_s to represent the point where sliding starts, these regions are:

a) Decreasing pressure region, $L-a < x_s \leq L$ (at the rear of the contact patch)

b) Central region of pressure distribution, $a < x_s \leq L-a$

c) Increasing pressure region, $0.0 \leq x_s \leq a$ (Here, the entire contact patch is sliding and there is no adhesion region in the contact patch.)

The resultant integrated equations describing the forces in the contact patch of the model are listed in Appendix A.

Measured Tire Properties Needed for Using the Model

The tire properties involved in the model, which must be provided as an input for the computer program described hereafter, are listed below. Those parameters, achieved under nominal conditions, are adjusted to the particular load and speed using linear and quadratic coefficients [1] employing the following generic equation:

$$C = C_0 + C_1 * (F_Z - F_{Z0}) + C_2 * (F_Z - F_{Z0})^2 + C_3 * (V - V_0) + C_4 * (V - V_0)^2$$

where:

F_{Z0}	=	tire nominal load, lbs
V_0	=	tire nominal speed, mph
C	=	the parameter in question
C_0	=	value of the parameter at nominal load and velocity
C_1	=	rate of change with respect to load
C_2	=	quadratic term or curvature with respect to load
C_3	=	rate of change with respect to velocity
C_4	=	quadratic term or curvature with respect to velocity
F_Z	=	simulation load, lbs
V	=	simulation velocity, mph

And the tire properties with their adjusting coefficients are:

- **Cornering Stiffness,** C_α

The cornering stiffness is obtained from the "Flatbed" measurements. Units used are Lb/deg. The coefficients with respect to load and velocity are in the following units:

Coefficient	Units
C_1	lb/deg/lb
C_2	lb/deg/lb^2
C_3	lb/deg/mph
C_4	lb/deg/mph^2

- **Longitudinal Stiffness,** C_s

The longitudinal stiffness is obtained from the tire mobile dynamometer measurements. Units used are Lb/unit slip. The coefficients with respect to load and velocity are in the following units:

Coefficient	Units
C_1	lb/lb
C_2	lb/lb^2
C_3	lb/mph
C_4	lb/mph^2

- **Lateral Deflection Stiffness,** C_y

The lateral deflection stiffness is obtained from the "Flatbed" measurements. Units used are Lb/in. The coefficients with respect to load and velocity are in the following units:

Coefficient	Units
C_1	lb/in/lb
C_2	lb/in/lb^2
C_3	lb/in/mph
C_4	lb/in/mph^2

- **Pneumatic Trail, X_p**

The pneumatic trail is obtained from the "Flatbed" measurements of aligning torque and lateral force, usually at a slip angle of 1°. Units used are inches. The coefficients with respect to load and velocity are in the following units:

Coefficient	Units
C_1	in/lb
C_2	in/lb^2
C_3	in/mph
C_4	in/mph^2

- **Pressure Distribution, A/l**

The pressure distribution is obtained from the "Flatbed" measurements, processed by the computer algorithm described in section 3.0 in reference [1]. This parameter is dimensionless. The coefficients with respect to load and velocity are in the following units:

Coefficient	Units
C_1	1/lb
C_2	1/lb^2
C_3	1/mph
C_4	1/mph^2

The parameters describing the frictional properties represented in the previous model [1] are not included here. The above discussion, pertaining to the elastic properties of the tire, applies to the revised model as well. The next section represents the new ideas used in representing the frictional conditions at the tire/road interface.

3.0 PREDICTION OF TRACTION FIELDS

The enhanced representation of tire forces capability has been incorporated into a model for predicting traction fields under different operational conditions during handling maneuvers involving combined longitudinal and lateral slip. (This model has been programmed for use on IBM PCs. Persons interested in computerized versions of the models should contact the authors of this report.) This section provides an overview of the elements of the methodology for predicting traction fields.

A Brief Description of the Computer Program

The computerized model first evaluates the frictional parameters that prevail at the tire road contact patch (using the algorithm described later). It then uses those frictional parameters to predict the tire forces— F_X and F_Y, the aligning torque, and roll-off tables relating F_X and F_Y for slip angles varying from 0° to 20° (0.35 radians), and longitudinal slips varying from 0.0 to 1.0 (free rolling to locked wheel). The forces, torques, and roll-off tables are evaluated using the tire model described in the previous section, and the equations listed in Appendix A. English units are used throughout the program. It should be noted that even though the friction and the tire model are integrated, the program still offers the user two modes of operations: the new, modified one that **includes** the friction parameters, and the previous one that **excludes** those parameters. The **exclude** mode follows the model algorithm of reference [1].

The computer program is capable of generating tables and plots in the above ranges, as well as computing a single table of forces and aligning moments for specified values of either the slip angle α or the longitudinal slip S_X. The calculations are performed at constant values of load and velocity.

Operational Conditions Pertinent to Roads and Tires

Under ideal operational conditions, the interface between the road and the tire will be dry, clean, and free of any lubricant or contamination. While performing tire tests in the laboratory (on the "Flatbed" for instance), we get as close as we can to those conditions. Since laboratory conditions seldom exist on the roadway, properties pertinent to the particular road and tire are employed for extrapolation and prediction of tire/road performance under specified operational conditions.

The following properties are used in connection with the tire model to describe pertinent properties of roads and tires:

- **Texture Depth, MD**

The mean texture depth represents the surface macrotexture characteristics of the road, and evaluates the road's ability to drain away any lubricant or contamination that reduces friction. It can be measured by a standard "sand-patch" test, where a known volume of fine sand is applied to cover some area of the road until level and flush. The depth is then easily evaluated from the magnitudes of the area and the sand volume. Units used are inches.

- **Skid Number, SN**

The skid number is a standard ASTM parameter, used to describe the adhesion level of the pavement. It is derived using a standard tire. Since the standard test evaluates the skid number at a speed of 40 mph, that number is referred to as SN_{40}. The skid number at any other speed (SN_v) can be derived analytically, as described later. The smoother the texture, the more lubricated and contaminated the road is, the lower the SN value. A poor, wet road is such that its SN is below some predetermined value; for example, a road with an SN value of 34 and below is considered dangerous by the Alabama State Highway Department [4].

Though the skid number and the mean texture depth are used as separate input parameters in the following friction model (and subsequently in the computer program), one should be aware that they relate to each other: a smooth road with a low measure of MD cannot have too high a value of SN, and vise versa. The skid number is dimensionless.

- **Groove Depth, GD**

The groove depth is a tire parameter that represents the same qualities as the mean texture depth of the road—the ability to evacuate contaminations. The model uses groove depth to compute the frictional characteristics of the tire/road interface.

Units used are inches. Yet it should be noted that the model is based on conventional tire measurements with a maximum tread depth of 12/32" (0.375"). This maximum tread depth is used as shown in the following tire model to determine the tire status (condition) between new and bald. The computer program, therefore, automatically replaces higher input values for GD with 0.375" (see Fig. 3 which qualitatively illustrates the frictional relationship between new and bald tire conditions).

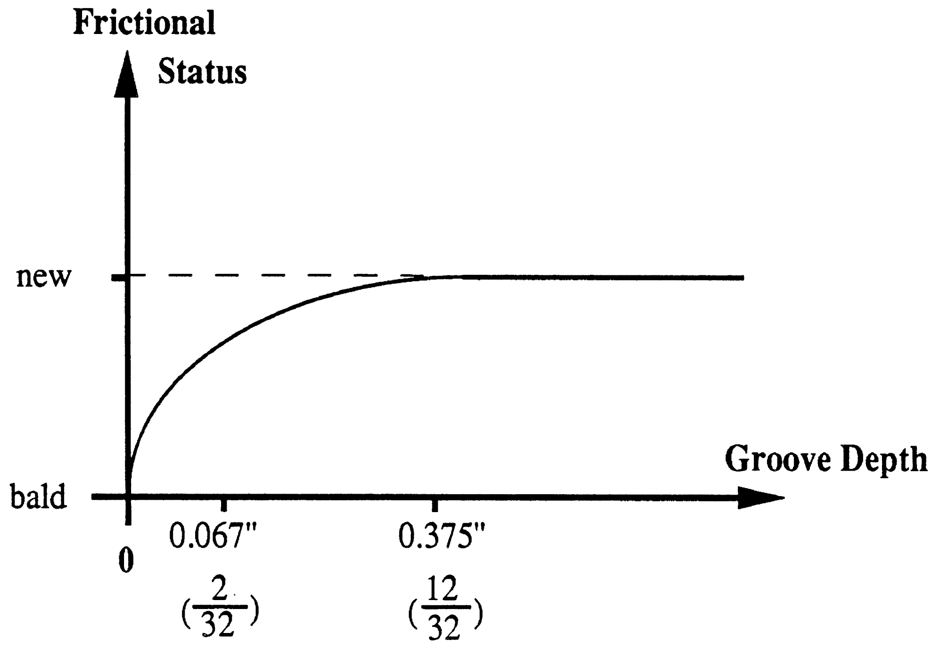


Figure 3: Variation of tire status with groove depth

Tire tread pattern was not brought into consideration in the frictional model, although is is known to influence wet traction. Perhaps groove volume might be used in future research and modeling efforts.

Furthermore, groove depth is known to have a strong influence on cornering stiffness. However, measured data from the flatbed machine can be used to determine the elastic properties of worn tires.

Friction Model and Frictional Effects

The previous friction model between the tire and the road was of a linear nature, involving factors which were rather complicated to evaluate V_S, the sliding velocity, and A_S, a friction reduction factor. This linear friction model was found to be a rather crude way of representing the frictional mechanism between the tire and the road. Some different friction models were developed and tested, and the one that consistently fit the available tire test data was of a parabolic nature. This semi-empirical friction model is based on an equation of the following form:

$$\mu = \mu_0 - (\mu_0 - \mu_{xs})\cdot[S_x^2 + \tan^2\alpha] \qquad \text{for } S_x^2 + \tan^2\alpha \leq 1$$

The form of the frictional model and the manner in which it governs the tire model is demonstrated in Fig. 4. This Figure provides a qualitative representation of the relationship between normalized longitudinal force and longitudinal slip.

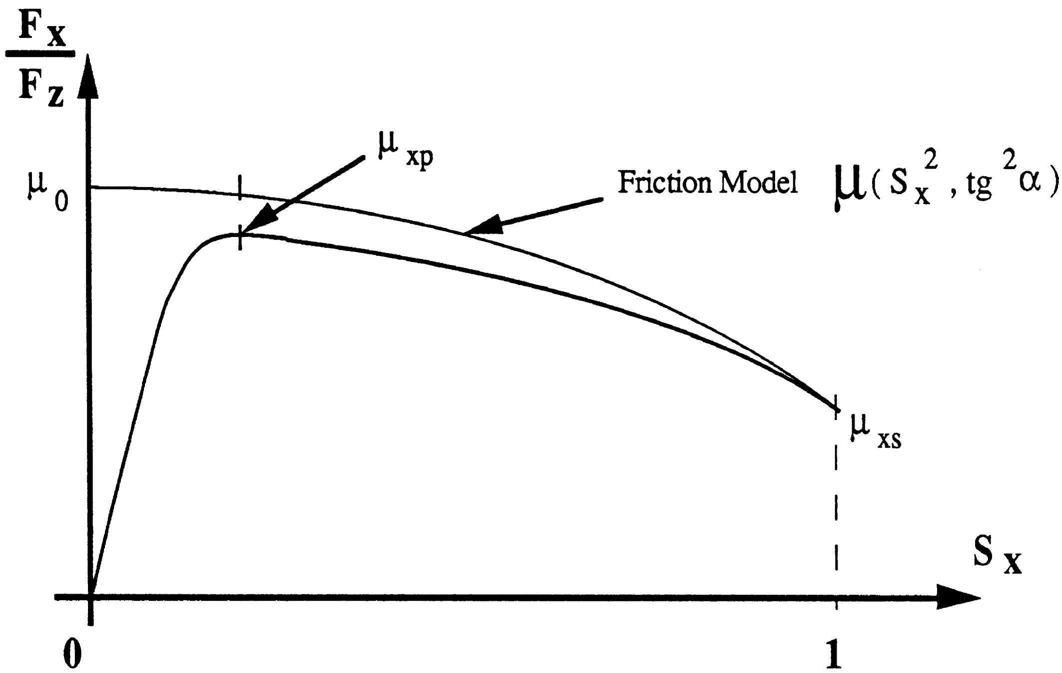


Figure 4: Friction and tire model—longitudinal force

The peak and sliding values of the friction (μ_{xp} and μ_{xs} respectively) are evaluated by employing the semi-empirical model described in Appendix B.

4.0 SAMPLE MODEL VERIFICATION

In order to verify and examine the accuracy of the model, measurements for a Michelin 11R22.5 XZA (new) tire were used [13]. The test, the results of which are listed in the following table, was conducted on both dry and wet concrete roads using various loads and speeds.

Approximate values of the road characteristics were:

Skid numbers (SN): 60 (dry concrete)
45 (wet concrete)
Mean texture depth (MD): 0.04 inch.

Dry concrete

V (mph)	20	40	55
	$F_z = 9060$ lb.		
Peak F_x	6886	—	—
Slide F_x	4610	—	—
	$F_z = 6040$ lb.		
Peak F_x	4903	4711	4772
Slide F_x	3886	3503	2899
	$F_z = 3020$ lb.		
Peak F_x	2627	—	—
Slide F_x	1981	—	—

Wet concrete

V (mph)	20	40	55
		F_z = 9060 lb.	
Peak F_x	6342	—	—
Slide F_x	4610	—	—
		F_z = 6040 lb.	
Peak F_x	4047	3443	2839
Slide F_x	3375	2657	2174
		F_z = 3020 lb.	
Peak F_x	2084	—	—
Slide F_x	1842	—	—

Using the same road and tire parameters a computer model simulation was performed. The resultant predicted peak and slide tire forces, were plotted for the different loads and speeds, versus the measured tire forces (Figure 5).

The fitted line for this particular set of data is: $Y = -115.8 + 1.03\ X$ (R=0.95). The deviation from the "ideal", theoretical line $Y = X$, is within reasonable limits.

Calculated model forces versus actual test data forces

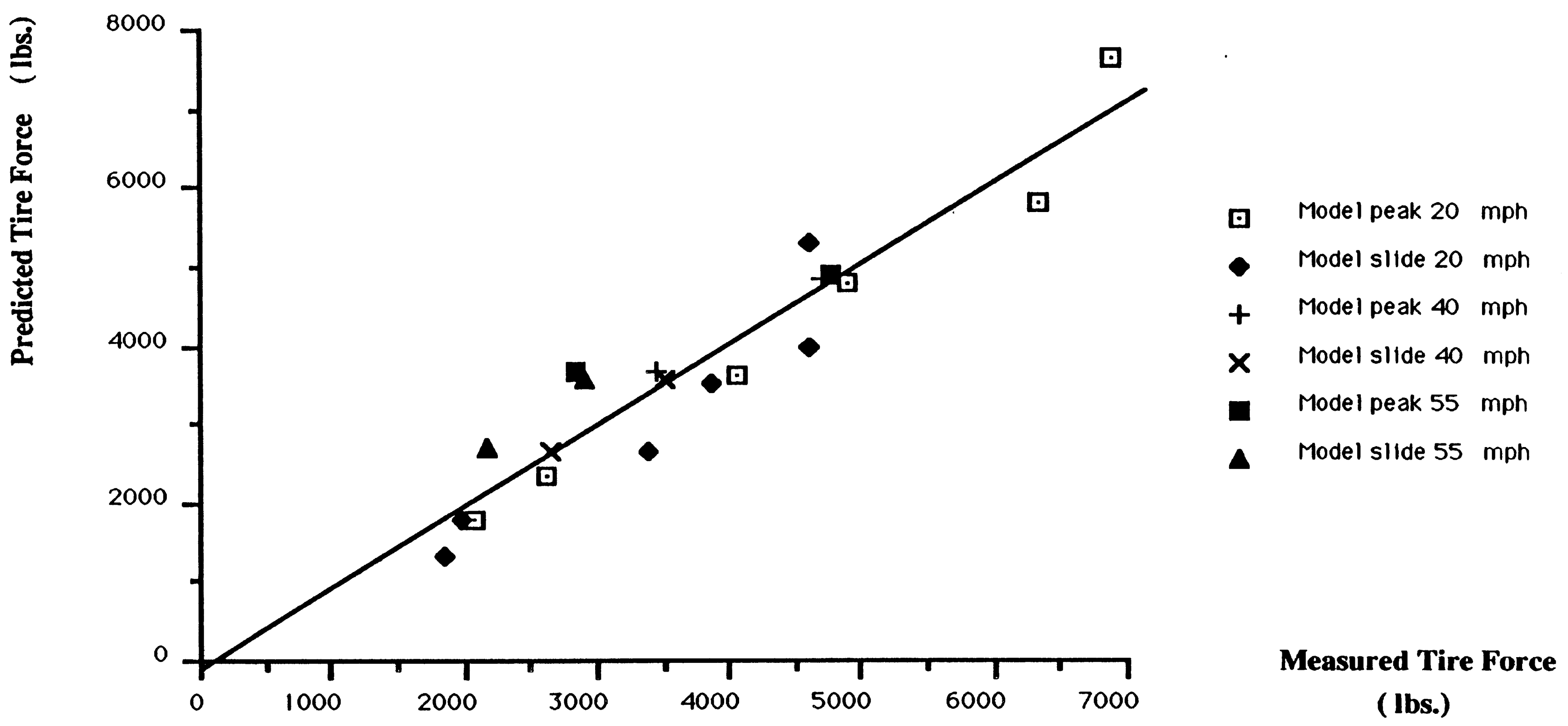


Figure 5

5.0 SENSITIVITY STUDY

The sensitivity of the model to variations in the road and loading parameters was studied by first establishing and using the model to analyze the tire/road performance for a reference set of conditions (baseline). Then the parameters were varied within a predefined range, and the model was employed to study these conditions. Simulation runs were performed for slip angles of 0°, 1°, 4° , and 8°. The baseline performance, and the influence of parametric variations on them, is described below.

Baseline Conditions

The following set of tire/road data was taken as a baseline set of conditions:

SN_{40}	= 40	
MD	= 0.04	inch
GD	= 0.2	inch
V	= 40	mph
F_z	= 6040	lb.

The set represents a used truck tire, under nominal rated load, rolling at a moderate speed on a typical road. Fig. 6 shows the tire's combined longitudinal (F_x) and lateral (F_y) forces for slip angles of 1°, 4°, and 8°.

Influences of Variations in Road and Tire Pertinent Properties

The results of the study of the influence of variations in tire-road properties have been portrayed in four aspects as follows:

1. Plotting the resultant tire combined forces— F_y versus F_x for each parameter variation (see Figures 9 through 28, which are similar to Figure 6).
2. Studying variations of normalized peak longitudinal force (F_x/F_z), for each variation in the parameters (see Figures 29 through 33). Each plot contains the variations for slip angles of 0°, 1°, 4°, and 8°.

Model simulation as a basis for comparison

(Baseline run)

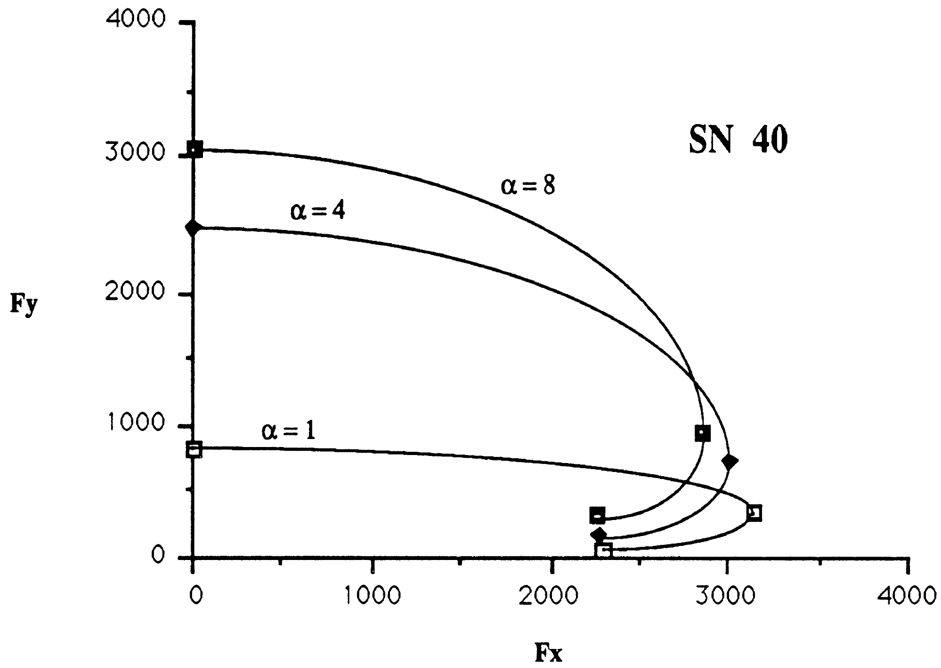


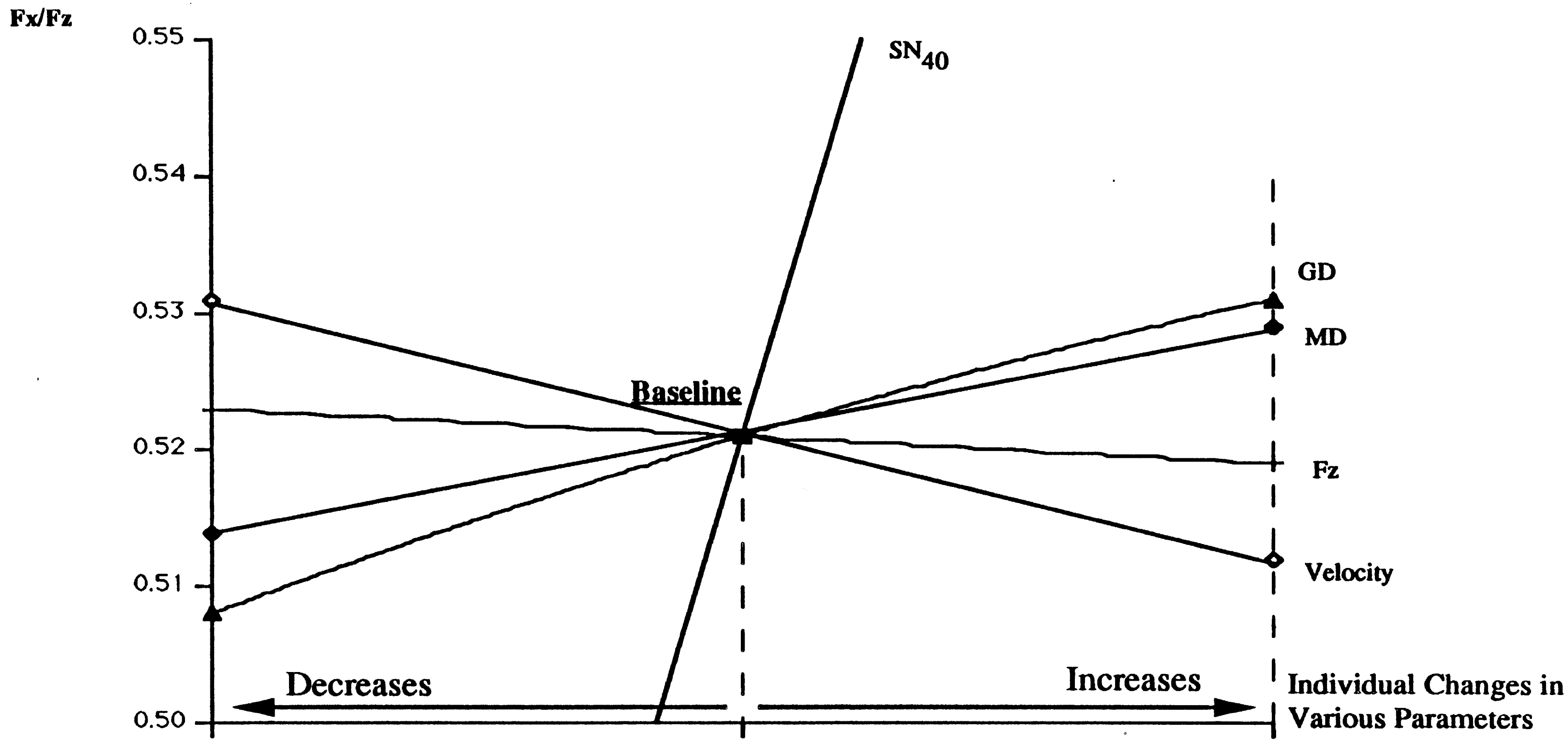
Figure 6.

3. For each change in a parameter, the value of the resultant normalized peak F_X/F_Z was plotted (Fig. 7). It should be further emphasized that during the parametric sensitivity study only the parameter in question was changed. The rest of the parameters remained at their baseline values. Since the changes were over a certain range of values for each parameter (see page 32), the common center "lever" point in Fig. 7 represents the baseline condition, whereas to its right and left on the X-axis, lay the upper/lower bounds of the individual parameters variations. Using those values, we get in Fig. 7 the lines along which the normalized force changes with the particular parameter. The larger the slope of that line, the more significant influence that parameter has on F_X/F_Z .

