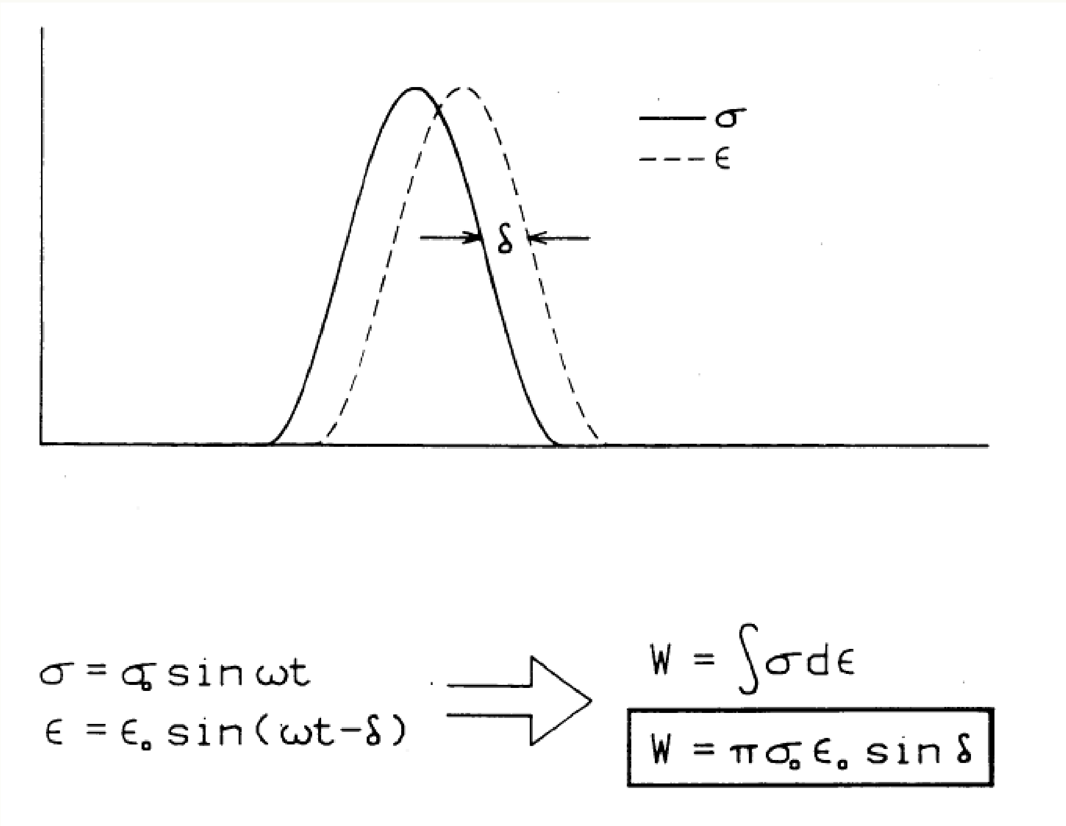
Material Properties & Tire Behavior

Introduction

This page will tackle the influence that rubber properties have on certain aspects of tire performance. In particular, the impact of rubber modulus and phase lag on a tire's heat generation, operating temperature(s), rolling resistance, and traction performance will be discussed.

Background

The key to many aspects of tire performance is the rate of heat generation in the tire as it rolls due to the hysteretic damping present in the rubber compounds. Hysteretic damping shows up as the phase lag between the stress and strain signals, as shown below.