4. A range bar chart was drawn. It shows the maximum and minimum resultant values of normalized force, as we change the parameters from one predetermined extreme to the other (Fig. 8). The "Baseline Run" line represents the normalized peak F_X under baseline conditions—0.521.

Figures 7 and 8 provide qualitative overviews summarizing the results. Detailed discussions of the influences of the individual parameters follow Figure 33.

Effect of different parameters on the normalized peak Fx



Lower Bound	Baseline Conditions	Upper Bound
MD = 0.02 in	MD = 0.04 in	MD = 0.06 in
GD = 0.06 in	GD = 0.2 in	GD = 0.375 in
V = 20 mph	V = 40 mph	V = 60 mph
Fz = 3020 lb	Fz = 6040 lb	Fz = 9060 lb
SN_{40} = 20	SN_{40} = 40	SN_{40} = 60

Figure 7

Range of normalized peak Fx with parameters

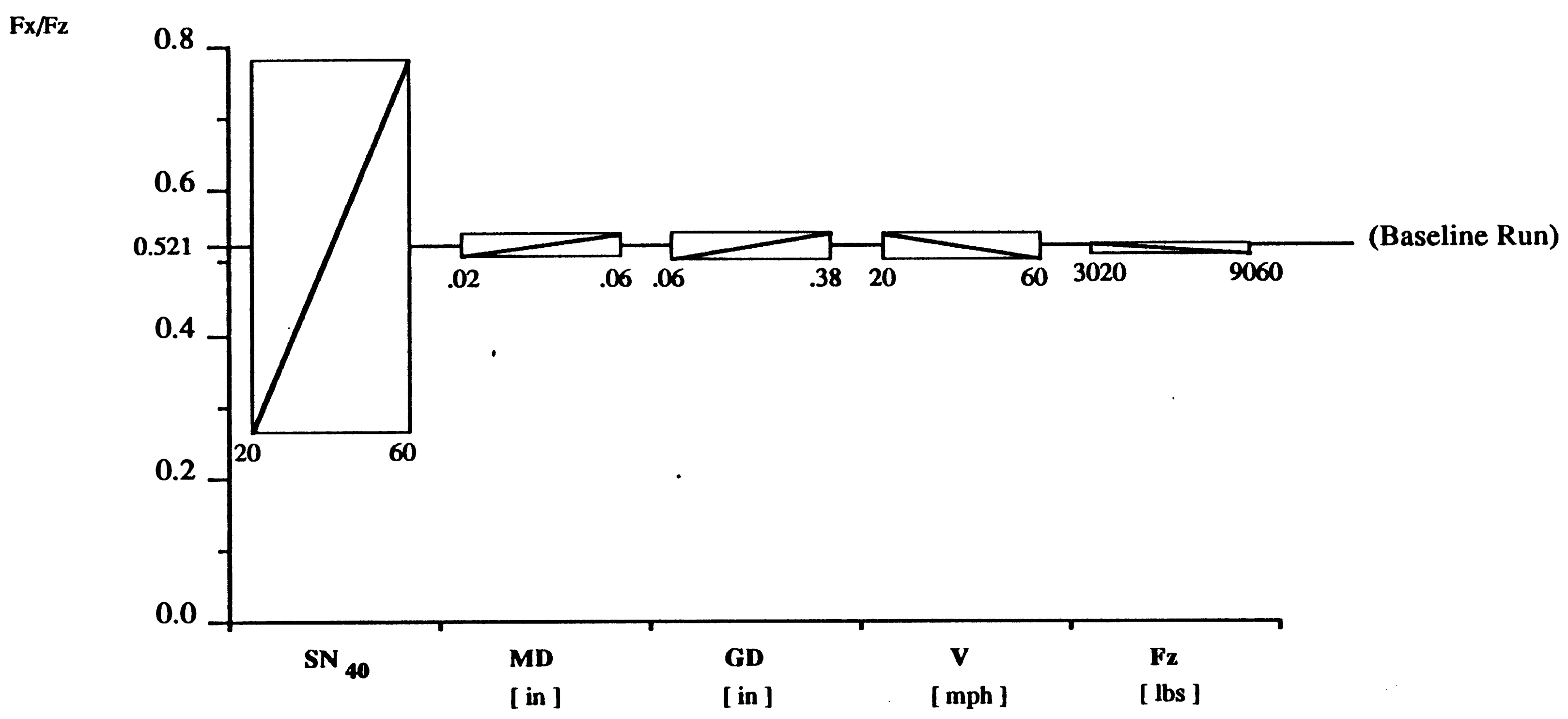


Figure 8

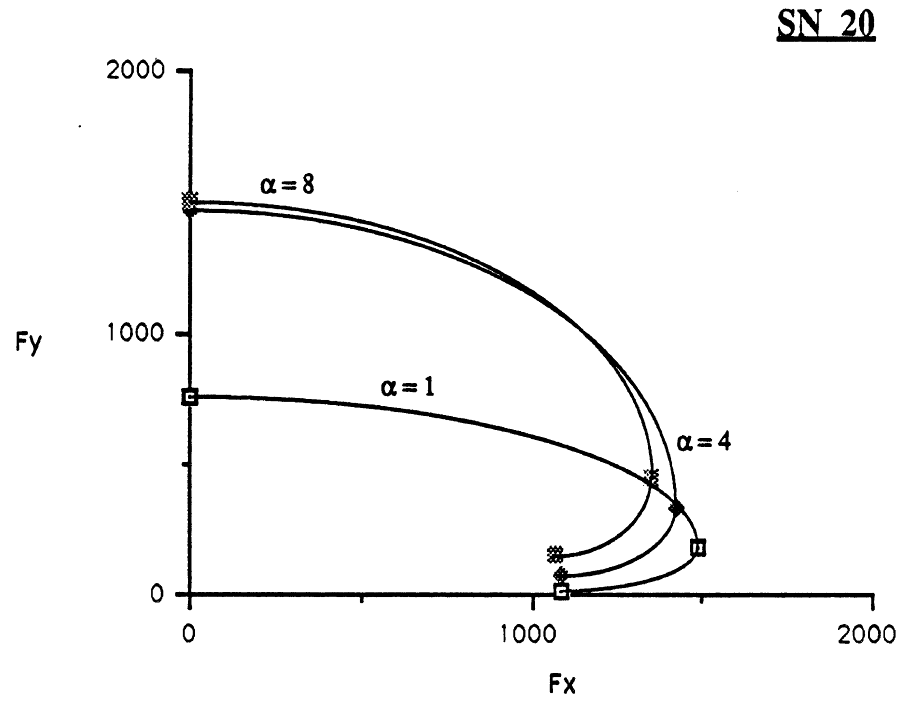


Figure 9

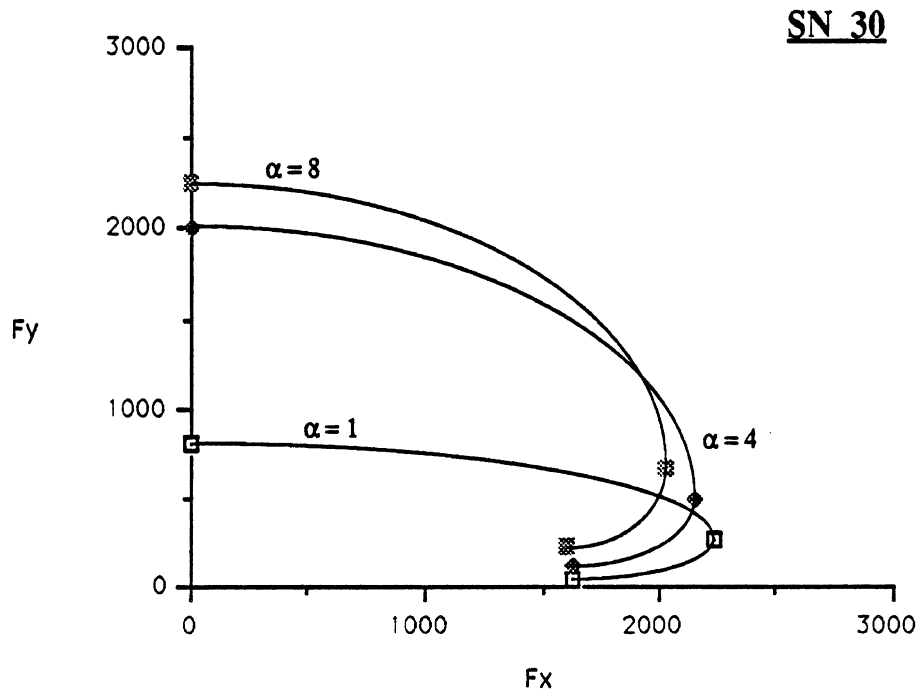


Figure 10

SN 50

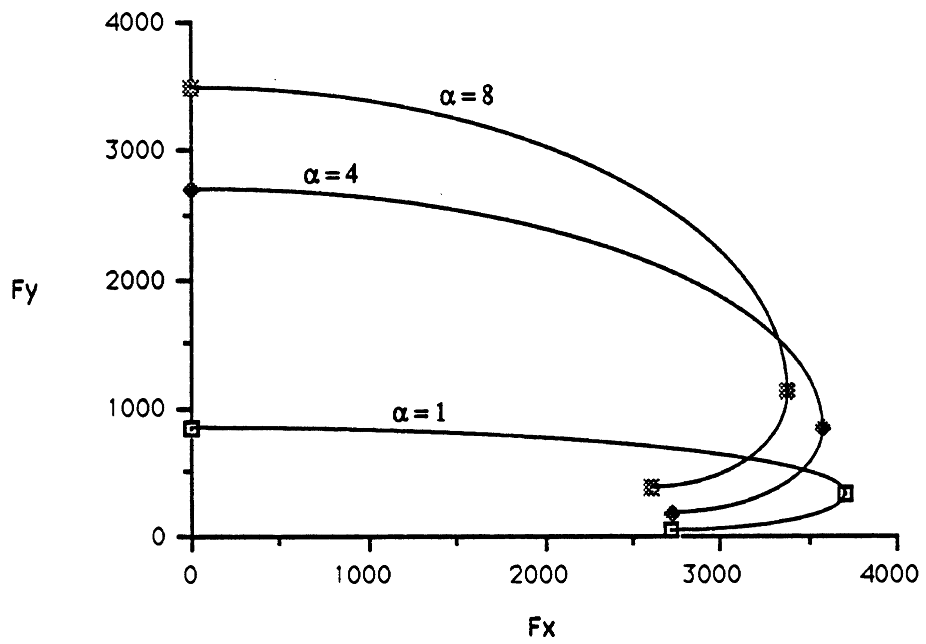


Figure 11

SN 60

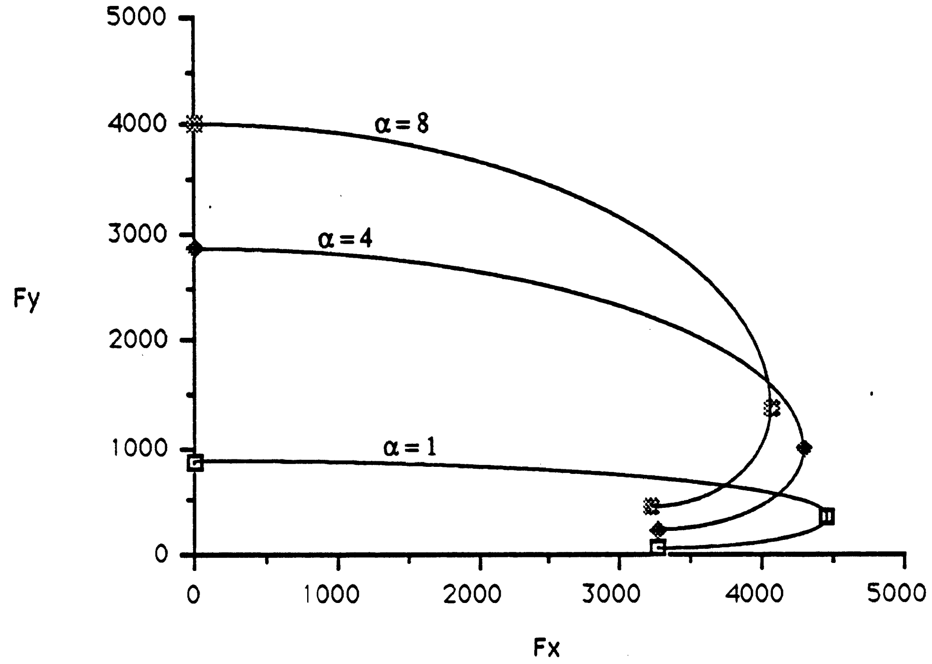


Figure 12

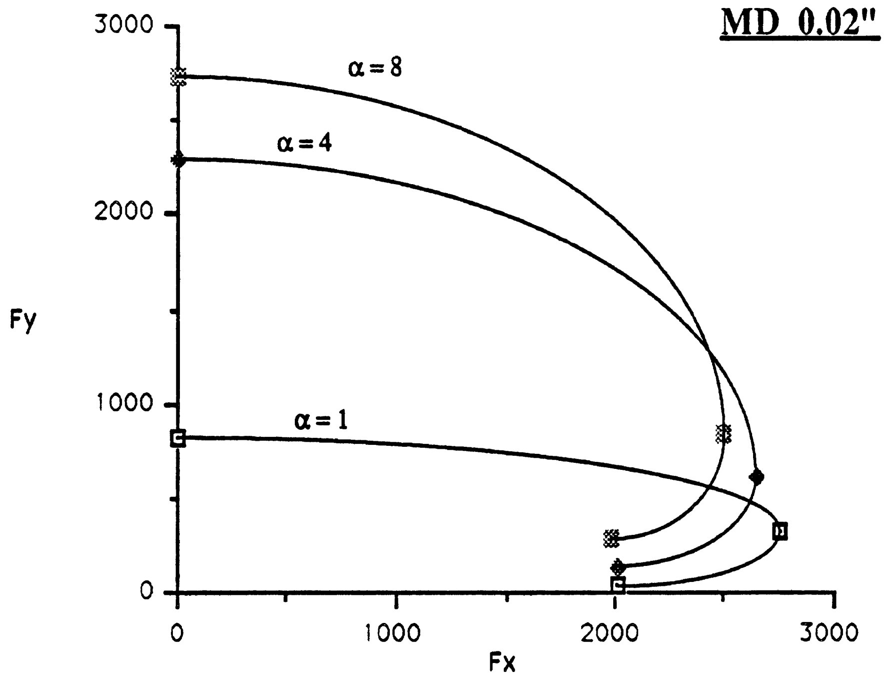


Figure 13

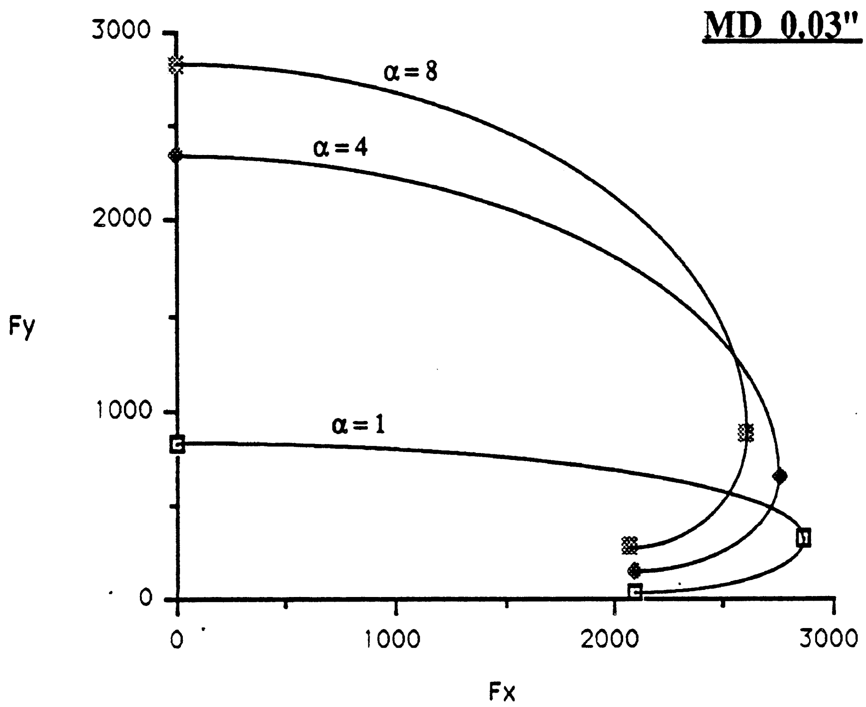


Figure 14

MD 0.05"

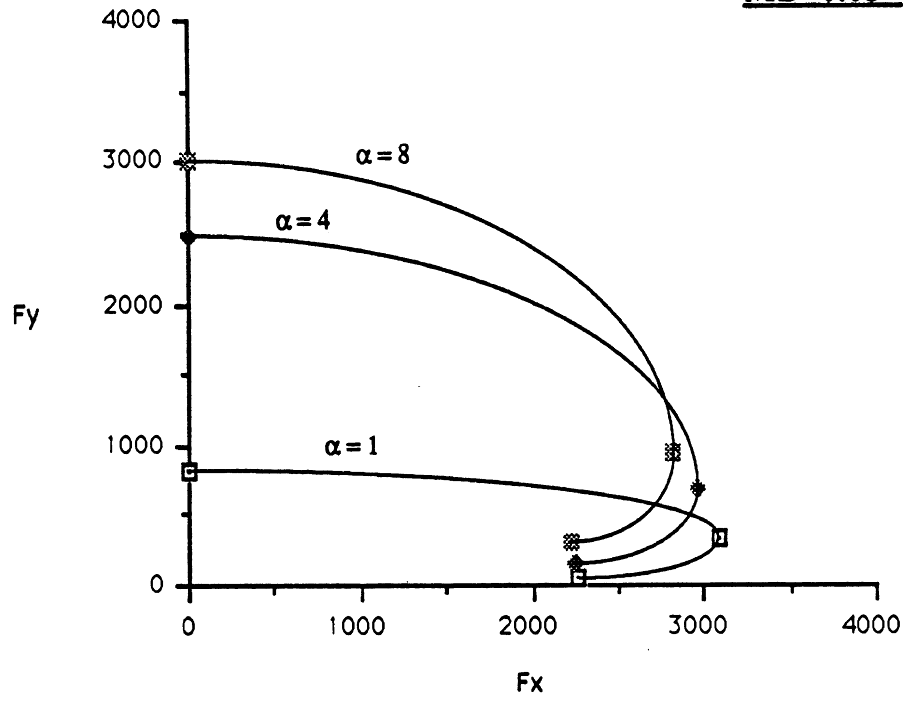


Figure 15

MD 0.06"

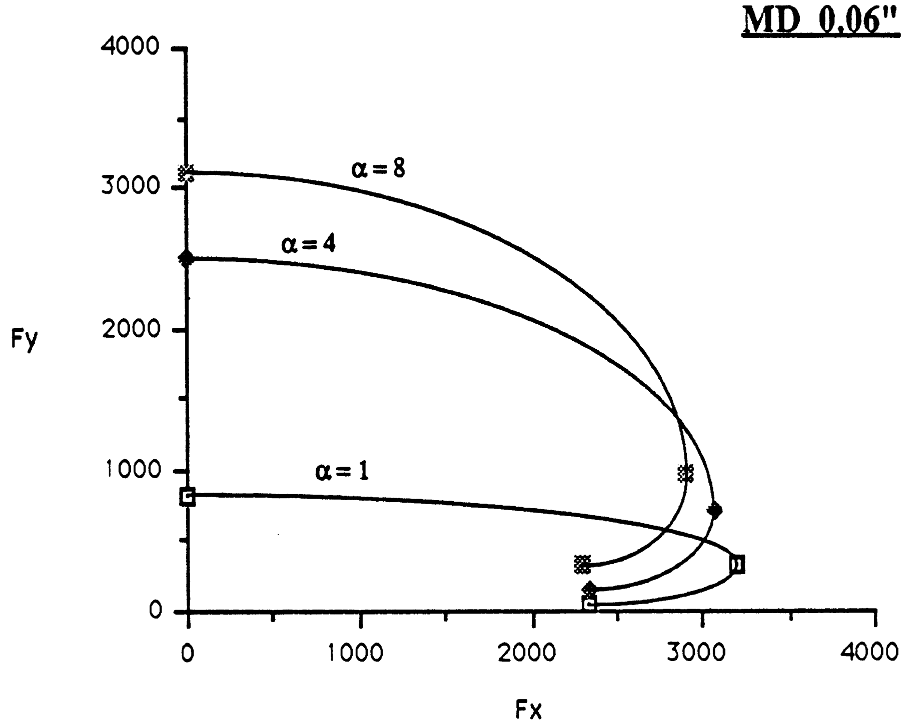


Figure 16

GD 0.06"

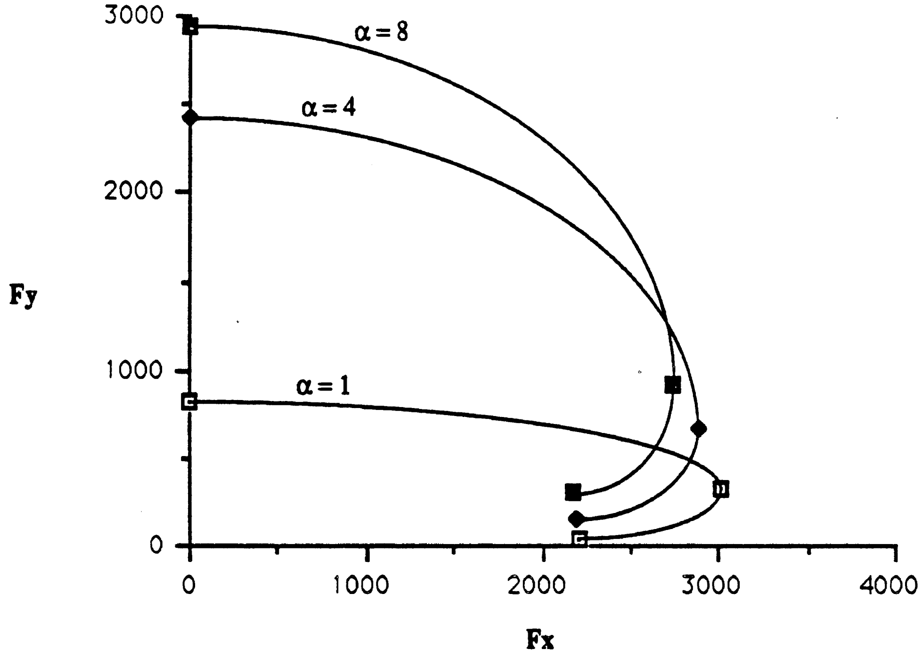


Figure 17

GD 0.13"

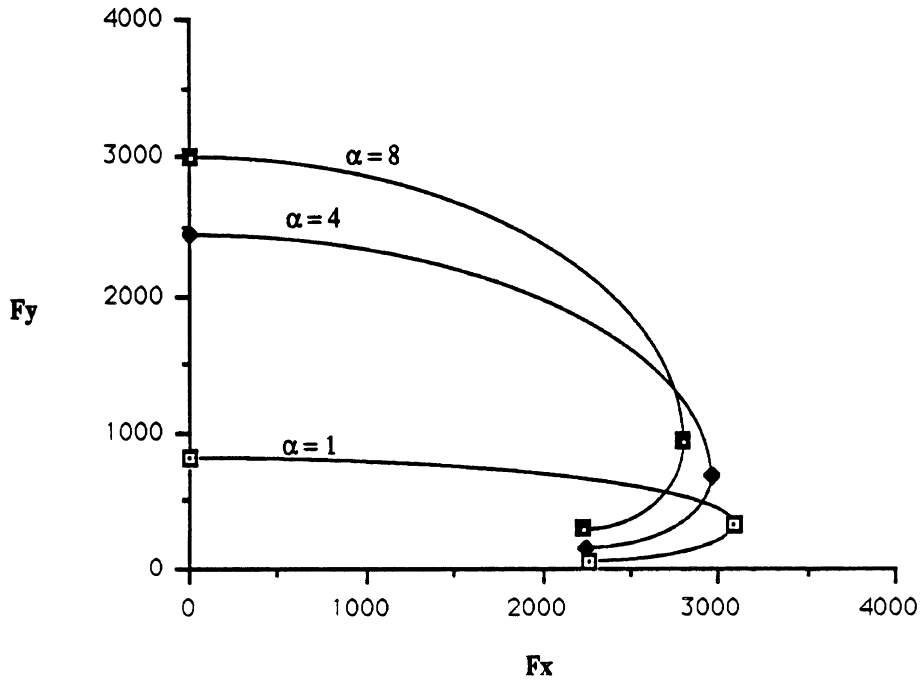


Figure 18

GD 0.29"