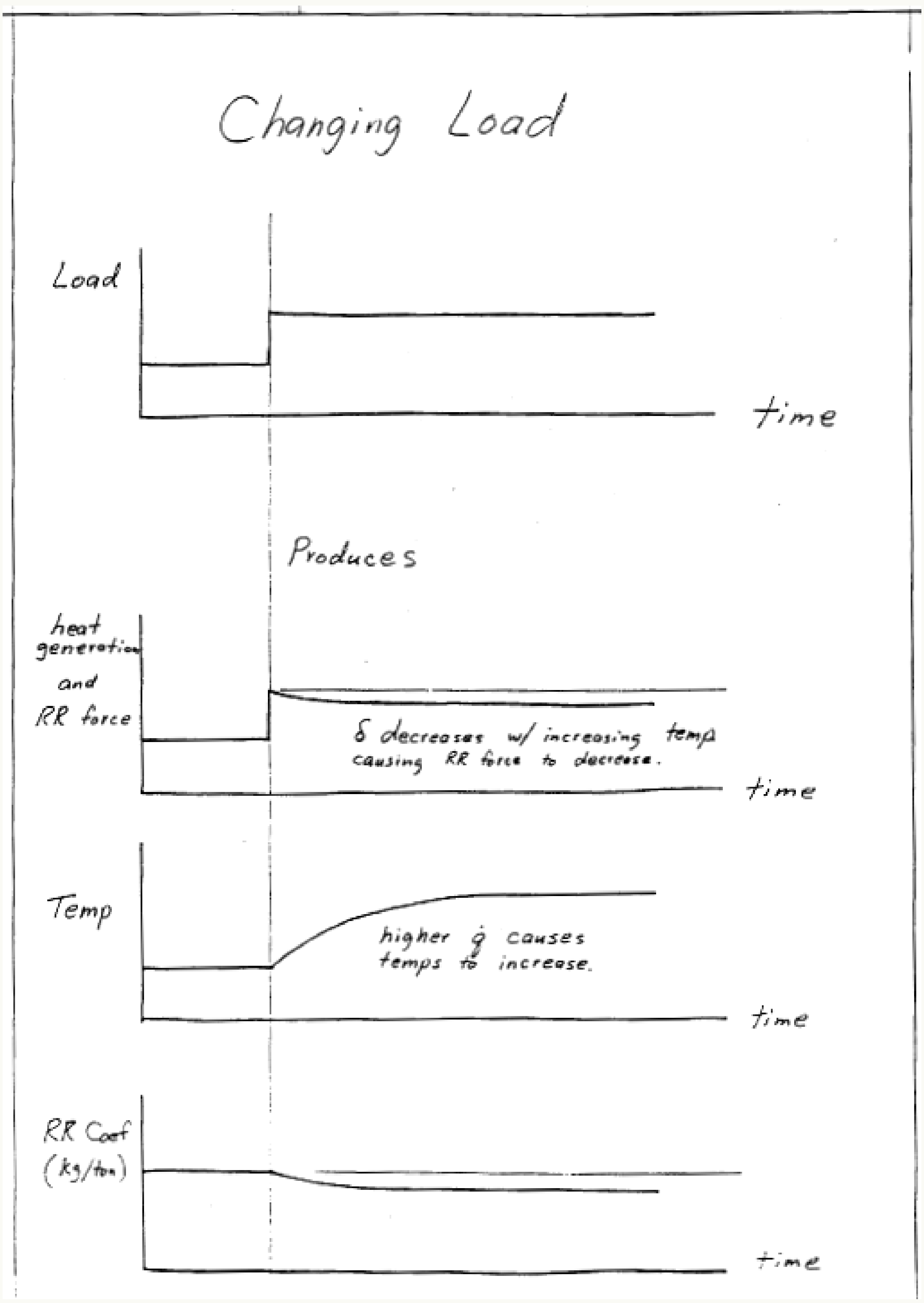


The boxed equation represents the mechanical energy loss per cycle, which would also be "per tire rotation" The mechanical energy lost must equal the heat generated in order to satisfy the 1st Law: $W_{\text{lost}} = Q_{\text{generated}}$. And multiplying this by the tire's rotational frequency, f, gives the heat generation rate, $\dot{Q}$.

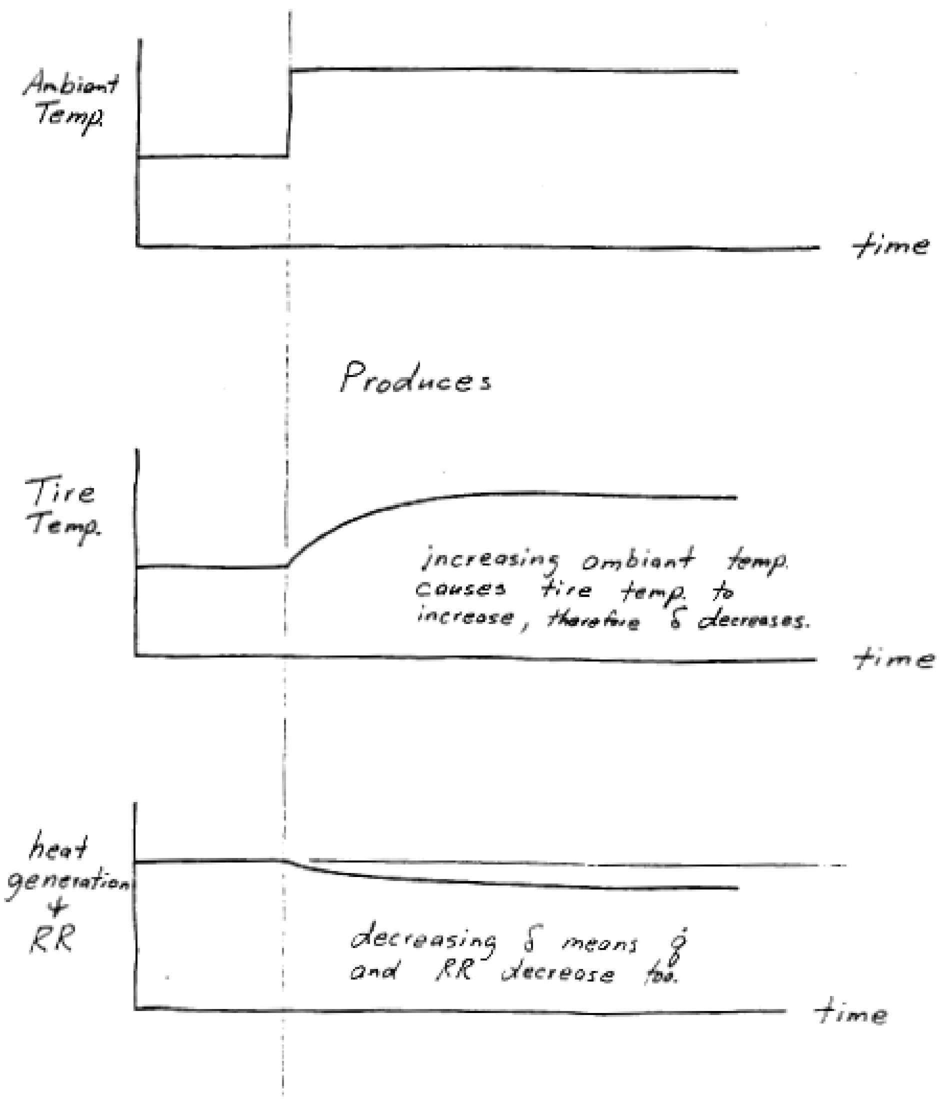
$$\dot{Q} = f \pi \sigma_o \epsilon_o \sin\delta$$