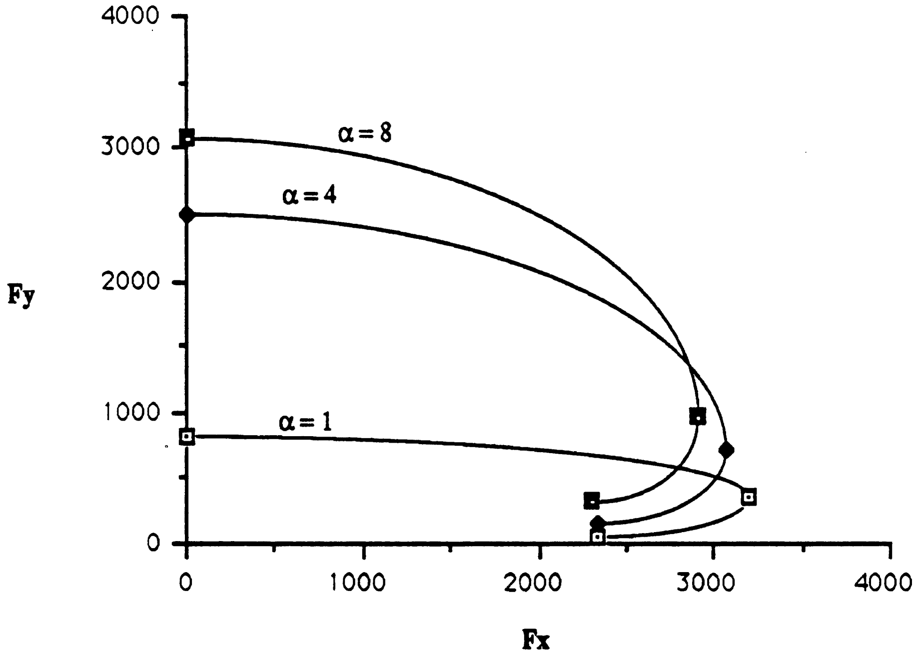


Figure 19

GD 0.38"

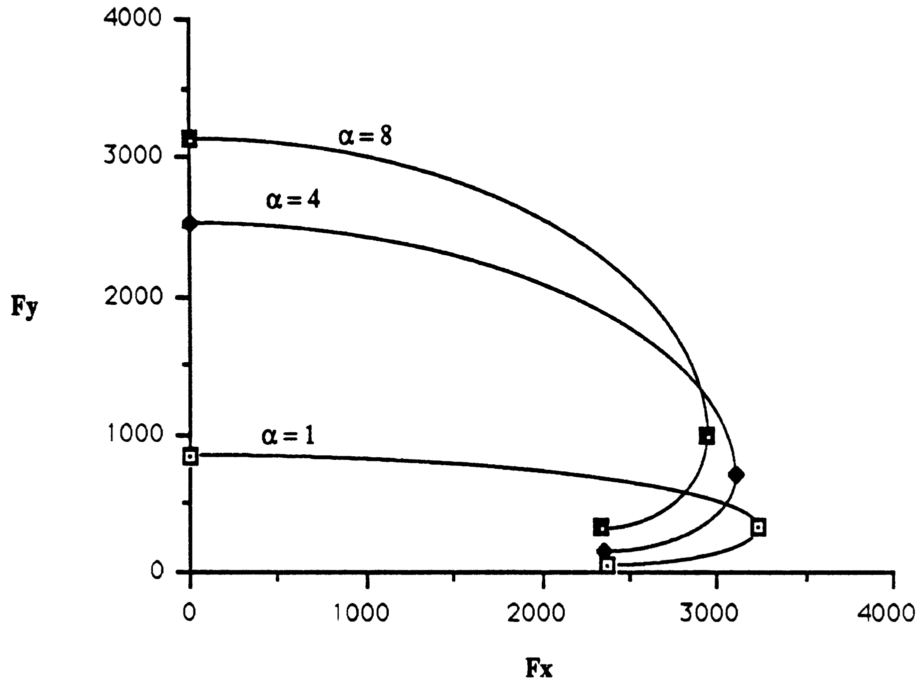


Figure 20

20 mph

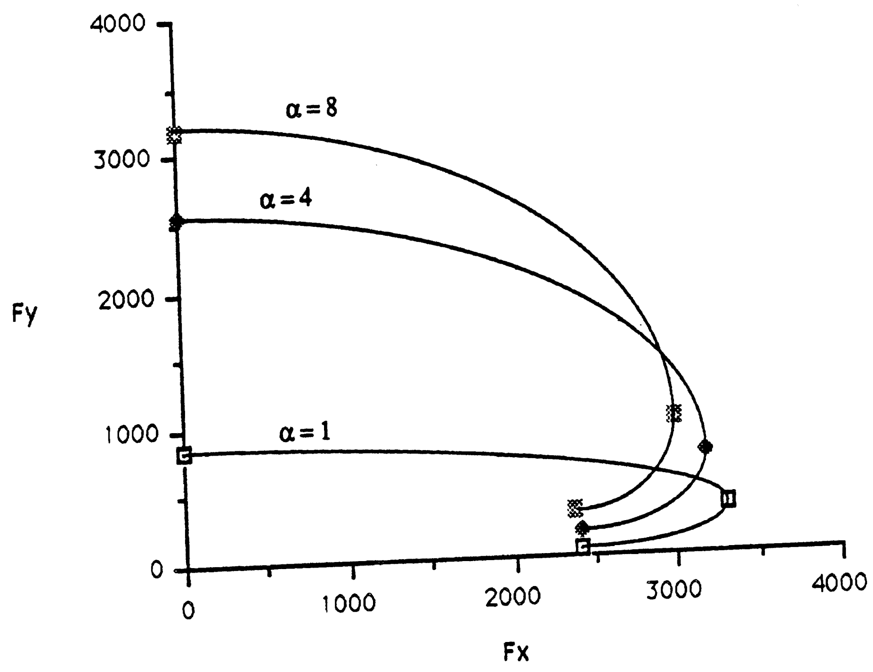


Figure 21

30 mph

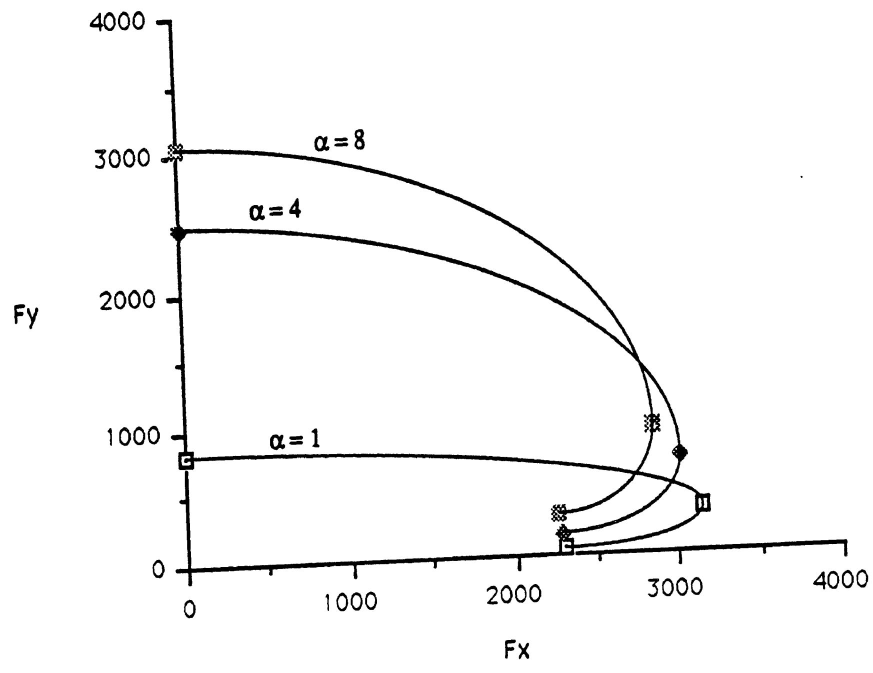


Figure 22

50 mph

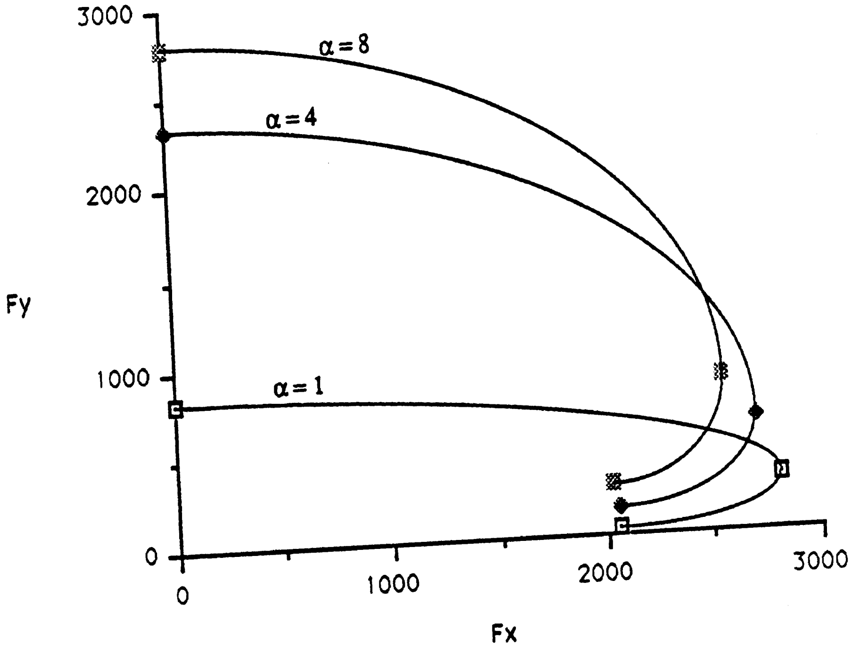


Figure 23

60 mph

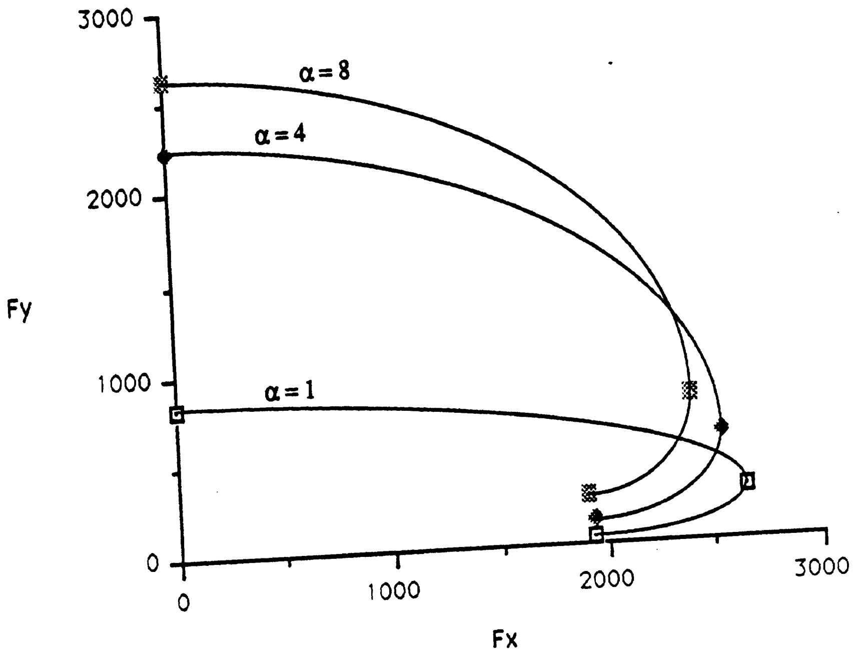


Figure 24

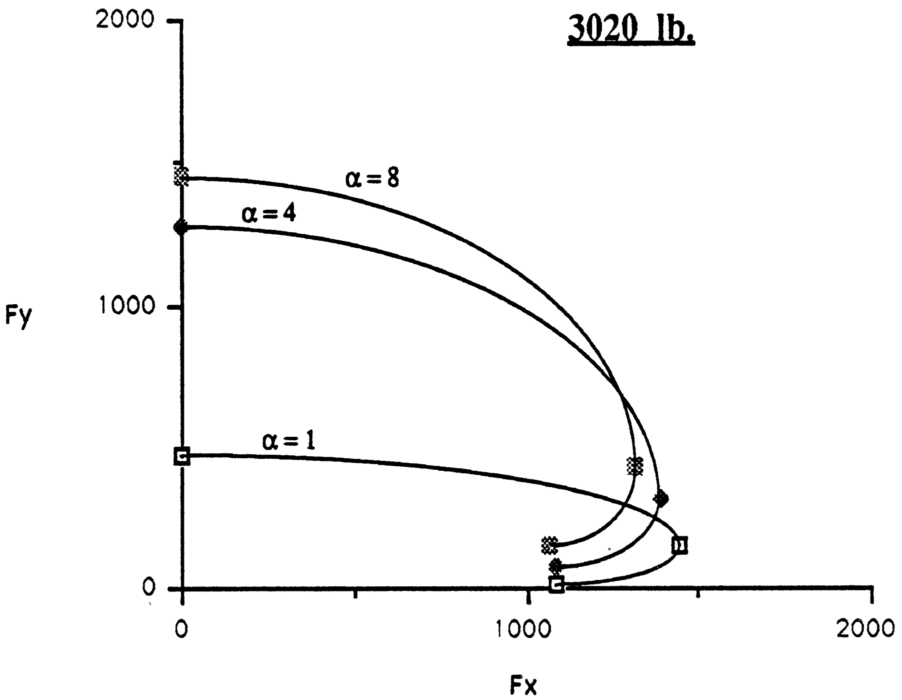


Figure 25

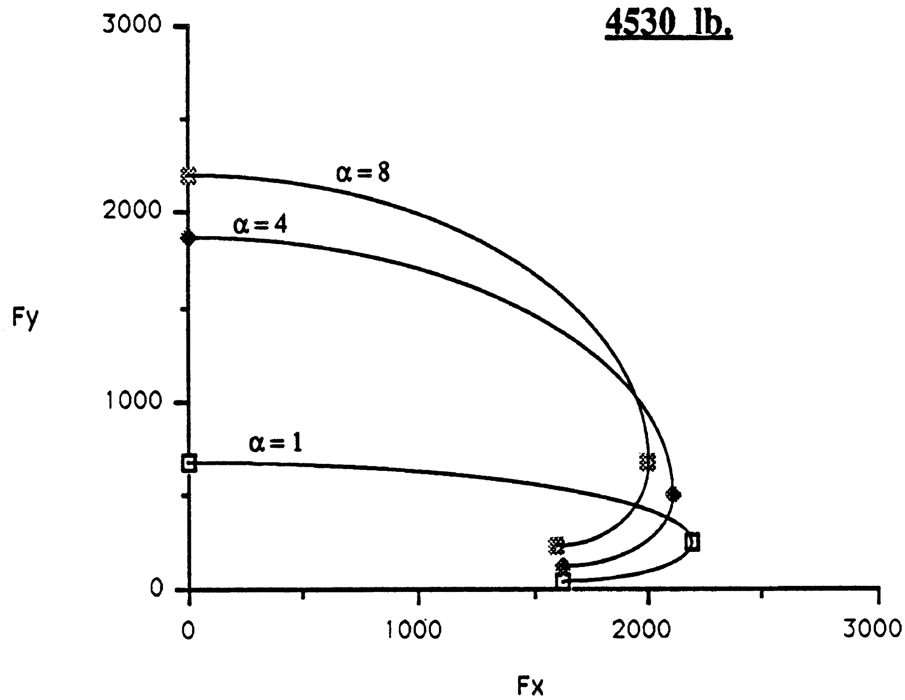


Figure 26

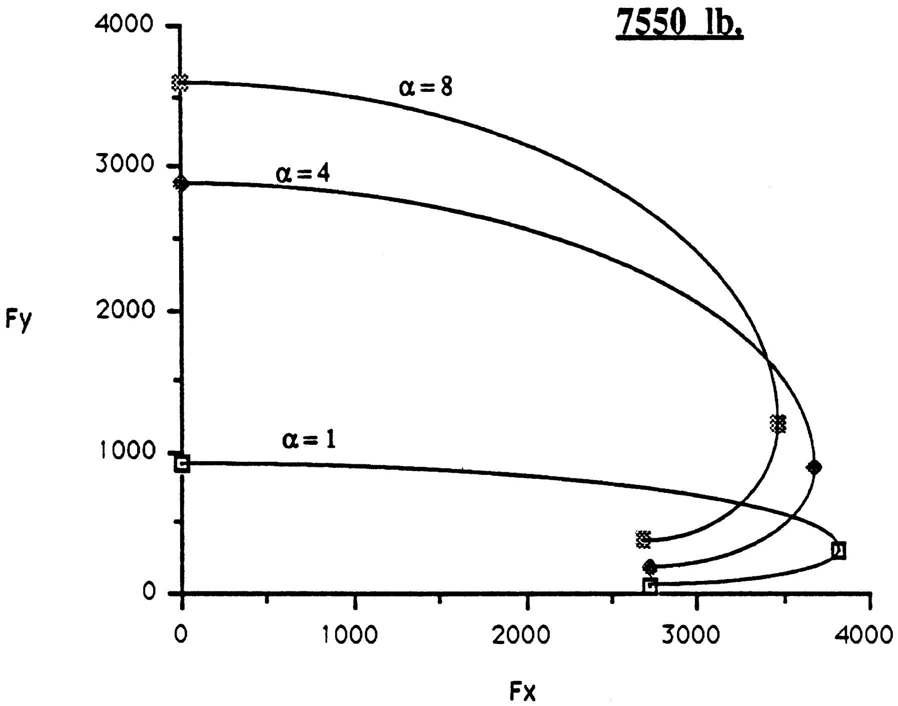


Figure 27

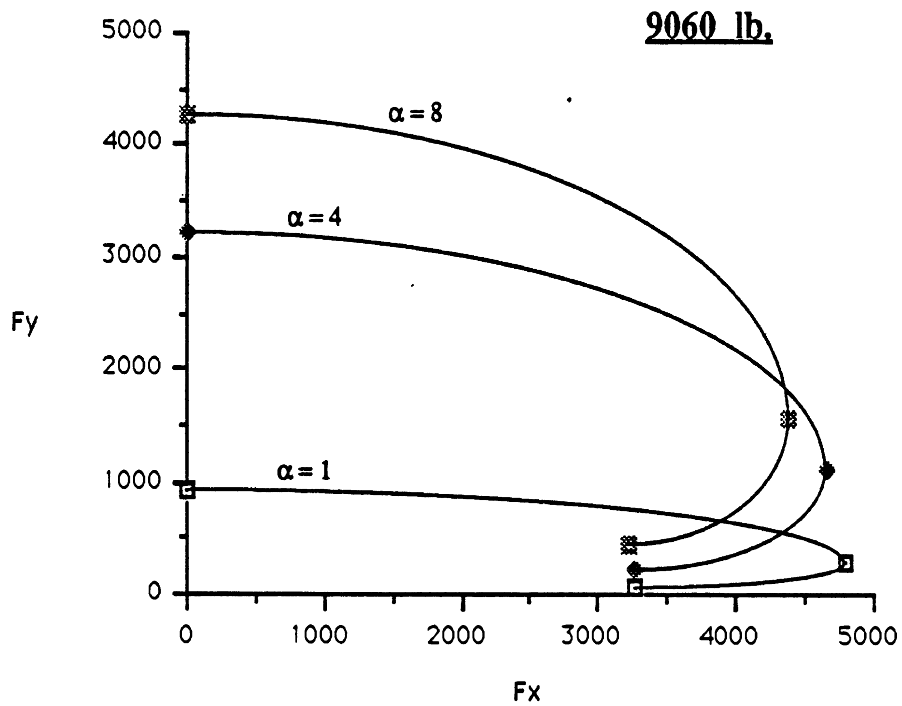


Figure 28

Variation of normalized peak Fx with Skid Number

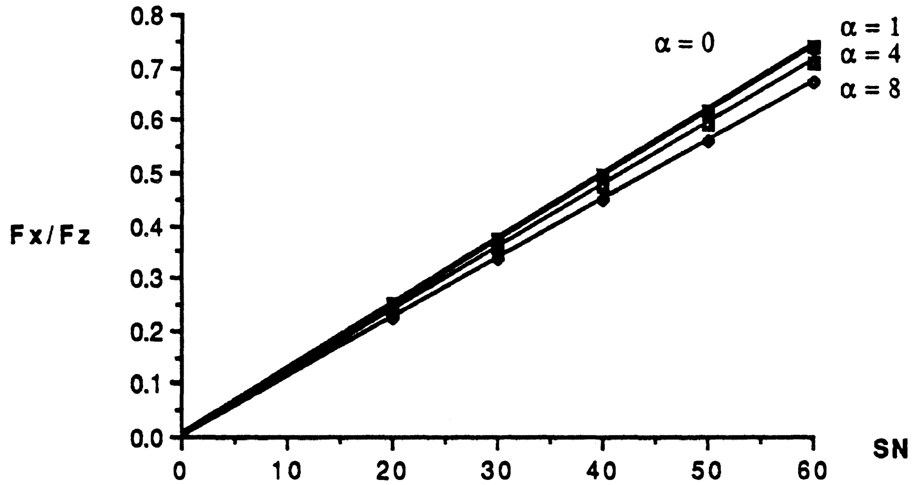


Figure 29.

Variation of normalized peak Fx with Texture Depth

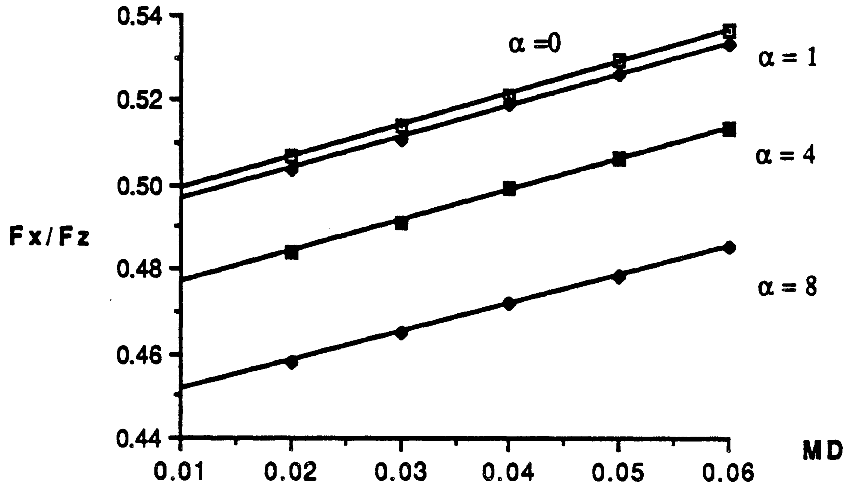


Figure 30.

Variation of normalized peak Fx with Groove Depth

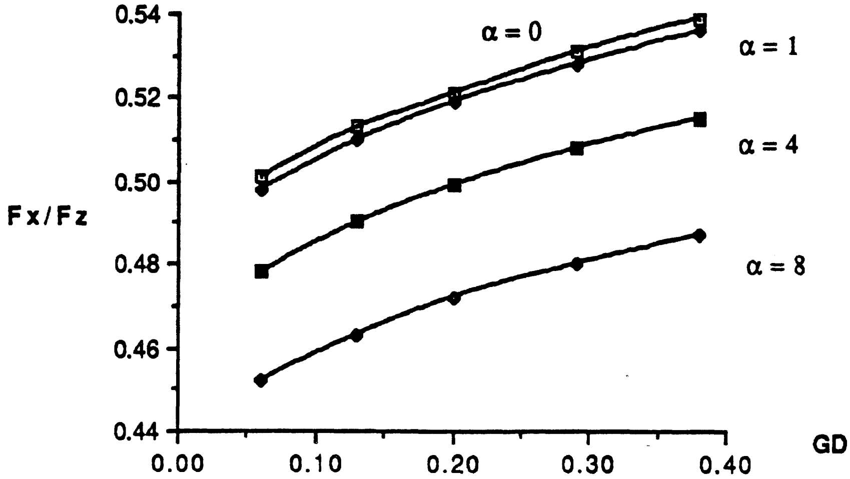


Figure 31.

Variations of normalized peak Fx with Load

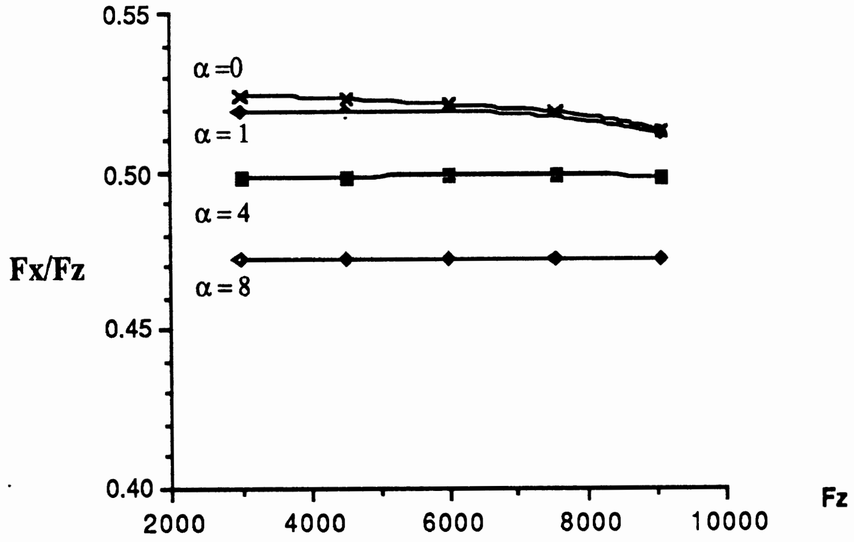


Figure 32.

Variation of normalized peak Fx with Speed

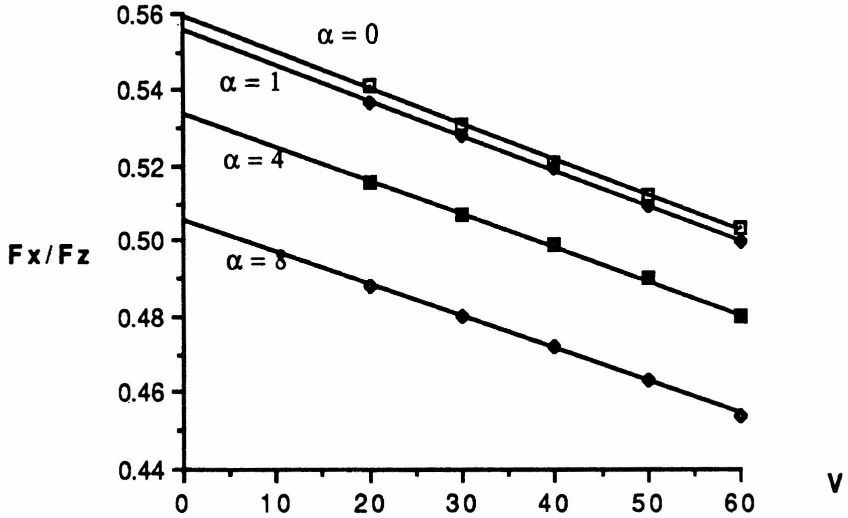


Figure 33.

- **Variations in SN_{40}** (Range : 20 to 60)

Of the parameters studied, SN has the most significant influence on the normalized road-holding performance of a tire. The slope by which the peak F_x changes with SN in Fig. 7 is obviously the greatest. The variation range of F_x due to the changes in SN is also the widest (Fig. 8). By examining Fig. 29, it can be seen that F_x varies in a linear manner with SN, a fact that also agrees with the equations of Appendix B.

The slip angle influence on F_x – while SN is changed – varies and has only secondary importance. That influence increases as SN grows and diminishes at low SN values. That is also sensible, because for low SN values only low α's can be developed before a complete sliding occurs. Observing Figures 9 through 12, it can be seen that for low SN values (very slippery road), the slip angle curve for $\alpha = 8°$ almost overlaps the one for 4° in the zone of pure lateral force ($F_x = 0$). This means that values of α higher than 4° are practically ineffective—the whole contact patch is sliding.

- **Variations in MD** (Range : 0.02 to 0.06 inch)

MD is the parameter which has the least influence on the road-holding (Fig. 7— smallest slope). The manner by which F_x changes as MD is changed is very close to linear, and does not change its slope as α is changed. F_x dependency on MD is consistent—only its value changes.

The above fact is emphasized in Figures 13 through 16. As MD increases, only the values on the F_x , F_y axes changes—the shape of the curves and the relations among them are similar for all MDs. There are no drastic changes in the F_x , F_y values.

- **Variations in GD** (Range : 0.06 to 0.38 inch)

The influence GD has on the road-holding is higher than MD. Still, the slopes of these two parameters are quite close (Fig. 7). Unlike its predecessor, GD is a highly non-linear factor concerning changes in F_x . In Fig. 31 , starting at the highest value of GD (new tire) and going along the curve to the lowest values (bald tire), the drop in F_x is linear and very moderate at first. In fact, for high groove depth values, variations in GD have only minor stronger drop in F_X is observed as the tire "loses its last rubber layers", approaching bald condition.

- **Variations in V** (Range : 20 to 60 mph)

Unlike the other parameters, V has a negative influence on the road-holding (Fig. 7). As the speed goes up, the road-holding becomes worse. The slope by which F_X changes with respect to V is significant. V is a factor second in its importance only to SN. The serious implications of high-speed driving on a poor wet road (low SN) are clearly demonstrated.

The manner by which V affects the normalized peak F_X (Fig. 33) is similar to MD, only that it works in the opposite direction. Differences in α also have smaller effect (than in MD) on F_X changes.

The set of graphs describing the combined forces (Figures 21 through 24) are also similar to those of MD. But again, the higher speed results (i.e Fig. 24) are qualitatively similar to those for the lower values of MD (i.e Fig. 13) and vice versa.

- **Variations in F_Z** (Range : 3020 to 9060 lb.)

The influences that variations in F_Z have on F_X are similar to the influences of variations in V, only in a more moderate and non-linear manner: Variations in high values of F_Z are more significant than in lower F_Z values. In Figure 7, in the region to the right of the baseline (high values), F_Z is more influential. In the region to the left of the baseline, the influence of F_Z on F_X is close to none.

As the tire reaches higher values of slip angle, F_Z loses its influence on the longitudinal force - F_X , which is practically constant throughout the range of F_Z.

In Figure 8 it can be seen that, compared to the other parameters, F_Z has the least influence on the peak normalized F_X.

6.0 SUMMARY AND RECOMMENDATIONS

In summary, this project pursued a method for including the influences of conditions at the tire/road interface in predicting tire traction performance. This method involved relationships between tire/road friction and skid number, pavement texture depth (macrostructure), and tire groove depth (tire wear). These relationships, which were based on results published in the literature, were aimed at predicting tire traction fields (longitudinal and lateral forces) on poor wet roads.

The new relationships pertaining to tire/road friction were employed in an existing, comprehensive tire model [1]. The parameters previously used to represent the frictional properties of the tire were removed from the existing model and a new set of frictional functions, developed in this study, were incorporated into the tire model.

This revised model was used to (1) compare results with an available set of data for a Michelin 11 R 22.5 XZA tire and (2) to perform a parameter sensitivity study. The results of these activities show that the model has reasonable, but by no means perfect, agreement with test results. The sensitivity study indicated that skid number had by far the most important influence on the results. The influence of mean road-texture depth and tire-tread groove depth were small when operating on a typical road at speeds approximately equal to 40 mph. More interesting and dramatic results might be obtained by going to the extreme of low texture depth, low tread depth, and high speed simultaneously.

Given the limited nature of this study, we do not have strong evidence to support recommendations. Nevertheless, the investigation indicates to us that the ongoing difficulty in knowing how to represent frictional properties for a variety of operating conditions has not been resolved. A small advance has been made towards the goal of being able to measure a few basic parameters and then to predict tire traction performance. However, the approach taken is this study is only partially satisfactory.

The basic problem all along has been to find relationships for representing friction that will provide accurate predictions of both the peak and slide traction forces. Since the peak force occurs when part of the contact patch is adhering without sliding, the direct determination of frictional properties is not possible from "peak and slide" data. In the past indirect methods have been used to determine frictional characteristics that will allow the model to match peak and slide data. For the time being, the matching of peak and slide data is a reasonable approach if the tire data exists for the surface conditions of interest.

However, if the data does not exist, the approach taken in this study can be used to obtain a "friction" function. Based on this friction function, the model would determine peak values for traction forces (tire shear forces) using elastic properties of the tire as determined by flatbed tests. The slide values would be directly determined by the friction function.

A very large experimental program would be needed to assess the accuracy attainable with this approach. This program would involve many test conditions pertaining to the surface and its contamination, conditions that are very difficult to control.

REFERENCES

1. Fancher P. and Balderas L. *"Representation of Truck Tire Properties in Braking and Handling Studies: The Influences of Vertical Load on Side Force Characteristics"*, MMVA project No. 8168 report, The Univ. of Michigan, Trans. Res. Inst., August 1988.

2. Olson, P.L., et al. *"Parameters Affecting Stopping Sight Distance."*, Nat. Coop. Highway Res. Prog., Report 270, The Univ. of Michigan, Trans. Res. Inst., June 1984.

3. Dunlap, D.F., Fancher, P.S.,Jr., Scott, R. E., McAdam, C. C., Segel, L., *"HIT Reports"*, The Univ. of Michigan, Trans. Res. Inst., Vol. 5, Dec. 1974.

4. Veith, A. G., *"Tires - Roads - Rainfall - Vehicles: The Traction Connection"*, Frictional Interaction of Tire and Pavement, ASTM STP 793, W. E. Meyer and J. D. Walter, Eds., American Society for Testing and Materials, 1983, pp. 3-40.

5. Leu, M. C. and Henry, J. J.,*"Prediction of Skid Resistance as a Function of Speed from Pavement and Texture Measurements."* Transportation Research Record 666 (1978) p. 7.

6. Dijks, A., *"Influence of Tread Depth on Wet Skid Resistance of Tires."* Transportation Research Record 621 (May 1977) p. 136.

7. Dijks, A., *"A Multifactor Examination of Wet Skid Resistance of Car Tires."* International Proceeding Automotive Tire Conference Toronto, (October 1970) p. 100.

8. Bernard, J. E., Segel, L., and Wild, R. E., *"Tire Shear Force Generation During Combined Steering and Braking Maneuvers."* SAE Paper No. 770582, 1977

9. Yeager, R. W., *"Tire Hydroplaning: Testing Analysis and Design."* The Physics of Tire Traction, Plenum Press (1974) p. 25

10. Dugoff, H., Fancher, P., and Segel, L. *"An Analysis of Tire Traction Properties and Their Influence on Vehicle Dynamic Performance."* 1970 International Automobile Safety Conference Compendium, SAE Paper No. 700377, New York 1970.

11. Balmer, G.G and Gallaway, B.M. *"Pavement Design and Controls for Minimizing Automotive Hydroplaning and Increasing Traction."* Frictional Interaction of Tire and Pavement, ASTM STP 793, W. E. Meyer and J. D. Walter, Eds., American Society for Testing and Materials, 1983, pp. 167-190.

12. Horne, W.B. and Buhlman, F., *"A Method for Rating the Skid Resistance and Micro/Macrotexture Characteristics of Wet Pavement."* Frictional Interaction of Tire and Pavement, ASTM STP 793, W. E. Meyer and J. D. Walter, Eds., American Society for Testing and Materials, 1983, pp. 191-218.

13. Thurman, G.R. and Leasure, W.A., Jr., "Noise and Traction Characteristics of Bias-Ply and Radial Tires for Heavy Duty Trucks." Final Report, No. DOT-TST-78-2, The Univ. of Michigan, Trans. Res. Inst., October 1977.

14. Ervin, R.D. and Winkler, C.B., "Braking Efficiency Testing Technique." Final Report, NHTSA Contract DOT-HS-031-3-765, The Univ. of Michigan, Trans. Res. Inst., (1976).

APPENDIX A

TIRE MODEL FOR COMBINED STEERING AND BRAKING MANEUVERS

This appendix lists the equations describing the semi-empirical tire model. The frictional coupling value (μ) is derived from the friction model described in Appendix B.

EQUATIONS

Define θ as the angle between the sliding direction and the undeformed center line of the contact patch:

(1) $$\theta = \tan^{-1}\left(\frac{\tan\alpha}{S_x}\right)$$

Defining also λ as:

(2) $$\lambda = \left[S_x^2 + \left(\frac{C_\alpha}{C_S} * \tan\alpha\right)^2\right]^{1/2}$$

Using these definitions and after the integration we obtain for each pressure zone.

- **Case (1)**

Decreasing pressure zone, $L\text{-}a < x_s \leq L$. Sliding will occur when:

(3) $$\frac{x_s}{L} = \frac{\mu * F_Z * (1 - S_x)}{\mu * F_Z * (1 - S_x) + 2 * C_S * \lambda\,(a/L) * (1 - a/L)}$$

(4) $$F_X = \frac{C_S * S_x}{1 - S_x}\left(\frac{x_s}{L}\right)^2 + \frac{\mu * |F_Z| \cos\theta}{2 * (a/L) * (1 - a/L)}\left(1 - \frac{x_s}{L}\right)^2$$

(5) $$F_Y = \frac{C_\alpha * \tan\alpha}{1 - S_x}\left(\frac{x_s}{L}\right)^2 + \frac{\mu * |F_Z| \sin\theta}{2 * (a/L) * (1 - a/L)}\left(1 - \frac{x_s}{L}\right)^2$$

• **Case (2)**

Central region of pressure distribution, $a < x_s \le L-a$. Sliding will occur when:

(6) $$\frac{x_s}{L} = \frac{\mu * F_Z * (1 - S_x)}{2 * C_S * \lambda * (1 - a/L)}$$

(7) $$F_X = \frac{C_S * S_X}{1 - S_x}\left(\frac{x_s}{L}\right)^2 + \frac{\mu * |F_Z| \cos\theta}{(1 - a/L)}\left(1 - \frac{x_s}{L} - \frac{a}{2L}\right)$$

(8) $$F_Y = \frac{C_\alpha * \tan\alpha}{1 - S_x}\left(\frac{x_s}{L}\right)^2 + \frac{\mu * |F_Z| \sin\theta}{(1 - a/L)}\left(1 - \frac{x_s}{L} - \frac{a}{2L}\right)$$

• **Case (3)**

Increasing pressure zone, $0.0 \le x_s \le a$. Sliding will occur at all points.

(9) $$F_X = \mu * |F_Z| * \cos\theta$$

(10) $$F_Y = \mu * |F_Z| * \sin\theta$$

ALIGNING TORQUE

The aligning torque is calculated as follows:

(11) $$A_T = -F_y * X_P * \left(\frac{x_s}{L}\right) + F_y * F_X / C_y$$

ROLL-OFF TABLES

The roll-off tables are computed as follows:

(12) $$\text{ROLL-X}_{\alpha,\, s_x} = \frac{F_{X_{\alpha, s_x}}}{F_{X_{\alpha=0, s_x}}}$$

(13) $$\text{ROLL-Y}_{\alpha,\, s_x} = \frac{F_{Y_{\alpha, s_x}}}{F_{Y_{\alpha, s_x=0}}}$$

APPENDIX B

FRICTION MODEL AND FRICTIONAL EFFECTS

This appendix lists the equations describing the semi-empirical friction model.

EQUATIONS

The skid number at some speed V (in MPH) is given by [5]:

(1) $$SN_V = SN_{40} \cdot e^{-0.041(V-40)(MD')^{-0.47}}$$

where $[MD'] = 10^{-3}$ inches. By converting it in such a way that the user's input will be in inches, we get:

(2) $$SN_V = SN_{40} e^{-0.016(V-40)MD^{-0.47}}$$ $[MD] = inch$

Using empirical values for peak and sliding coefficients (for truck tires in a new condition), SN_V is dimensionless percentage expression:

(3) $$(\mu_{xs})_{NEW} = 0.00987 \cdot SN_V (1.167)^{\left(\frac{V-40}{20}\right)}$$

(4) $$\mu_{xp} = 1.305 \, \mu_{xs}$$

The tire wear is represented by the percentage drop in the value of μ from new to bald tire condition [6]:

(5) $$\%\Delta\mu = -20 \cdot MD + 0.5 \cdot V$$

$[\%\Delta\mu] = \%$
$[MD] = mm$
$[V] = km/h$

Converting into inches and mph, and using a wear ratio rather than percentage, we get:

(6) $$\frac{\Delta\mu}{\mu_n} = -5.08 \cdot MD + 0.008045 \cdot V \quad \geq 0$$

The relationship for expressing μ as a function of tire condition is as follows:

(7) $$\mu_w = \mu_n - \Delta\mu \cdot \left(1 - \sqrt{\frac{W}{100}}\right)$$

Where: μ_w - is the value of μ for a tire in condition W
W - is tire wear status (100 - new ; 0 - bald)
$\Delta\mu$ - is reduction in μ from new to bald
μ_n - is μ value for a new tire

combining (6) and (7) we get for the peak and sliding μ values at some percentage - W of wear level:

(8) $$\mu_{xs} = (\mu_{xs})_{new} - (\mu_{xs})_{new} \cdot \left[-5.08 \cdot MD + 0.008045 \cdot V\right] \cdot \left(1 - \sqrt{\frac{W}{100}}\right)$$

As explained in section 3, the assumed maximum groove depth is 12/32 inches. Hence, at some present depth of GD inches, the value of W in percentage is:

(9) $$W = \frac{GD}{12/32} 100 = 266.7 \cdot GD$$

So that the expression for the sliding friction for some groove depth GD is:

(10) $$\mu_{xs} = (\mu_{xs})_{new} \cdot \left[1 - (0.008045 \cdot V - 5.08 \cdot MD) \cdot (1 - \sqrt{2.667 \cdot GD})\right]$$

where: [GD] = inch
[MD] = inch
[V] = mph

As μ_{xp} and $(\mu_{xs})_{new}$ are given by equations (4) and (2) respectively.

The semi-empirical friction model that is used (see fig. 4), has the form:

(11) $$\mu = \mu_0 - (\mu_0 - \mu_{xs}) \cdot [S_x^2 + \tan^2\alpha]$$

The value of μ_0 , could be approximated by the intersection of the line through μ_{xs} and μ_{xp} with the vertical axis. Since the location of μ_{xs} along the S_x axis is 1, and the location of μ_{xp} along that axis is at the value of slip that corresponds to the peak (S_{xp}), the slope of the line could be written as:

(12) $$\text{SLOPE} = \frac{\mu_{xp} - \mu_{xs}}{1 - S_{xp}}$$

An assumption that we make is that the value of slip that corresponds to the peak friction when the tire is under its nominal load is approximately 0.2. That assumption was found to be very reasonable. Errors made by this assumption were found to have such a small influence on the slope, that the overall effects on μ_0 and subsequently on the tire forces were minor.

μ_0 can now be calculated using the following equation, combined with (10):

(13) $$\mu_0 = \text{SLOPE} + \mu_{xs}$$

Substituting (13) into (11), the value of μ is calculated to be used as an input to the tire model (see the equations listed in Appendix A).

APPENDIX C

TRACTION FIELDS — COMPUTER OUTPUT OF THE MODEL

This appendix lists the results computed by the computer model for various tire/road conditions. These output lists were obtained while performing the sensitivity study.

The following combinations of tire/road parameters are presented in this appendix:

- Baseline:
  SN_{40} = 40
  MD = 0.04 in
  GD = 0.2 in
  V = 40 mph
  Fz = 6040 lb

- Variations in SN_{40} (while keeping the rest of the parameters as baseline):
  SN_{40} = 20
  SN_{40} = 60

- Variations in MD (while keeping the rest of the parameters as baseline):
  MD = 0.02 in
  MD = 0.06 in

- Variations in GD (while keeping the rest of the parameters as baseline):
  GD = 0.06 in
  GD = 0.38 in

- Variations in V (while keeping the rest of the parameters as baseline):
  V = 20 mph
  V = 60 mph

- Variations in Fz (while keeping the rest of the parameters as baseline):
  Fz = 3020 lbs.
  Fz = 9060 lbs.

BASELINE

COMBINED TIRE MODEL

FILE NAME:A:TIRE#3.FXY

Simulation Load = 6040.00 Lb
Simulation Velocity = 40.000 MPH

Alpha = .00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	.00	.00
.10	2829.40	.00	.00
.20	3139.76	.00	.00
.30	3095.94	.00	.00
.40	3034.60	.00	.00
.60	2859.34	.00	.00
.80	2613.98	.00	.00
1.00	2298.51	.00	.00

Alpha = 1.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	826.19	-1614.72
.10	2798.74	502.26	-116.05
.20	3127.60	272.96	48.51
.30	3090.45	179.81	30.55
.40	3031.45	132.29	20.83
.60	2857.87	83.14	10.05
.80	2613.09	57.01	3.95
1.00	2297.89	40.11	.11

Alpha = 2.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1515.57	-2715.96
.10	2712.53	972.04	-202.42
.20	3091.91	539.86	91.88
.30	3074.12	357.84	59.56
.40	3022.04	263.83	41.01
.60	2853.44	166.07	19.92
.80	2610.42	113.95	7.83
1.00	2296.04	80.18	.19

Alpha = 4.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2481.33	-2993.59
.10	2434.18	1737.84	-257.42
.20	2959.78	1034.84	147.29
.30	3010.95	701.82	107.46
.40	2985.05	521.84	77.05
.60	2835.86	330.50	38.41
.80	2599.78	227.24	15.10
1.00	2288.63	160.04	.14

Alpha = 8.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3047.44	-1821.79
.10	1825.50	2565.57	-248.26
.20	2554.76	1795.24	102.25
.30	2787.88	1306.04	138.56
.40	2846.70	1000.19	118.52
.60	2767.14	648.16	65.93
.80	2557.50	449.29	25.85
1.00	2259.00	317.48	-1.71

Alpha = 10.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3147.57	-1515.77
.10	1548.42	2730.29	-423.67
.20	2334.71	2058.36	21.76
.30	2645.57	1554.95	118.33
.40	2751.85	1213.06	119.49
.60	2717.19	798.52	72.82
.80	2526.10	556.77	28.35
1.00	2236.76	394.40	-3.97

Alpha = 12.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3135.22	-1509.82
.10	1330.95	2829.01	-568.67
.20	2124.45	2257.82	-76.20
.30	2493.84	1766.94	77.95
.40	2644.79	1405.42	106.72
.60	2657.90	941.59	74.10
.80	2488.06	661.07	28.36
1.00	2209.55	469.65	-7.43

Alpha = 16.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3102.76	-1494.19
.10	1018.83	2921.44	-779.46
.20	1754.96	2516.14	-280.89
.30	2185.96	2089.38	-43.43
.40	2407.79	1726.06	44.83
.60	2514.85	1201.87	58.34
.80	2392.86	857.68	19.58
1.00	2140.21	613.69	-18.67

Mu-x Roll-Off Table

Longitudinal Slip, Sx

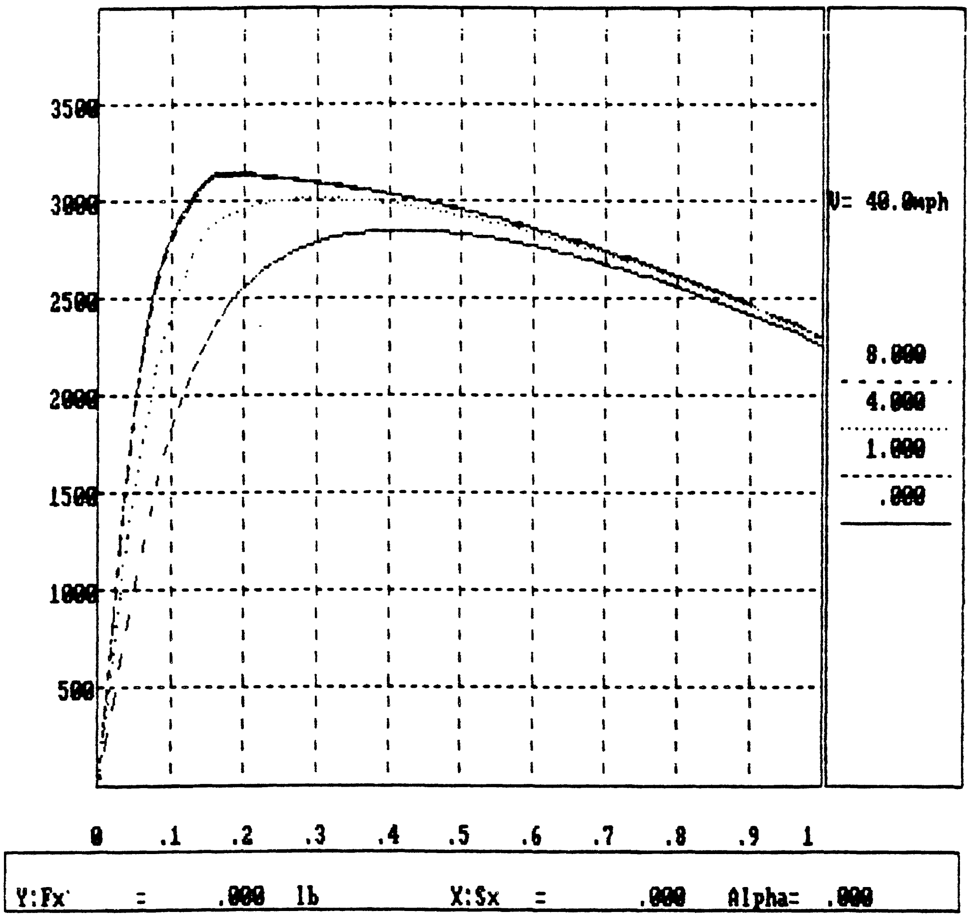
Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.989	.996	.998	.999	.999	1.000	1.000
2.00	1.000	.959	.985	.993	.996	.998	.999	.999
4.00	1.000	.860	.943	.973	.984	.992	.995	.996
8.00	1.000	.645	.814	.900	.938	.968	.978	.983
10.00	1.000	.547	.744	.855	.907	.950	.966	.973
12.00	1.000	.470	.677	.806	.872	.930	.952	.961
16.00	1.000	.360	.559	.706	.793	.880	.915	.931

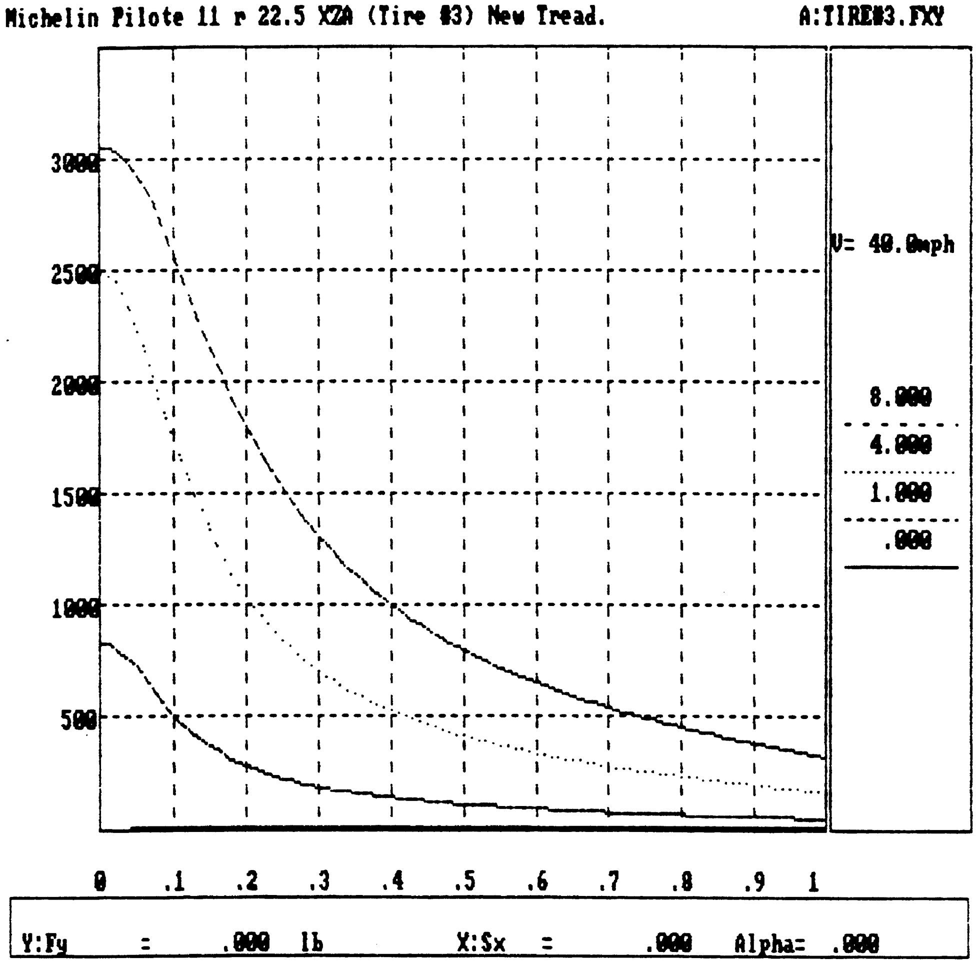
Mu-y Roll-Off Table

Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.608	.330	.218	.160	.101	.069	.049
2.00	1.000	.641	.356	.236	.174	.110	.075	.053
4.00	1.000	.700	.417	.283	.210	.133	.092	.064
8.00	1.000	.842	.589	.429	.328	.213	.147	.104
10.00	1.000	.867	.654	.494	.385	.254	.177	.125
12.00	1.000	.902	.720	.564	.448	.300	.211	.150
16.00	1.000	.942	.811	.673	.556	.387	.276	.198

Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread. A:TIRE#3.FXY




Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.
A:TIRE#3.FXY
3000
2500
2000
1500
1000
500
V= 40.0mph
8.000
4.000
1.000
.000
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
Y:Fy = .000 lb
X:Sx = .000
Alpha= .000

VARIATIONS IN SN_{40}

$SN_{40} = 20$

COMBINED TIRE MODEL

FILE NAME:A:TIRE#3.FXY

Simulation Load = 6040.00 Lb
Simulation Velocity = 40.000 MPH

Alpha = .00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	.00	.00
.10	1583.02	.00	.00
.20	1569.88	.00	.00
.30	1547.97	.00	.00
.40	1517.30	.00	.00
.60	1429.67	.00	.00
.80	1306.99	.00	.00
1.00	1149.25	.00	.00

Alpha = 1.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	757.62	-1357.82
.10	1559.31	272.18	-41.61
.20	1563.80	136.48	-20.74
.30	1545.23	89.91	-14.01
.40	1515.73	66.14	-10.72
.60	1428.93	41.57	-7.50
.80	1306.54	28.51	-5.88
1.00	1148.94	20.05	-4.80

Alpha = 2.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1240.64	-1500.11
.10	1494.02	521.72	-86.94
.20	1545.96	269.93	-42.03
.30	1537.06	178.92	-28.19
.40	1511.02	131.91	-21.51
.60	1426.72	83.04	-15.02
.80	1305.21	56.97	-11.76
1.00	1148.02	40.09	-9.60

Alpha = 4.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1527.43	-921.38
.10	1295.55	905.94	-188.87
.20	1479.89	517.42	-87.76
.30	1505.47	350.91	-57.63
.40	1492.52	260.92	-43.56
.60	1417.93	165.25	-30.19
.80	1299.89	113.62	-23.58
1.00	1144.32	80.02	-19.23

Alpha = 8.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1578.75	-760.28
.10	912.75	1282.78	-370.94
.20	1277.38	897.62	-190.57
.30	1393.94	653.02	-122.60
.40	1423.35	500.10	-90.79
.60	1383.57	324.08	-61.55
.80	1278.75	224.65	-47.63
1.00	1129.50	158.74	-38.65

Alpha = 10.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1573.78	-757.88
.10	774.21	1365.14	-434.62
.20	1167.36	1029.18	-242.37
.30	1322.79	777.48	-157.62
.40	1375.93	606.53	-116.17
.60	1358.60	399.26	-77.93
.80	1263.05	278.39	-59.94
1.00	1118.38	197.20	-48.48

Alpha = 12.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1567.61	-754.91
.10	665.47	1414.51	-482.76
.20	1062.22	1128.91	-290.88
.30	1246.92	883.47	-193.24
.40	1322.39	702.71	-142.52
.60	1328.95	470.79	-94.83
.80	1244.03	330.53	-72.50
1.00	1104.78	234.83	-58.40

Alpha = 16.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1551.38	-747.10
.10	509.41	1460.72	-546.58
.20	877.48	1258.07	-373.15
.30	1092.98	1044.69	-262.40
.40	1203.89	863.03	-196.59
.60	1257.43	600.94	-130.11
.80	1196.43	428.84	-98.36
1.00	1070.10	306.85	-78.55

Mu-x Roll-Off Table

Longitudinal Slip, Sx

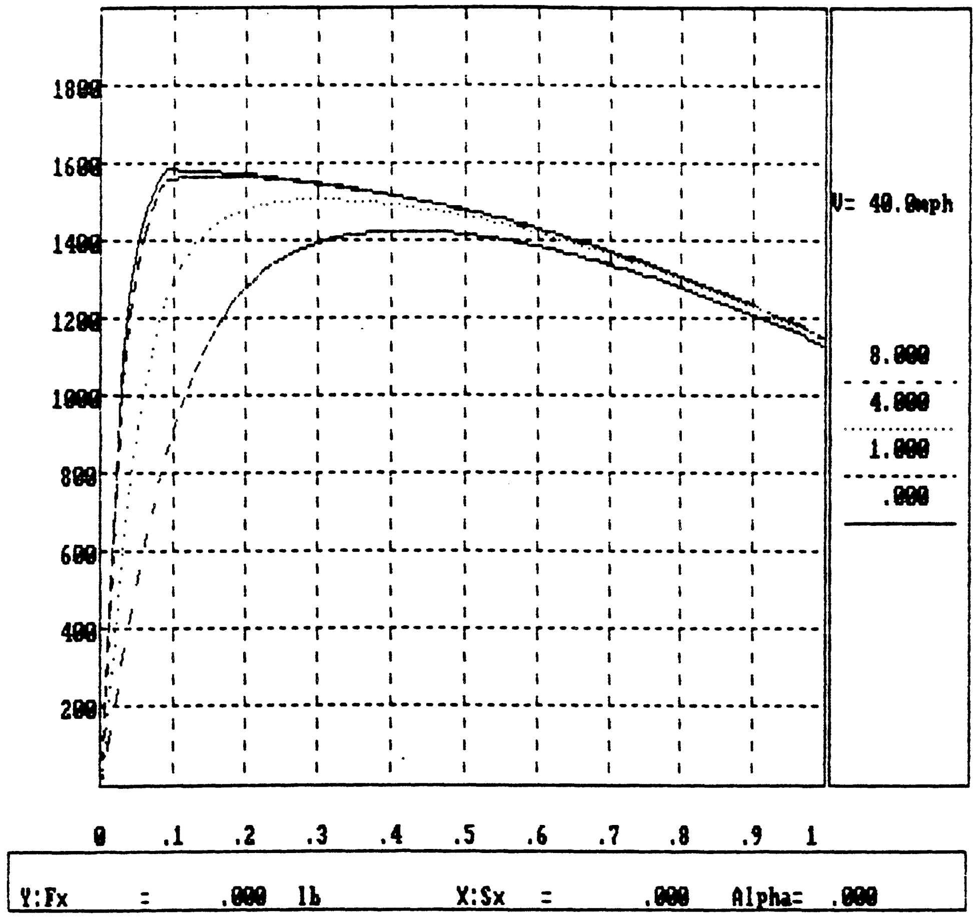
Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.985	.996	.998	.999	.999	1.000	1.000
2.00	1.000	.944	.985	.993	.996	.998	.999	.999
4.00	1.000	.818	.943	.973	.984	.992	.995	.996
8.00	1.000	.577	.814	.900	.938	.968	.978	.983
10.00	1.000	.489	.744	.855	.907	.950	.966	.973
12.00	1.000	.420	.677	.806	.872	.930	.952	.961
16.00	1.000	.322	.559	.706	.793	.880	.915	.931

Mu-y Roll-Off Table

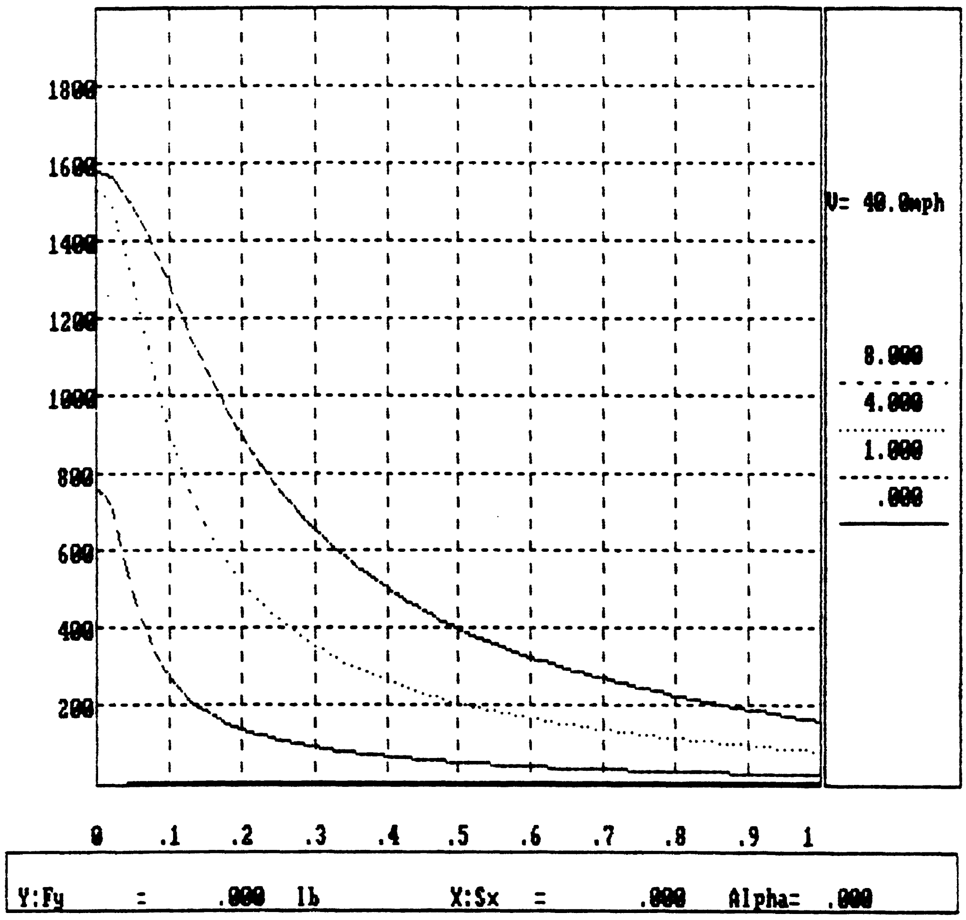
Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.359	.180	.119	.087	.055	.038	.026
2.00	1.000	.421	.218	.144	.106	.067	.046	.032
4.00	1.000	.593	.339	.230	.171	.108	.074	.052
8.00	1.000	.813	.569	.414	.317	.205	.142	.101
10.00	1.000	.867	.654	.494	.385	.254	.177	.125
12.00	1.000	.902	.720	.564	.448	.300	.211	.150
16.00	1.000	.942	.811	.673	.556	.387	.276	.198

Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread. A:TIRE#3.FXY



Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread. A:TIRE#3.FXY



$$SN_{40} = 60$$

COMBINED TIRE MODEL

FILE NAME:A:TIRE#3.FXY

Simulation Load = 6040.00 Lb
Simulation Velocity = 40.000 MPH

Alpha = .00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	.00	.00
.10	3648.70	.00	.00
.20	4609.04	.00	.00
.30	4643.92	.00	.00
.40	4551.91	.00	.00
.60	4289.01	.00	.00
.80	3920.97	.00	.00
1.00	3447.76	.00	.00

Alpha = 1.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	851.89	-1716.74
.10	3620.42	662.85	-310.44
.20	4594.20	407.90	170.59
.30	4635.68	269.72	133.67
.40	4547.18	198.43	94.64
.60	4286.80	124.71	52.63
.80	3919.63	85.52	29.48
1.00	3446.83	60.16	14.74

Alpha = 2.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1604.38	-3043.59
.10	3538.54	1291.49	-547.77
.20	4550.52	808.04	336.61
.30	4611.18	536.75	263.24
.40	4533.06	395.74	187.57
.60	4280.17	249.11	104.79
.80	3915.63	170.92	58.77
1.00	3444.06	120.27	29.40

Alpha = 4.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2874.30	-4878.41
.10	3252.93	2354.98	-721.00
.20	4387.12	1558.25	638.39
.30	4516.42	1052.73	495.27
.40	4477.57	782.76	361.85
.60	4253.80	495.76	205.79
.80	3899.67	340.86	116.05
1.00	3432.95	240.06	58.11

Alpha = 8.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	4146.62	-3718.33
.10	2542.36	3648.08	-512.01
.20	3832.14	2692.86	878.46
.30	4181.82	1959.05	783.48
.40	4270.05	1500.29	627.91
.60	4150.71	972.24	382.45
.80	3836.25	673.94	220.44
1.00	3388.50	476.22	110.82

Alpha = 10.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	4394.43	-3130.91
.10	2233.09	4004.10	-392.14
.20	3502.07	3087.55	792.39
.30	3968.36	2332.43	827.85
.40	4127.78	1819.60	706.98
.60	4075.79	1197.79	452.26
.80	3789.15	835.16	264.88
1.00	3355.13	591.60	133.51

Alpha = 12.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	4551.72	-2679.67
.10	1971.00	4248.11	-299.56
.20	3186.67	3386.74	644.01
.30	3740.76	2650.41	813.56
.40	3967.18	2108.13	747.72
.60	3986.84	1412.38	506.80
.80	3732.09	991.60	302.57
1.00	3314.33	704.48	152.92

Alpha = 16.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	4654.14	-2241.29
.10	1528.24	4382.16	-698.63
.20	2632.44	3774.20	276.77
.30	3278.94	3134.07	656.93
.40	3611.68	2589.08	724.29
.60	3772.28	1802.81	565.36
.80	3589.29	1286.51	353.83
1.00	3210.31	920.54	179.63

Mu-x Roll-Off Table

Longitudinal Slip, Sx

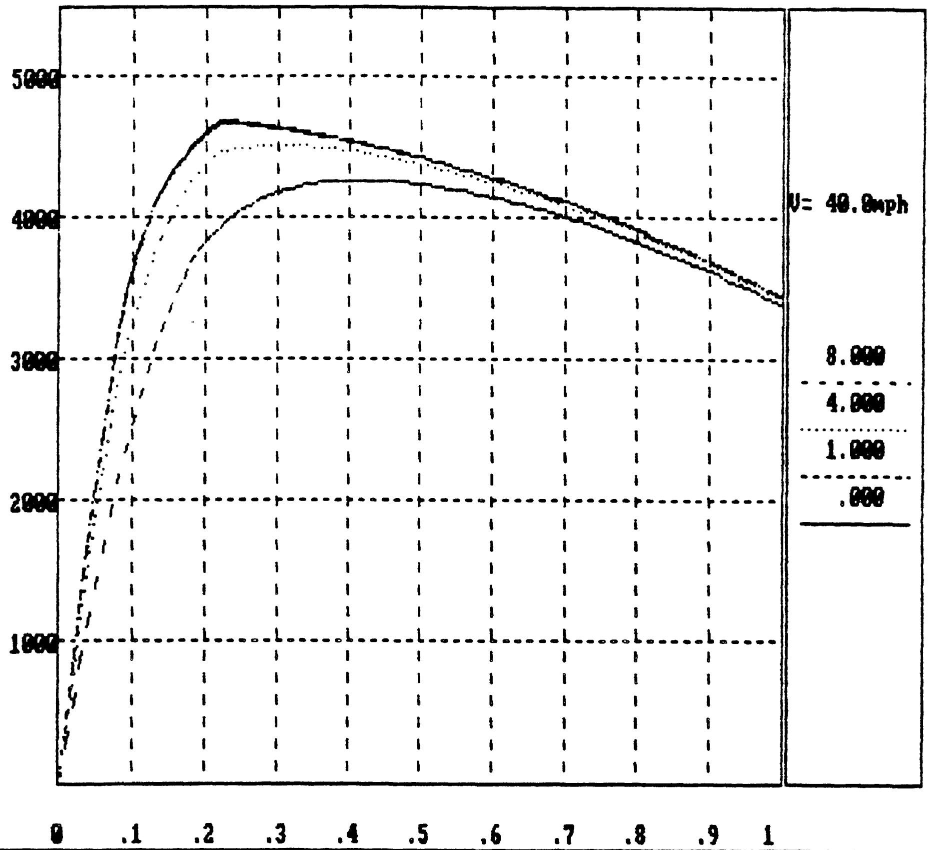
Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.992	.997	.998	.999	.999	1.000	1.000
2.00	1.000	.970	.987	.993	.996	.998	.999	.999
4.00	1.000	.892	.952	.973	.984	.992	.995	.996
8.00	1.000	.697	.831	.900	.938	.968	.978	.983
10.00	1.000	.612	.760	.855	.907	.950	.966	.973
12.00	1.000	.540	.691	.806	.872	.930	.952	.961
16.00	1.000	.419	.571	.706	.793	.880	.915	.931

Mu-y Roll-Off Table

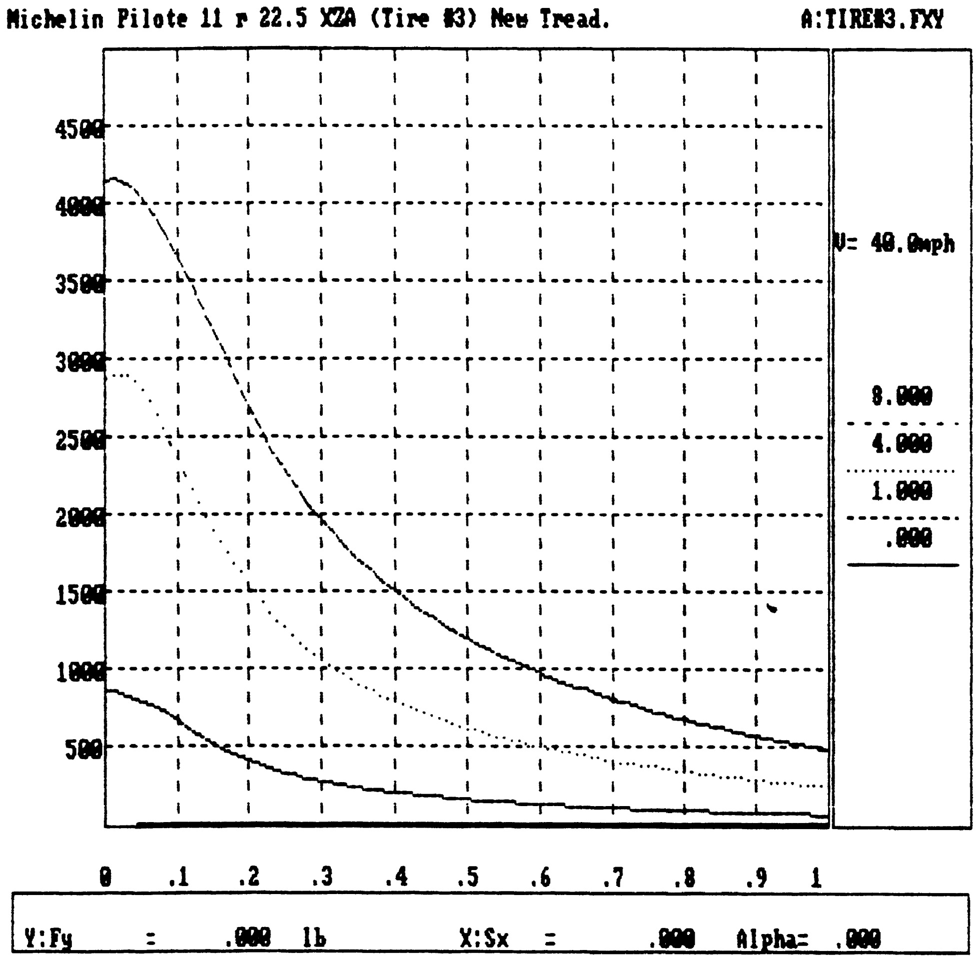
Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.778	.479	.317	.233	.146	.100	.071
2.00	1.000	.805	.504	.335	.247	.155	.107	.075
4.00	1.000	.819	.542	.366	.272	.172	.119	.084
8.00	1.000	.880	.649	.472	.362	.234	.163	.115
10.00	1.000	.911	.703	.531	.414	.273	.190	.135
12.00	1.000	.933	.744	.582	.463	.310	.218	.155
16.00	1.000	.942	.811	.673	.556	.387	.276	.198

Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread. A:TIRE#3.FXY



Y:Fx = .000 lb X:Sx = .000 Alpha= .000


Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.
A:TIRE#3.FXY
4500
4000
3500
3000
2500
2000
1500
1000
500
V= 40.0mph
8.000
4.000
1.000
.000
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
Y:Fy = .000 lb
X:Sx = .000
Alpha= .000

VARIATIONS IN MD

MD = 0.02 in.

COMBINED TIRE MODEL

FILE NAME:A:TIRE#3.FXY

Simulation Load = 6040.00 Lb
Simulation Velocity = 40.000 MPH

Alpha = .00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	.00	.00
.10	2771.15	.00	.00
.20	3050.90	.00	.00
.30	3008.32	.00	.00
.40	2948.72	.00	.00
.60	2778.42	.00	.00
.80	2540.00	.00	.00
1.00	2233.45	.00	.00

Alpha = 1.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	824.02	-1606.24
.10	2740.71	491.36	-108.12
.20	3039.09	265.24	42.19
.30	3002.98	174.72	26.46
.40	2945.65	128.54	17.91
.60	2776.98	80.79	8.39
.80	2539.13	55.40	2.97
1.00	2232.85	38.97	-.42

Alpha = 2.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1508.27	-2689.87
.10	2655.20	950.64	-188.46
.20	3004.41	524.58	79.60
.30	2987.11	347.71	51.49
.40	2936.51	256.36	35.23
.60	2772.69	161.37	16.60
.80	2536.54	110.72	5.88
1.00	2231.06	77.91	-.88

Alpha = 4.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2442.65	-2863.52
.10	2379.90	1697.89	-239.16
.20	2876.01	1005.55	125.37
.30	2925.73	681.96	92.17
.40	2900.56	507.07	65.84
.60	2755.60	321.15	31.89
.80	2526.20	220.81	11.25
1.00	2223.86	155.51	-1.99

Alpha = 8.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2976.76	-1729.17
.10	1773.83	2492.96	-268.39
.20	2482.46	1744.43	72.77
.30	2708.98	1269.07	113.54
.40	2766.13	971.89	98.66
.60	2688.82	629.82	53.67
.80	2485.12	436.58	18.46
1.00	2195.06	308.50	-5.82

Alpha = 10.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3058.48	-1472.87
.10	1504.60	2653.01	-436.18
.20	2268.64	2000.11	-6.71
.30	2570.69	1510.94	91.13
.40	2673.97	1178.73	96.75
.60	2640.29	775.92	58.18
.80	2454.61	541.02	19.39
1.00	2173.45	383.24	-8.98

Alpha = 12.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3046.49	-1467.09
.10	1293.28	2748.95	-574.41
.20	2064.32	2193.92	-101.85
.30	2423.26	1716.93	50.20
.40	2569.93	1365.64	82.15
.60	2582.67	914.94	57.49
.80	2417.64	642.36	18.02
1.00	2147.02	456.36	-13.23

Alpha = 16.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3014.94	-1451.90
.10	989.99	2838.76	-774.66
.20	1705.29	2444.92	-298.54
.30	2124.09	2030.24	-68.67
.40	2339.64	1677.20	19.47
.60	2443.68	1167.86	39.17
.80	2325.13	833.40	7.13
1.00	2079.63	596.32	-25.76

Mu-x Roll-Off Table

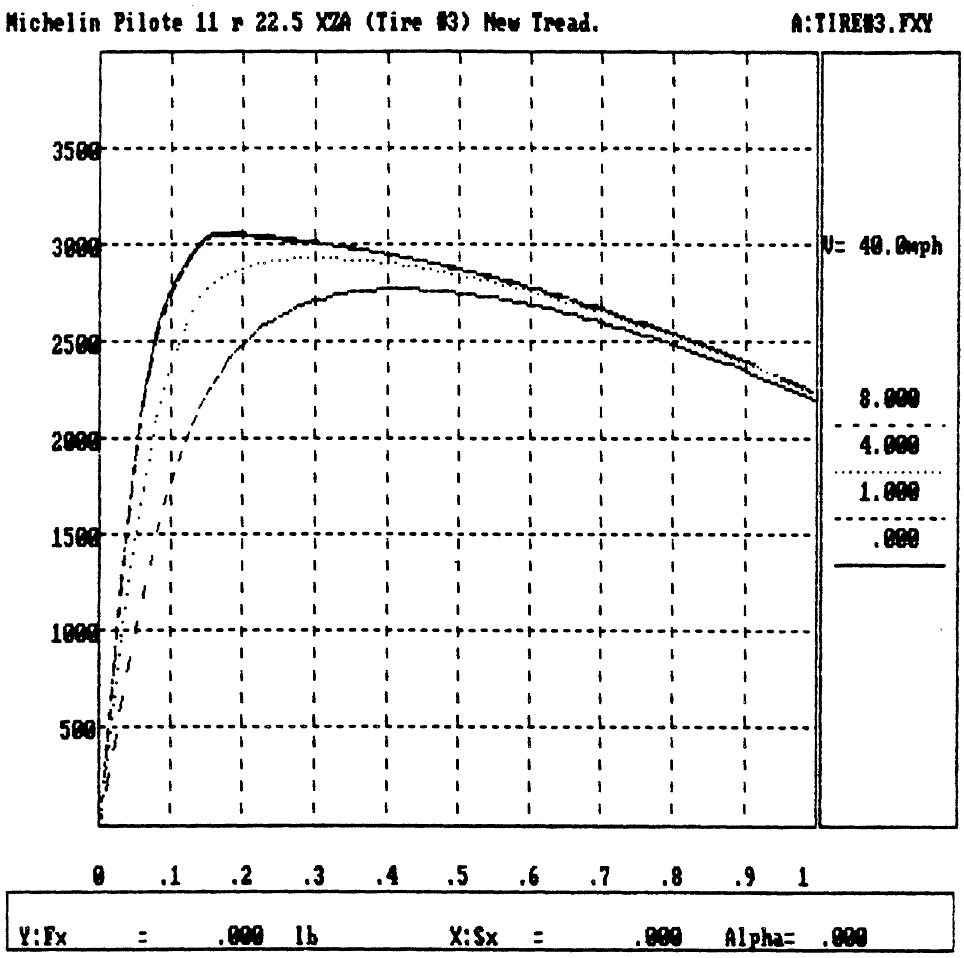
Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.989	.996	.998	.999	.999	1.000	1.000
2.00	1.000	.958	.985	.993	.996	.998	.999	.999
4.00	1.000	.859	.943	.973	.984	.992	.995	.996
8.00	1.000	.640	.814	.900	.938	.968	.978	.983
10.00	1.000	.543	.744	.855	.907	.950	.966	.973
12.00	1.000	.467	.677	.806	.872	.930	.952	.961
16.00	1.000	.357	.559	.706	.793	.880	.915	.931

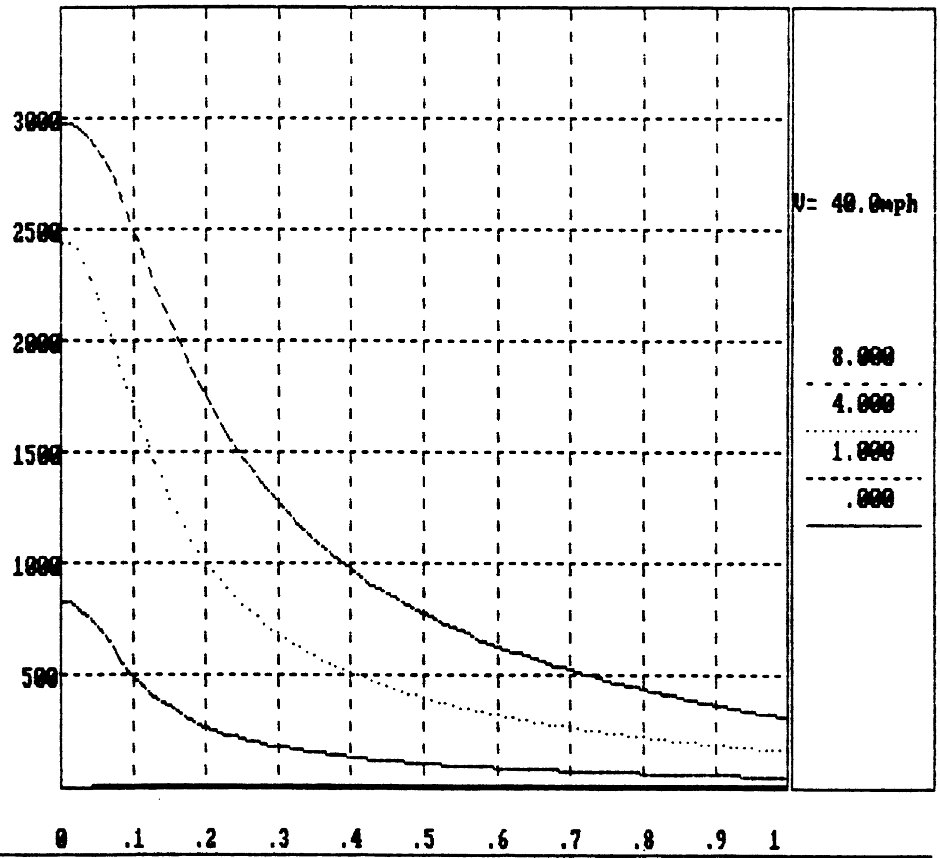
Mu-y Roll-Off Table

Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.596	.322	.212	.156	.098	.067	.047
2.00	1.000	.630	.348	.231	.170	.107	.073	.052
4.00	1.000	.695	.412	.279	.208	.131	.090	.064
8.00	1.000	.837	.586	.426	.326	.212	.147	.104
10.00	1.000	.867	.654	.494	.385	.254	.177	.125
12.00	1.000	.902	.720	.564	.448	.300	.211	.150
16.00	1.000	.942	.811	.673	.556	.387	.276	.198


Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.
A:TIRE#3.FXY
3500
3000
2500
2000
1500
1000
500
V= 40.0mph
8.000
4.000
1.000
.000
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
Y:Fx = .000 lb
X:Sx = .000
Alpha= .000

Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread. A:TIRE#3.FXY



Y:Fy = .000 lb X:Sx = .000 Alpha= .000

$MD = 0.06$ in.

COMBINED TIRE MODEL

FILE NAME:A:TIRE#3.FXY

Simulation Load = 6040.00 Lb
Simulation Velocity = 40.000 MPH

Alpha = .00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	.00	.00
.10	2886.37	.00	.00
.20	3228.62	.00	.00
.30	3183.57	.00	.00
.40	3120.49	.00	.00
.60	2940.27	.00	.00
.80	2687.96	.00	.00
1.00	2363.56	.00	.00

Alpha = 1.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	828.26	-1622.79
.10	2855.54	512.96	-124.30
.20	3216.12	280.69	55.12
.30	3177.92	184.90	34.82
.40	3117.25	136.03	23.88
.60	2938.75	85.49	11.79
.80	2687.04	58.63	4.97
1.00	2362.93	41.25	.68

Alpha = 2.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1522.53	-2740.96
.10	2768.73	993.09	-216.96
.20	3179.42	555.14	104.72
.30	3161.13	367.96	67.99
.40	3107.57	271.30	47.07
.60	2934.20	170.77	23.39
.80	2684.30	117.17	9.87
1.00	2361.02	82.45	1.33

Alpha = 4.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2518.17	-3124.03
.10	2487.62	1777.25	-276.50
.20	3043.55	1064.13	170.25
.30	3096.17	721.68	123.47
.40	3069.53	536.61	88.79
.60	2916.13	339.86	45.25
.80	2673.36	233.67	19.15
1.00	2353.41	164.57	2.39

Alpha = 8.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3117.22	-1916.24
.10	1877.16	2638.18	-226.56
.20	2627.07	1846.05	133.28
.30	2866.78	1343.00	164.82
.40	2927.27	1028.50	139.34
.60	2845.45	666.50	78.80
.80	2629.89	462.01	33.63
1.00	2322.93	326.47	2.64

Alpha = 10.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3230.00	-1577.61
.10	1592.25	2807.56	-409.72
.20	2400.79	2116.62	51.86
.30	2720.45	1598.96	146.91
.40	2829.73	1247.40	143.35
.60	2794.10	821.12	88.19
.80	2597.59	572.53	37.78
1.00	2300.06	405.56	1.33

Alpha = 12.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3223.96	-1552.56
.10	1368.62	2909.08	-561.67
.20	2184.57	2321.73	-48.93
.30	2564.42	1816.95	107.19
.40	2719.64	1445.19	132.54
.60	2733.12	968.24	91.55
.80	2558.48	679.78	39.25
1.00	2272.09	482.95	-1.27

Alpha = 16.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3190.58	-1536.48
.10	1047.66	3004.12	-783.26
.20	1804.63	2587.35	-261.75
.30	2247.83	2148.51	-16.64
.40	2475.93	1774.91	71.60
.60	2586.03	1235.89	78.54
.80	2460.58	881.95	32.72
1.00	2200.78	631.06	-11.15

Mu-x Roll-Off Table

Longitudinal Slip, Sx

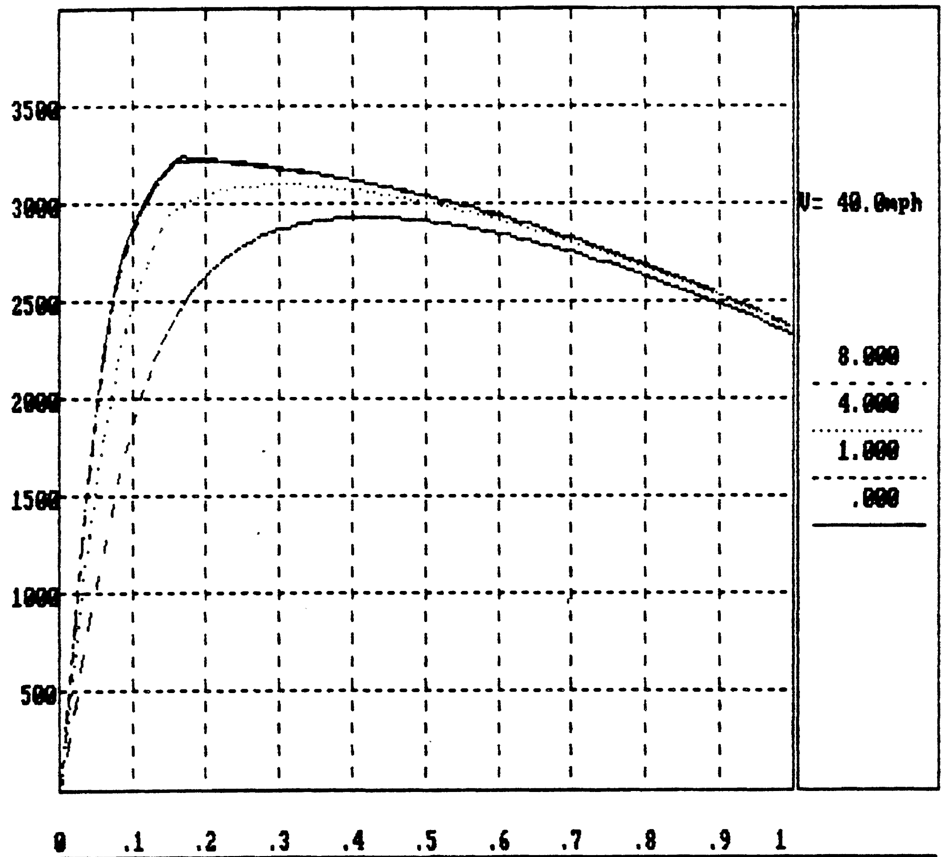
Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.989	.996	.998	.999	.999	1.000	1.000
2.00	1.000	.959	.985	.993	.996	.998	.999	.999
4.00	1.000	.862	.943	.973	.984	.992	.995	.996
8.00	1.000	.650	.814	.900	.938	.968	.978	.983
10.00	1.000	.552	.744	.855	.907	.950	.966	.973
12.00	1.000	.474	.677	.806	.872	.930	.952	.961
16.00	1.000	.363	.559	.706	.793	.880	.915	.931

Mu-y Roll-Off Table

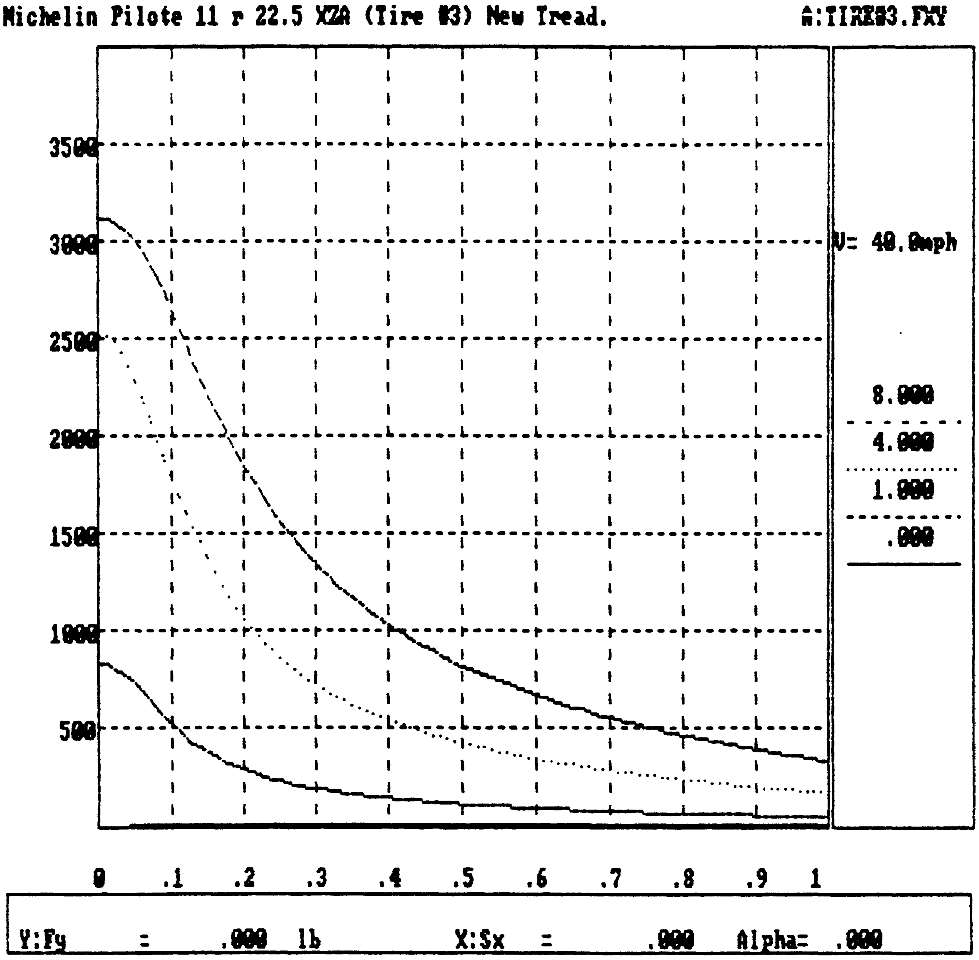
Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.619	.339	.223	.164	.103	.071	.050
2.00	1.000	.652	.365	.242	.178	.112	.077	.054
4.00	1.000	.706	.423	.287	.213	.135	.093	.065
8.00	1.000	.846	.592	.431	.330	.214	.148	.105
10.00	1.000	.869	.655	.495	.386	.254	.177	.126
12.00	1.000	.902	.720	.564	.448	.300	.211	.150
16.00	1.000	.942	.811	.673	.556	.387	.276	.198

Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread. A:TIRE#3.FXY



Y:Fx = .000 lb X:Sx = .000 Alpha= .000


Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.
A:TIRES3.FXY
3500
3000
2500
2000
1500
1000
500
V= 40.0mph
8.000
4.000
1.000
.000
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
Y:Fy = .000 lb X:Sx = .000 Alpha= .000

VARIATIONS IN GD

GD = 0.06 in.

COMBINED TIRE MODEL

FILE NAME:A:TIRE#3.FXY

Simulation Load = 6040.00 Lb
Simulation Velocity = 40.000 MPH

Alpha = .00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	.00	.00
.10	2745.72	.00	.00
.20	3012.69	.00	.00
.30	2970.65	.00	.00
.40	2911.79	.00	.00
.60	2743.63	.00	.00
.80	2508.19	.00	.00
1.00	2205.49	.00	.00

Alpha = 1.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	823.05	-1602.46
.10	2715.39	486.62	-104.81
.20	3001.03	261.92	39.56
.30	2965.38	172.54	24.76
.40	2908.77	126.93	16.70
.60	2742.21	79.78	7.70
.80	2507.34	54.71	2.57
1.00	2204.89	38.49	-.65

Alpha = 2.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1505.03	-2678.31
.10	2630.21	941.33	-182.64
.20	2966.78	518.01	74.49
.30	2949.71	343.35	48.14
.40	2899.74	253.15	32.83
.60	2737.97	159.35	15.23
.80	2504.78	109.34	5.08
1.00	2203.12	76.93	-1.32

Alpha = 4.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2425.45	-2807.76
.10	2356.29	1680.54	-231.56
.20	2840.00	992.96	116.26
.30	2889.10	673.42	85.81
.40	2864.24	500.72	61.18
.60	2721.10	317.13	29.18
.80	2494.57	218.05	9.65
1.00	2196.01	153.56	-2.87

Alpha = 8.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2946.09	-1689.92
.10	1751.62	2461.74	-276.55
.20	2451.37	1722.59	60.57
.30	2675.05	1253.18	103.15
.40	2731.49	959.72	90.41
.60	2655.15	621.93	48.58
.80	2454.00	431.11	15.40
1.00	2167.58	304.63	-7.51

Alpha = 10.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3020.19	-1454.43
.10	1485.76	2619.79	-441.12
.20	2240.23	1975.06	-18.46
.30	2538.50	1492.02	79.87
.40	2640.48	1163.97	87.33
.60	2607.23	766.21	52.11
.80	2423.87	534.24	15.69
1.00	2146.23	378.44	-11.03

Alpha = 12.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3008.34	-1448.72
.10	1277.08	2714.52	-576.48
.20	2038.47	2166.45	-112.38
.30	2392.91	1695.43	38.72
.40	2537.75	1348.54	71.97
.60	2550.33	903.48	50.62
.80	2387.37	634.31	13.75
1.00	2120.13	450.65	-15.62

Alpha = 16.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2977.19	-1433.72
.10	977.60	2803.21	-772.28
.20	1683.94	2414.31	-305.67
.30	2097.49	2004.82	-79.05
.40	2310.34	1656.20	9.00
.60	2413.08	1153.23	31.24
.80	2296.02	822.97	1.99
1.00	2053.59	588.86	-28.67

Mu-x Roll-Off Table

Longitudinal Slip, Sx

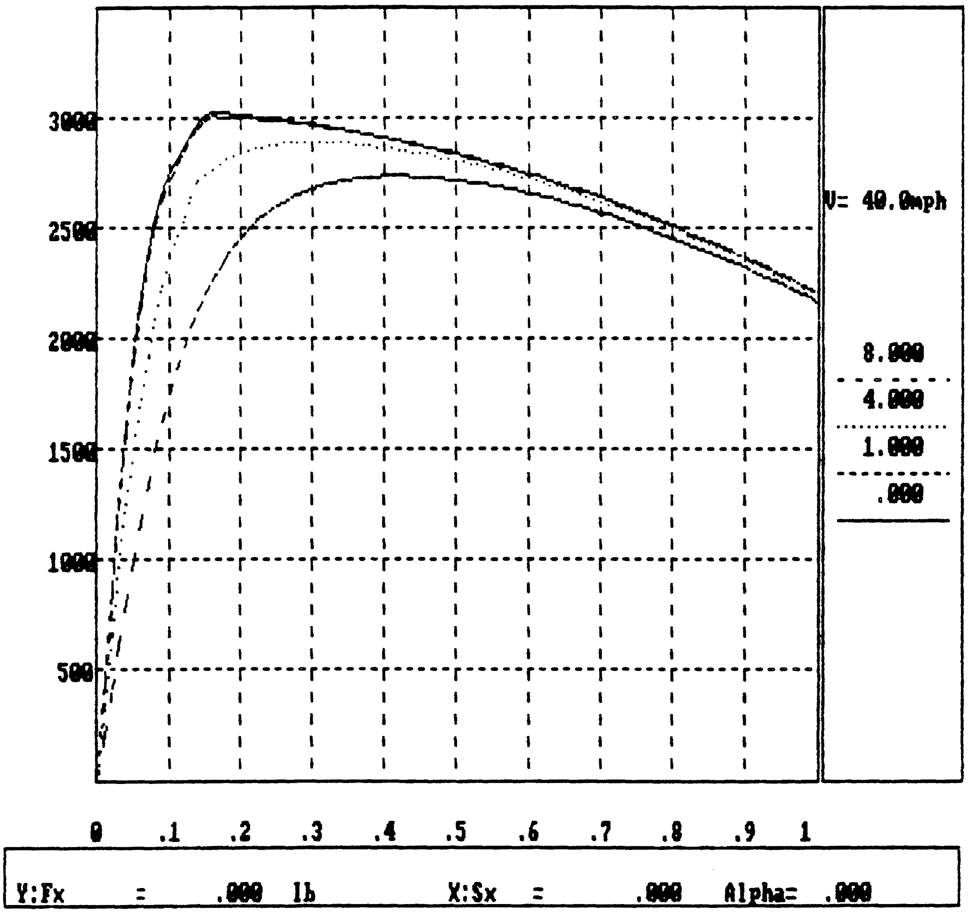
Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.989	.996	.998	.999	.999	1.000	1.000
2.00	1.000	.958	.985	.993	.996	.998	.999	.999
4.00	1.000	.858	.943	.973	.984	.992	.995	.996
8.00	1.000	.638	.814	.900	.938	.968	.978	.983
10.00	1.000	.541	.744	.855	.907	.950	.966	.973
12.00	1.000	.465	.677	.806	.872	.930	.952	.961
16.00	1.000	.356	.559	.706	.793	.880	.915	.931

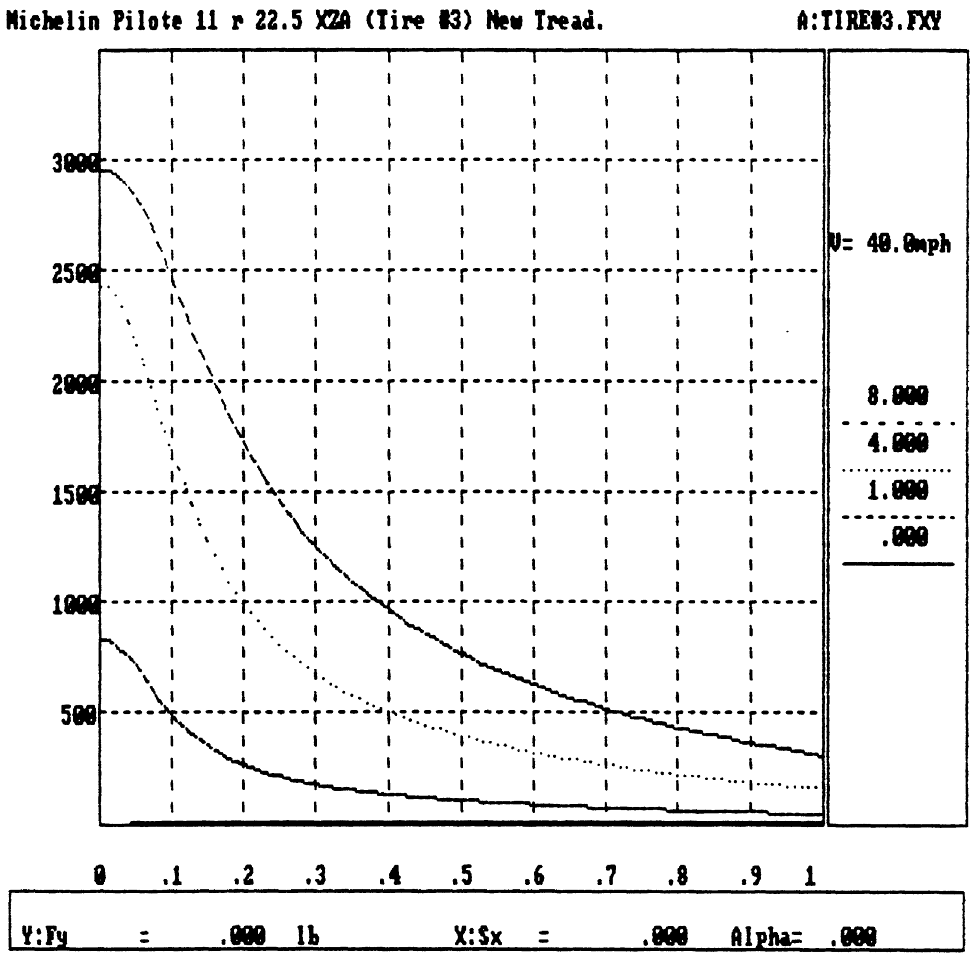
Mu-y Roll-Off Table

Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.591	.318	.210	.154	.097	.066	.047
2.00	1.000	.625	.344	.228	.168	.106	.073	.051
4.00	1.000	.693	.409	.278	.206	.131	.090	.063
8.00	1.000	.836	.585	.425	.326	.211	.146	.103
10.00	1.000	.867	.654	.494	.385	.254	.177	.125
12.00	1.000	.902	.720	.564	.448	.300	.211	.150
16.00	1.000	.942	.811	.673	.556	.387	.276	.198

Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread. A:TIRE#3.FXY




Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.
A:TIRE#3.FXY
3000
2500
2000
1500
1000
500
V= 40.0mph
8.000
4.000
1.000
.000
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
Y:Fy = .000 lb
X:Sx = .000
Alpha= .000

$GD = 0.38$ in.

COMBINED TIRE MODEL

FILE NAME:A:TIRE#3.FXY

Simulation Load = 6040.00 Lb
Simulation Velocity = 40.000 MPH

Alpha = .00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	.00	.00
.10	2895.78	.00	.00
.20	3243.49	.00	.00
.30	3198.23	.00	.00
.40	3134.86	.00	.00
.60	2953.81	.00	.00
.80	2700.34	.00	.00
1.00	2374.44	.00	.00

Alpha = 1.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	828.59	-1624.11
.10	2864.92	514.73	-125.71
.20	3230.93	281.98	56.25
.30	3192.55	185.75	35.55
.40	3131.60	136.66	24.40
.60	2952.28	85.89	12.09
.80	2699.42	58.90	5.15
1.00	2373.81	41.43	.78

Alpha = 2.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1523.66	-2745.04
.10	2778.02	996.58	-219.45
.20	3194.07	557.70	106.92
.30	3175.68	369.66	69.44
.40	3121.88	272.55	48.10
.60	2947.72	171.56	23.98
.80	2696.67	117.71	10.23
1.00	2371.90	82.83	1.52

Alpha = 4.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2524.16	-3145.87
.10	2496.48	1783.80	-279.78
.20	3057.57	1069.03	174.19
.30	3110.42	725.01	126.21
.40	3083.67	539.08	90.81
.60	2929.55	341.42	46.42
.80	2685.67	234.75	19.85
1.00	2364.25	165.32	2.78

Alpha = 8.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3128.80	-1932.22
.10	1885.81	2650.33	-222.77
.20	2639.17	1854.55	138.62
.30	2879.99	1349.19	169.34
.40	2940.75	1033.24	142.92
.60	2858.56	669.57	81.01
.80	2642.00	464.14	34.97
1.00	2333.63	327.97	3.39

Alpha = 10.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3242.68	-1591.10
.10	1599.58	2820.49	-407.25
.20	2411.85	2126.37	57.05
.30	2732.97	1606.32	151.83
.40	2842.77	1253.14	147.45
.60	2806.96	824.91	90.84
.80	2609.56	575.17	39.40
1.00	2310.65	407.43	2.24

Alpha = 12.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3238.80	-1559.71
.10	1374.92	2922.48	-560.37
.20	2194.63	2332.42	-44.21
.30	2576.23	1825.31	112.22
.40	2732.17	1451.85	136.98
.60	2745.71	972.70	94.55
.80	2570.26	682.91	41.13
1.00	2282.55	485.17	-.21

Alpha = 16.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3205.27	-1543.56
.10	1052.49	3017.96	-783.80
.20	1812.94	2599.26	-258.40
.30	2258.18	2158.41	-12.00
.40	2487.34	1783.08	76.22
.60	2597.94	1241.58	82.02
.80	2471.91	886.01	34.99
1.00	2210.91	633.97	-9.84

Mu-x Roll-Off Table

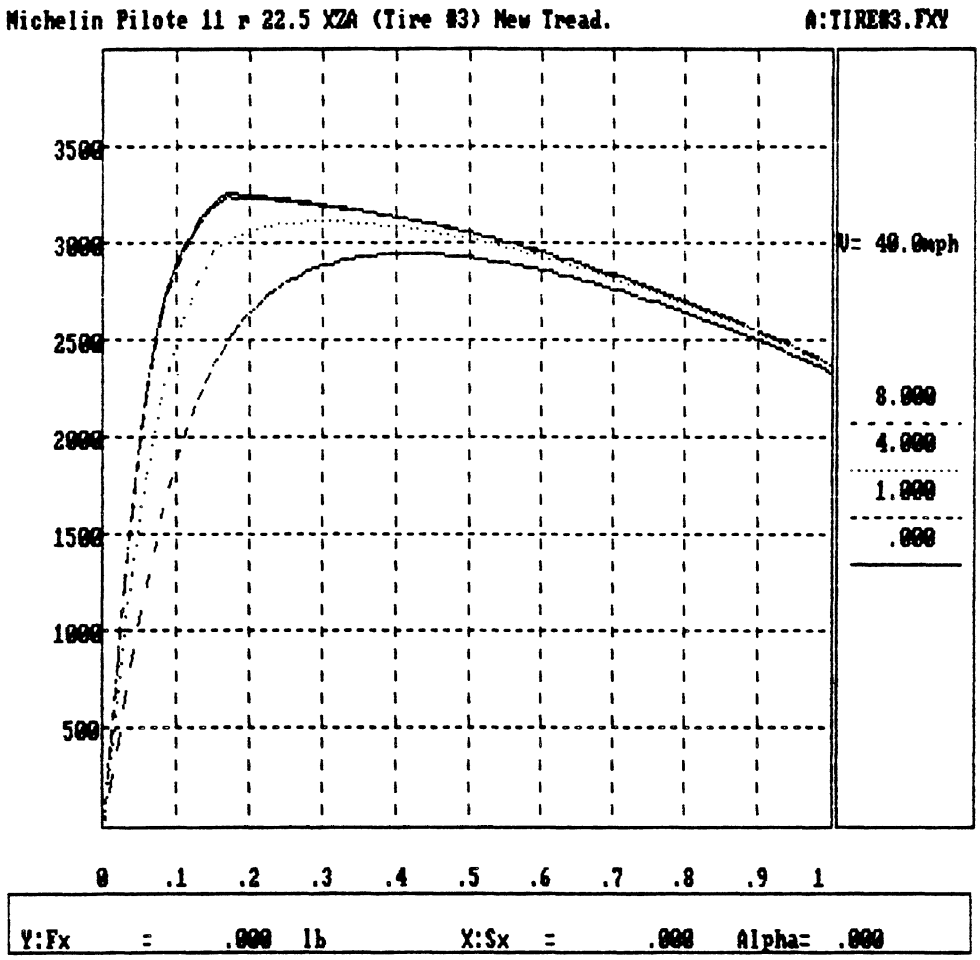
Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.989	.996	.998	.999	.999	1.000	1.000
2.00	1.000	.959	.985	.993	.996	.998	.999	.999
4.00	1.000	.862	.943	.973	.984	.992	.995	.996
8.00	1.000	.651	.814	.900	.938	.968	.978	.983
10.00	1.000	.552	.744	.855	.907	.950	.966	.973
12.00	1.000	.475	.677	.806	.872	.930	.952	.961
16.00	1.000	.363	.559	.706	.793	.880	.915	.931

Mu-y Roll-Off Table

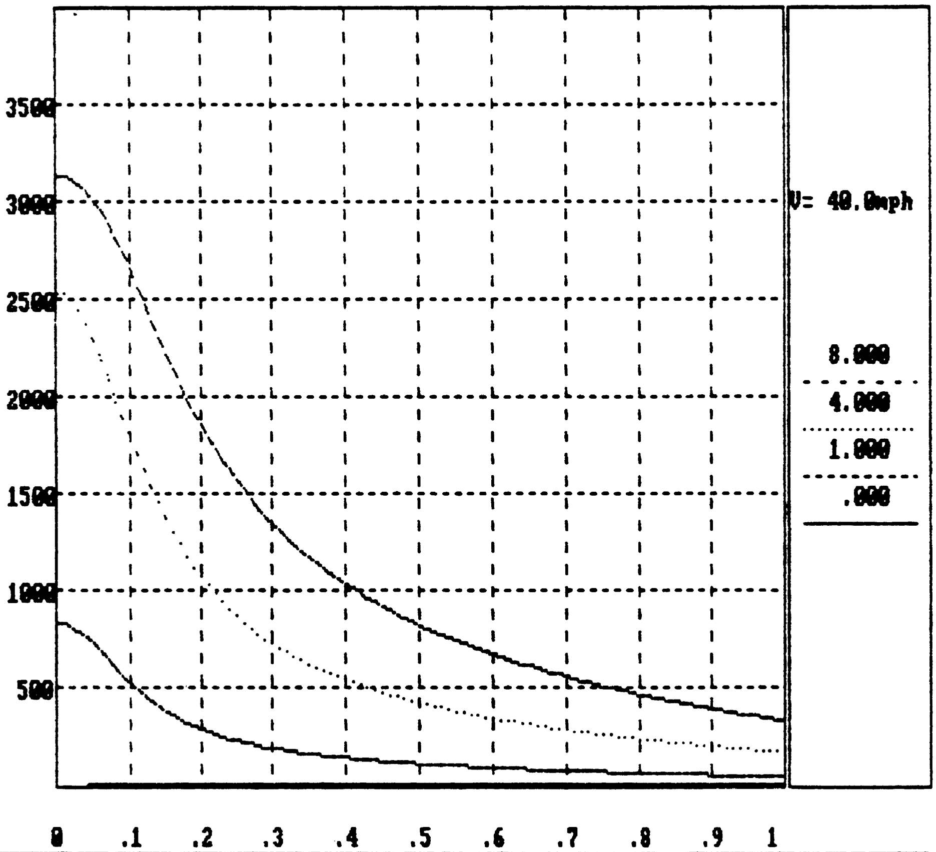
Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.621	.340	.224	.165	.104	.071	.050
2.00	1.000	.654	.366	.243	.179	.113	.077	.054
4.00	1.000	.707	.424	.287	.214	.135	.093	.065
8.00	1.000	.847	.593	.431	.330	.214	.148	.105
10.00	1.000	.870	.656	.495	.386	.254	.177	.126
12.00	1.000	.902	.720	.564	.448	.300	.211	.150
16.00	1.000	.942	.811	.673	.556	.387	.276	.198



Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.
A:TIRE#3.FXY
3500
3000
2500
2000
1500
1000
500
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
V= 40.0mph
8.000
4.000
1.000
.000
Y:Fx = .000 lb
X:Sx = .000
Alpha= .000

Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread. A:TIRE#3.FXY



Y:Fy = .000 lb X:Sx = .000 Alpha= .000

VARIATIONS IN V

V = 20 mph.

COMBINED TIRE MODEL

FILE NAME:A:TIRE#3.FXY

Simulation Load = 6040.00 Lb
Simulation Velocity = 20.000 MPH

Alpha = .00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	.00	.00
.10	3000.78	.00	.00
.20	3250.56	.00	.00
.30	3205.20	.00	.00
.40	3141.69	.00	.00
.60	2960.25	.00	.00
.80	2706.22	.00	.00
1.00	2379.62	.00	.00

Alpha = 1.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	828.75	-1624.73
.10	2966.90	514.38	-65.40
.20	3237.98	282.60	56.79
.30	3199.51	186.16	35.90
.40	3138.43	136.95	24.65
.60	2958.72	86.07	12.23
.80	2705.30	59.03	5.24
1.00	2378.98	41.53	.83

Alpha = 2.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1524.19	-2746.97
.10	2871.88	996.43	-116.80
.20	3201.03	558.91	107.97
.30	3182.60	370.46	70.13
.40	3128.69	273.14	48.60
.60	2954.14	171.93	24.27
.80	2702.54	117.97	10.39
1.00	2377.07	83.01	1.62

Alpha = 4.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2526.98	-3156.26
.10	2567.41	1785.47	-159.26
.20	3064.23	1071.36	176.08
.30	3117.20	726.59	127.53
.40	3090.39	540.25	91.77
.60	2935.94	342.17	46.98
.80	2691.53	235.26	20.18
1.00	2369.40	165.68	2.96

Alpha = 8.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3134.30	-1939.84
.10	1889.92	2656.11	-220.96
.20	2644.92	1858.60	141.18
.30	2886.26	1352.13	171.50
.40	2947.16	1035.49	144.63
.60	2864.79	671.03	82.07
.80	2647.76	465.15	35.61
1.00	2338.72	328.69	3.75

Alpha = 10.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3248.70	-1597.53
.10	1603.07	2826.64	-406.06
.20	2417.10	2131.00	59.54
.30	2738.93	1609.83	154.19
.40	2848.96	1255.87	149.41
.60	2813.08	826.70	92.10
.80	2615.25	576.42	40.18
1.00	2315.69	408.32	2.68

Alpha = 12.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3245.86	-1563.11
.10	1377.92	2928.85	-559.74
.20	2199.42	2337.50	-41.95
.30	2581.84	1829.29	114.63
.40	2738.12	1455.01	139.11
.60	2751.69	974.82	95.99
.80	2575.86	684.40	42.03
1.00	2287.53	486.23	.30

Alpha = 16.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3212.26	-1546.92
.10	1054.78	3024.54	-784.05
.20	1816.89	2604.93	-256.80
.30	2263.10	2163.11	-9.78
.40	2492.76	1786.97	78.42
.60	2603.60	1244.28	83.68
.80	2477.30	887.94	36.08
1.00	2215.73	635.35	-9.22

Mu-x Roll-Off Table

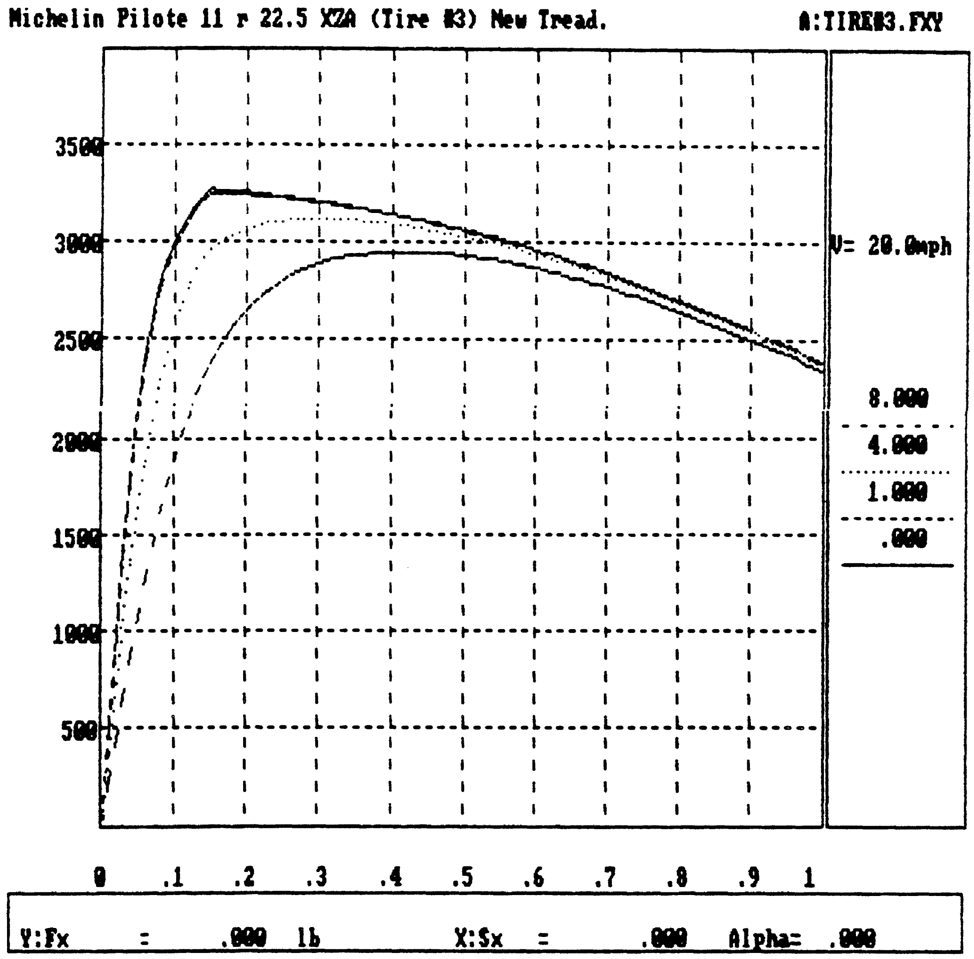
Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.989	.996	.998	.999	.999	1.000	1.000
2.00	1.000	.957	.985	.993	.996	.998	.999	.999
4.00	1.000	.856	.943	.973	.984	.992	.995	.996
8.00	1.000	.630	.814	.900	.938	.968	.978	.983
10.00	1.000	.534	.744	.855	.907	.950	.966	.973
12.00	1.000	.459	.677	.806	.872	.930	.952	.961
16.00	1.000	.352	.559	.706	.793	.880	.915	.931

Mu-y Roll-Off Table

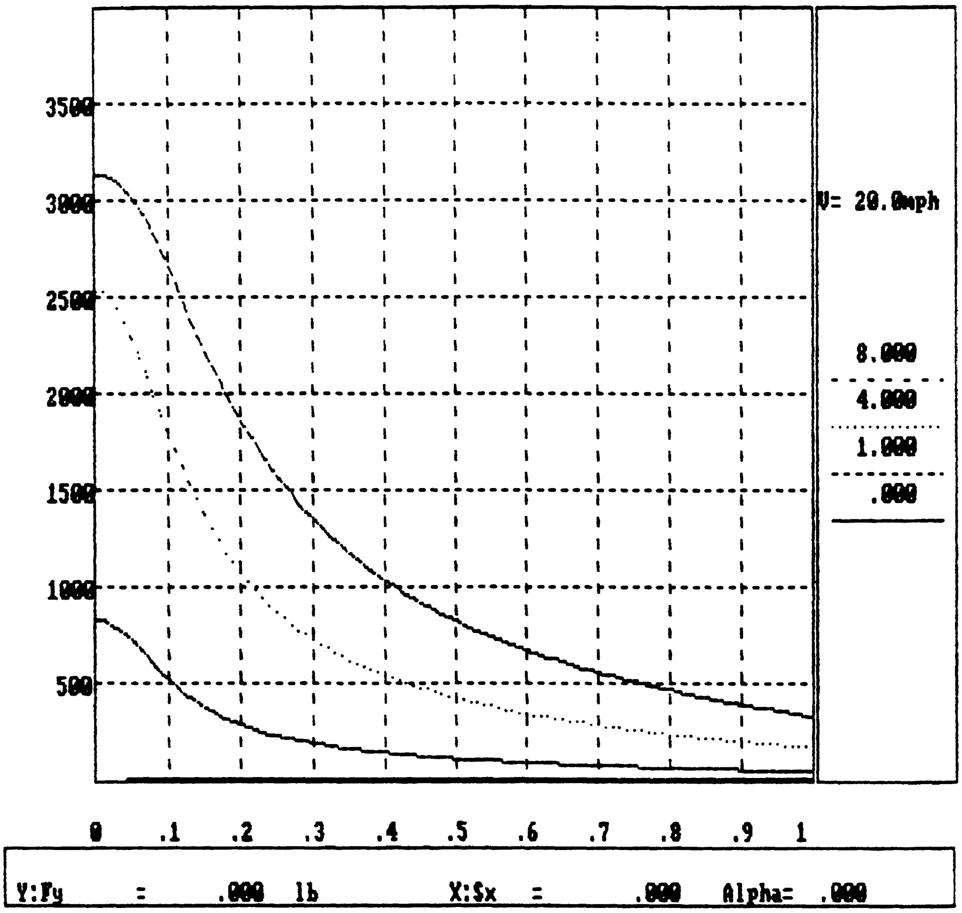
Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.621	.341	.225	.165	.104	.071	.050
2.00	1.000	.654	.367	.243	.179	.113	.077	.054
4.00	1.000	.707	.424	.288	.214	.135	.093	.066
8.00	1.000	.847	.593	.431	.330	.214	.148	.105
10.00	1.000	.870	.656	.496	.387	.254	.177	.126
12.00	1.000	.902	.720	.564	.448	.300	.211	.150
16.00	1.000	.942	.811	.673	.556	.387	.276	.198



Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.
A:TIRE#3.FXY
3500
3000
2500
2000
1500
1000
500
V= 20.0mph
8.000
4.000
1.000
.000
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
Y:Fx = .000 lb
X:Sx = .000
Alpha= .000

Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.   A:TIRE#3.FXY



V = 60 mph.

COMBINED TIRE MODEL

FILE NAME:A:TIRE#3.FXY

Simulation Load = 6040.00 Lb
Simulation Velocity = 60.000 MPH

Alpha = .00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	.00	.00
.10	2680.71	.00	.00
.20	3026.64	.00	.00
.30	2984.41	.00	.00
.40	2925.27	.00	.00
.60	2756.33	.00	.00
.80	2519.80	.00	.00
1.00	2215.70	.00	.00

Alpha = 1.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	823.41	-1603.85
.10	2652.58	492.02	-151.91
.20	3014.92	263.13	40.51
.30	2979.11	173.34	25.38
.40	2922.24	127.52	17.14
.60	2754.90	80.15	7.95
.80	2518.94	54.96	2.72
1.00	2215.10	38.66	-.57

Alpha = 2.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1506.22	-2682.56
.10	2573.52	950.08	-260.43
.20	2980.52	520.41	76.35
.30	2963.37	344.94	49.36
.40	2913.16	254.32	33.70
.60	2750.64	160.09	15.73
.80	2516.38	109.84	5.37
1.00	2213.32	77.29	-1.16

Alpha = 4.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2431.77	-2828.10
.10	2317.23	1690.77	-316.22
.20	2853.15	997.56	119.56
.30	2902.47	676.54	88.12
.40	2877.50	503.04	62.87
.60	2733.69	318.60	30.16
.80	2506.12	219.06	10.23
1.00	2206.18	154.27	-2.55

Alpha = 8.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2957.31	-1704.21
.10	1759.73	2473.14	-273.61
.20	2462.72	1730.56	64.99
.30	2687.44	1258.98	106.92
.40	2744.14	964.16	93.40
.60	2667.44	624.81	50.43
.80	2465.36	433.11	16.51
1.00	2177.61	306.04	-6.90

Alpha = 10.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3034.17	-1461.16
.10	1492.64	2631.92	-439.35
.20	2250.60	1984.21	-14.20
.30	2550.26	1498.93	83.95
.40	2652.71	1169.36	90.75
.60	2619.30	769.75	54.31
.80	2435.09	536.72	17.03
1.00	2156.17	380.19	-10.29

Alpha = 12.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3022.27	-1455.43
.10	1283.00	2727.09	-575.75
.20	2047.91	2176.48	-108.57
.30	2403.99	1703.28	42.88
.40	2549.50	1354.78	75.66
.60	2562.14	907.67	53.11
.80	2398.42	637.25	15.29
1.00	2129.95	452.73	-14.76

Alpha = 16.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	2990.98	-1440.36
.10	982.12	2816.19	-773.17
.20	1691.74	2425.49	-303.10
.30	2107.21	2014.10	-75.30
.40	2321.04	1663.87	12.79
.60	2424.25	1158.57	34.11
.80	2306.65	826.78	3.85
1.00	2063.10	591.58	-27.62

Mu-x Roll-Off Table

Longitudinal Slip, Sx

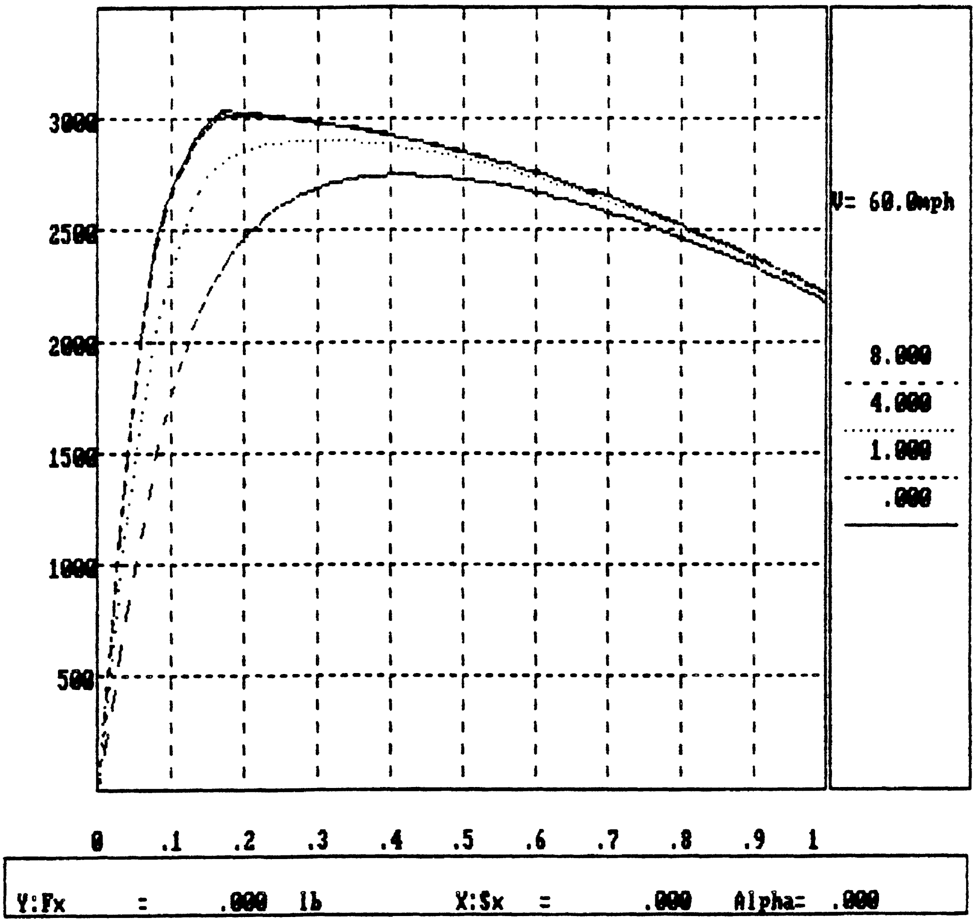
Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.990	.996	.998	.999	.999	1.000	1.000
2.00	1.000	.960	.985	.993	.996	.998	.999	.999
4.00	1.000	.864	.943	.973	.984	.992	.995	.996
8.00	1.000	.656	.814	.900	.938	.968	.978	.983
10.00	1.000	.557	.744	.855	.907	.950	.966	.973
12.00	1.000	.479	.677	.806	.872	.930	.952	.961
16.00	1.000	.366	.559	.706	.793	.880	.915	.931

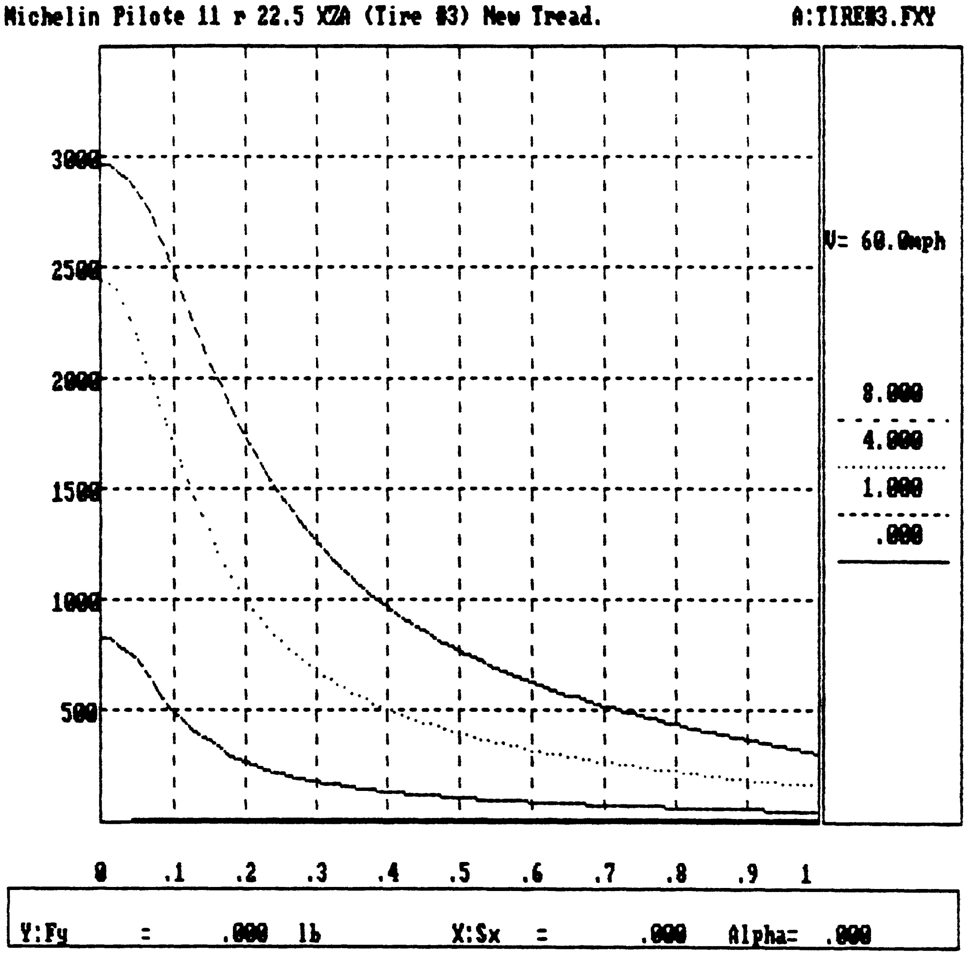
Mu-y Roll-Off Table

Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.598	.320	.211	.155	.097	.067	.047
2.00	1.000	.631	.346	.229	.169	.106	.073	.051
4.00	1.000	.695	.410	.278	.207	.131	.090	.063
8.00	1.000	.836	.585	.426	.326	.211	.146	.103
10.00	1.000	.867	.654	.494	.385	.254	.177	.125
12.00	1.000	.902	.720	.564	.448	.300	.211	.150
16.00	1.000	.942	.811	.673	.556	.387	.276	.198

Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread. A:TIRE#3.FXY





Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.
A:TIRE#3.FXY
3000
2500
2000
1500
1000
500
V= 60.0mph
8.000
4.000
1.000
.000
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
Y:Fy = .000 lb
X:Sx = .000
Alpha= .000

VARIATIONS IN Fz

$Fz = 3020$ lbs.

COMBINED TIRE MODEL

FILE NAME:A:TIRE#3.FXY

Simulation Load = 3020.00 Lb
Simulation Velocity = 40.000 MPH

Alpha = .00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	.00	.00
.10	1534.83	.00	.00
.20	1523.14	.00	.00
.30	1503.67	.00	.00
.40	1476.41	.00	.00
.60	1398.51	.00	.00
.80	1289.46	.00	.00
1.00	1149.25	.00	.00

Alpha = 1.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	478.80	-529.01
.10	1511.85	263.89	-8.13
.20	1517.26	132.42	-3.93
.30	1501.01	87.33	-2.89
.40	1474.89	64.36	-2.49
.60	1397.80	40.66	-2.23
.80	1289.04	28.13	-2.19
1.00	1148.96	20.06	-2.15

Alpha = 2.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	851.64	-836.59
.10	1448.57	505.85	-22.34
.20	1499.98	261.90	-8.73
.30	1493.11	173.80	-6.04
.40	1470.34	128.36	-5.08
.60	1395.68	81.23	-4.49
.80	1287.76	56.21	-4.39
1.00	1148.08	40.09	-4.31

Alpha = 4.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1315.71	-805.39
.10	1256.25	878.46	-74.41
.20	1436.00	502.07	-23.50
.30	1462.56	340.91	-14.05
.40	1452.48	253.92	-11.01
.60	1387.22	161.67	-9.23
.80	1282.67	112.12	-8.87
1.00	1144.55	80.04	-8.66

Alpha = 8.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1531.03	-535.11
.10	885.36	1244.30	-202.68
.20	1239.93	871.30	-76.80
.30	1354.69	634.63	-40.59
.40	1385.67	486.86	-27.96
.60	1354.17	317.19	-20.32
.80	1262.44	221.78	-18.50
1.00	1130.45	158.87	-17.67

Alpha = 10.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1526.61	-533.57
.10	751.18	1324.54	-253.21
.20	1133.43	999.28	-110.51
.30	1285.90	755.79	-59.30
.40	1339.89	590.65	-39.62
.60	1330.15	390.90	-27.02
.80	1247.41	274.94	-23.80
1.00	1119.87	197.46	-22.40

Alpha = 12.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1521.13	-531.65
.10	645.89	1372.89	-292.92
.20	1031.70	1096.48	-144.78
.30	1212.56	859.13	-80.68
.40	1288.22	684.55	-53.37
.60	1301.65	461.12	-34.65
.80	1229.22	326.60	-29.53
1.00	1106.93	235.28	-27.34

Alpha = 16.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1506.70	-526.61
.10	494.86	1418.99	-347.94
.20	853.03	1223.02	-207.55
.30	1063.85	1016.84	-127.37
.40	1173.91	841.53	-85.89
.60	1232.93	589.23	-52.81
.80	1183.70	424.28	-42.43
1.00	1073.95	307.95	-37.92

Mu-x Roll-Off Table

Longitudinal Slip, Sx

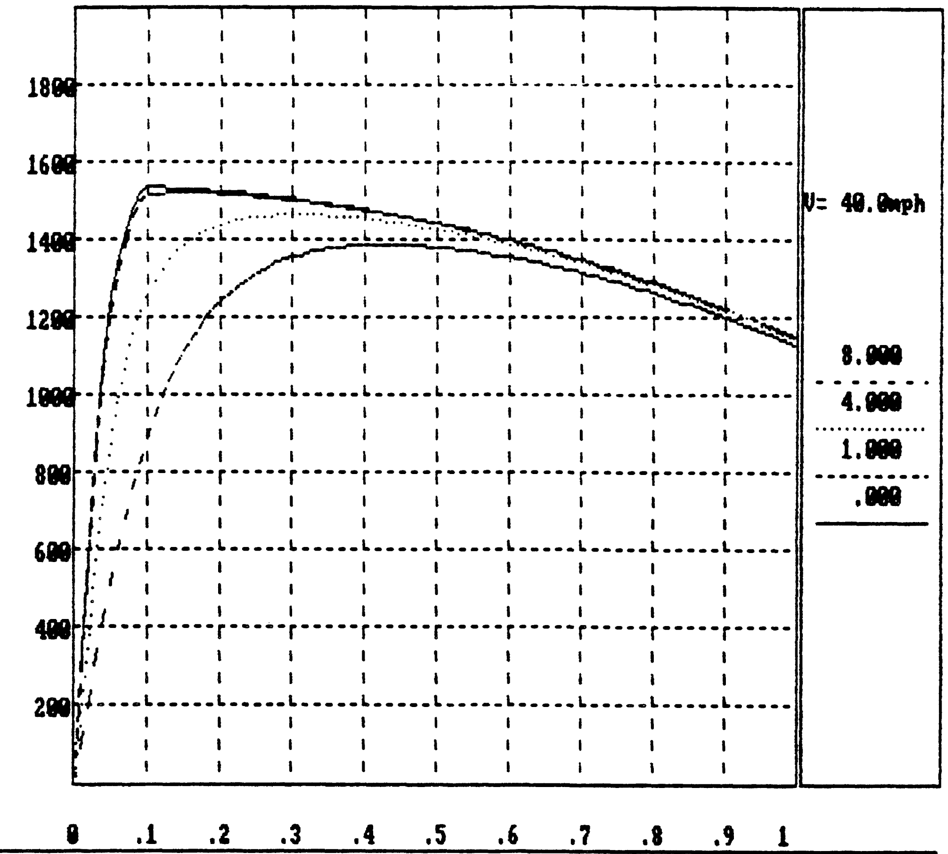
Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.985	.996	.998	.999	.999	1.000	1.000
2.00	1.000	.944	.985	.993	.996	.998	.999	.999
4.00	1.000	.818	.943	.973	.984	.992	.995	.996
8.00	1.000	.577	.814	.901	.939	.968	.979	.984
10.00	1.000	.489	.744	.855	.908	.951	.967	.974
12.00	1.000	.421	.677	.806	.873	.931	.953	.963
16.00	1.000	.322	.560	.708	.795	.882	.918	.934

Mu-y Roll-Off Table

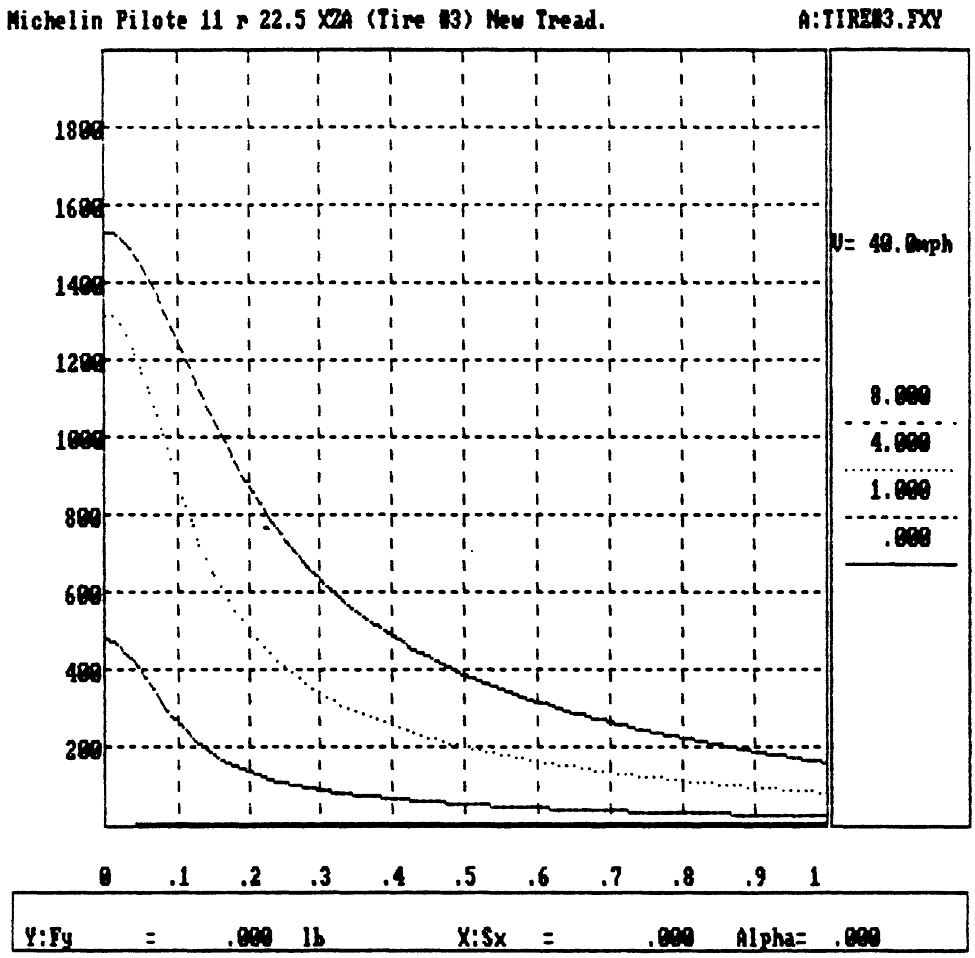
Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.551	.277	.182	.134	.085	.059	.042
2.00	1.000	.594	.308	.204	.151	.095	.066	.047
4.00	1.000	.668	.382	.259	.193	.123	.085	.061
8.00	1.000	.813	.569	.415	.318	.207	.145	.104
10.00	1.000	.868	.655	.495	.387	.256	.180	.129
12.00	1.000	.903	.721	.565	.450	.303	.215	.155
16.00	1.000	.942	.812	.675	.559	.391	.282	.204

Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread. A:TIRE#3.FXY



Y:Fx = .000 lb X:Sx = .000 Alpha= .000



Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.
A:TIRE#3.FXY
1800
1600
1400
1200
1000
800
600
400
200
V= 40.0mph
8.000
4.000
1.000
.000
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1
Y:Fy = .000 lb
X:Sx = .000
Alpha= .000

$Fz = 9060$ lbs.

COMBINED TIRE MODEL

FILE NAME:A:TIRE#3.FXY

Simulation Load = 9060.00 Lb
Simulation Velocity = 40.000 MPH

Alpha = .00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	.00	.00
.10	3844.63	.00	.00
.20	4796.27	.00	.00
.30	5040.66	.00	.00
.40	4919.95	.00	.00
.60	4569.43	.00	.00
.80	4078.70	.00	.00
1.00	3447.76	.00	.00

Alpha = 1.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	931.29	-2754.01
.10	3813.44	725.46	-709.14
.20	4780.63	430.68	91.04
.30	5032.40	297.89	179.57
.40	4914.74	214.47	124.16
.60	4566.97	132.86	67.18
.80	4077.20	88.96	35.79
1.00	3446.70	60.16	16.21

Alpha = 2.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	1782.71	-5044.23
.10	3723.97	1406.63	-1256.19
.20	4734.59	852.72	182.99
.30	5006.69	582.79	348.68
.40	4899.18	427.71	246.20
.60	4559.58	265.37	133.76
.80	4072.68	177.78	71.36
1.00	3443.52	120.25	32.32

Alpha = 4.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	3267.44	-7887.26
.10	3416.47	2535.35	-1703.15
.20	4562.57	1641.40	368.65
.30	4902.65	1142.75	658.65
.40	4838.01	845.77	475.95
.60	4530.20	527.97	262.85
.80	4054.67	354.41	140.92
1.00	3430.81	239.91	63.84

Alpha = 8.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	4443.69	-5310.30
.10	2659.09	3866.14	-1397.64
.20	4018.47	2886.92	690.16
.30	4535.04	2124.53	1059.89
.40	4609.12	1619.42	833.19
.60	4415.31	1034.22	489.85
.80	3983.09	699.73	267.67
1.00	3379.93	475.02	121.31

Alpha = 10.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	4666.57	-4427.74
.10	2330.80	4222.58	-1174.47
.20	3711.46	3335.59	794.47
.30	4300.35	2527.56	1135.91
.40	4452.09	1962.56	944.76
.60	4331.76	1273.01	580.53
.80	3929.88	866.18	321.63
1.00	3341.72	589.23	145.74

Alpha = 12.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	4804.72	-3763.64
.10	2053.14	4462.29	-987.66
.20	3410.31	3685.53	856.68
.30	4049.94	2869.47	1138.10
.40	4274.71	2271.54	1008.57
.60	4232.50	1499.41	652.40
.80	3865.41	1027.02	367.39
1.00	3294.97	700.37	166.32

Alpha = 16.00

Sx	Fx (lb)	Fy (lb)	Alig. Torq. (in-lb)
.00	.00	4944.96	-2834.91
.10	1624.00	4732.23	-716.60
.20	2852.46	4089.65	589.75
.30	3541.13	3384.67	979.42
.40	3881.53	2782.53	1004.84
.60	3992.79	1908.19	733.84
.80	3703.86	1327.58	429.70
1.00	3175.68	910.61	193.36

Mu-x Roll-Off Table

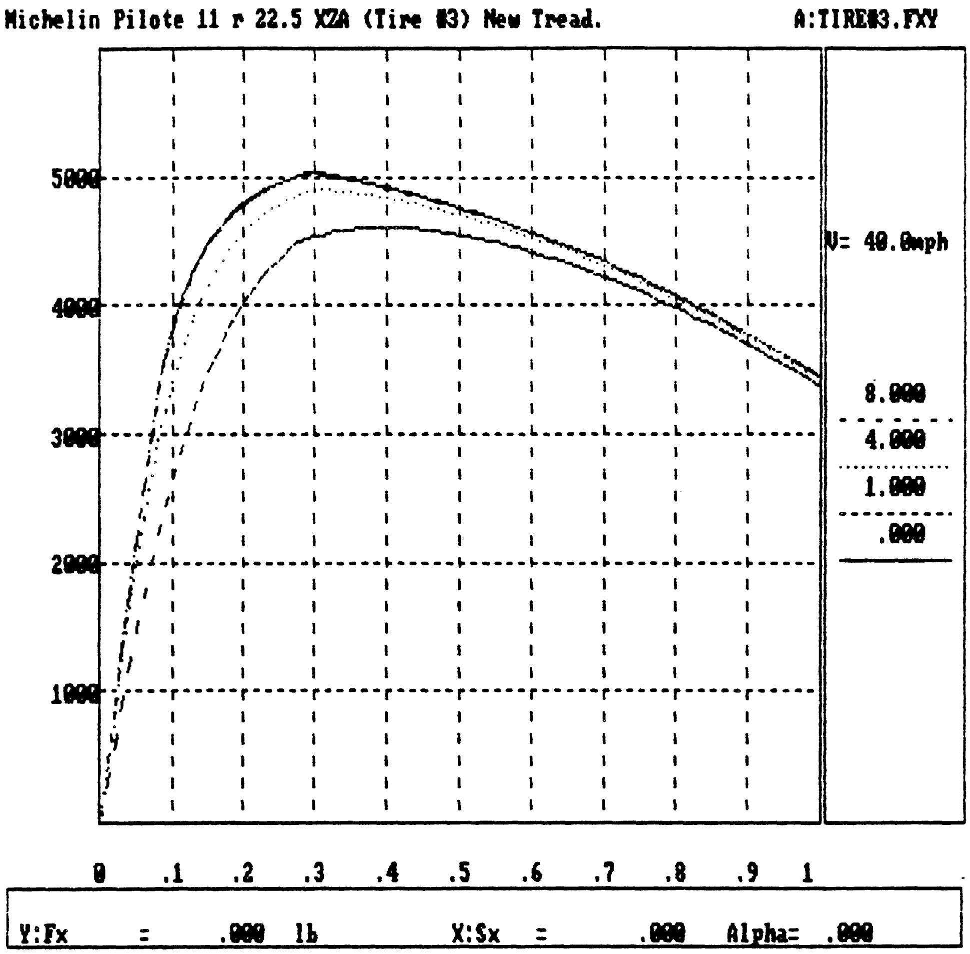
Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.992	.997	.998	.999	.999	1.000	1.000
2.00	1.000	.969	.987	.993	.996	.998	.999	.999
4.00	1.000	.889	.951	.973	.983	.991	.994	.995
8.00	1.000	.692	.838	.900	.937	.966	.977	.980
10.00	1.000	.606	.774	.853	.905	.948	.964	.969
12.00	1.000	.534	.711	.803	.869	.926	.948	.956
16.00	1.000	.422	.595	.703	.789	.874	.908	.921

Mu-y Roll-Off Table

Longitudinal Slip, Sx

Alpha	.00	.10	.20	.30	.40	.60	.80	1.00
.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.00	1.000	.779	.462	.320	.230	.143	.096	.065
2.00	1.000	.789	.478	.327	.240	.149	.100	.067
4.00	1.000	.776	.502	.350	.259	.162	.108	.073
8.00	1.000	.870	.650	.478	.364	.233	.157	.107
10.00	1.000	.905	.715	.542	.421	.273	.186	.126
12.00	1.000	.929	.767	.597	.473	.312	.214	.146
16.00	1.000	.957	.827	.684	.563	.386	.268	.184



Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.
A:TIRE#3.FXY
5000
4000
3000
2000
1000
V= 40.0mph
8.000
4.000
1.000
.000
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
Y:Fx = .000 lb
X:Sx = .000
Alpha= .000

Michelin Pilote 11 r 22.5 XZA (Tire #3) New Tread.   A:TIRE#3.FXY