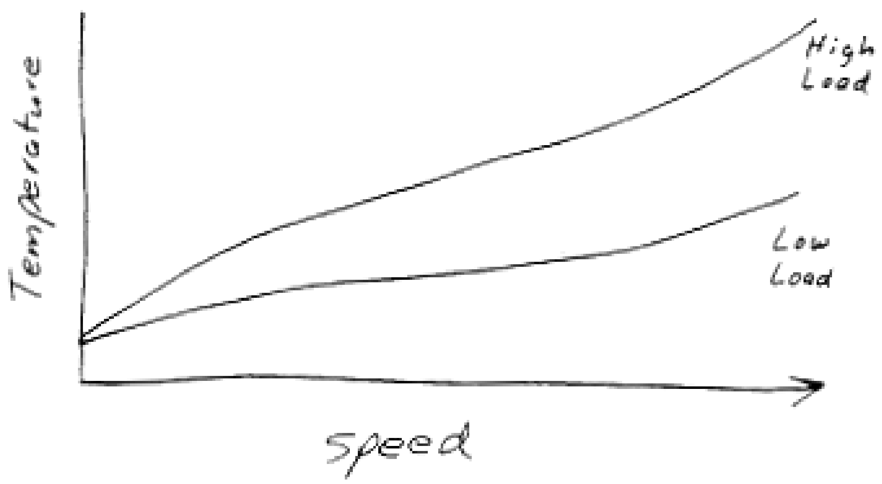
Of course, this is simplified. In the real tire, 3-D deformations take place (secondary shears may be present), and the deformation shapes are not perfect sinusoids. But the trends here are correct. Heat generation increases with (i) the tire's rotational frequency, *f*, (ii) the material's phase lag, and (iii) the product of the stress and strain cyclic amplitudes.

Rolling Resistance Force * Speed = Heat Generation Rate



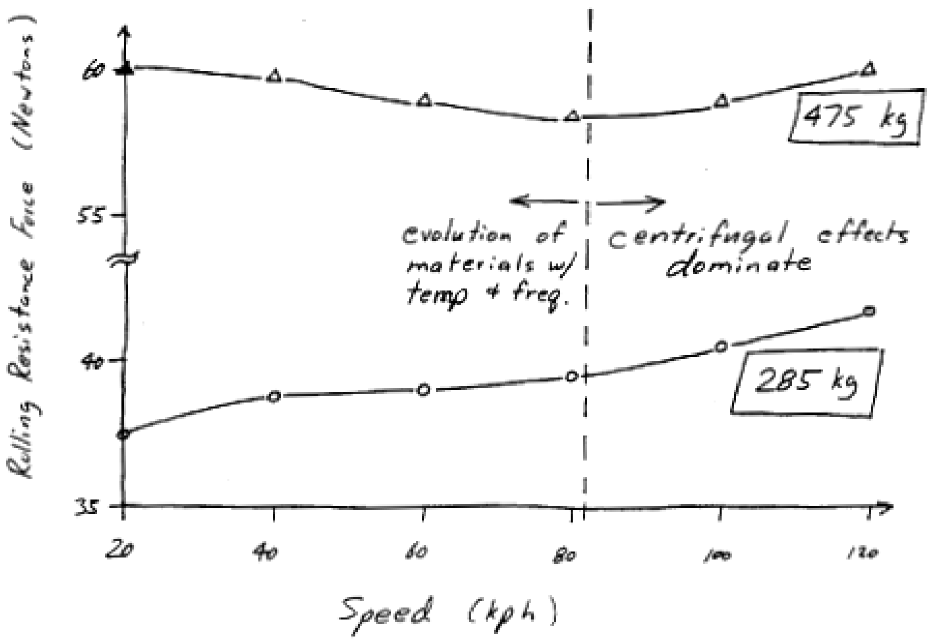
Changing Ambiant Temperature



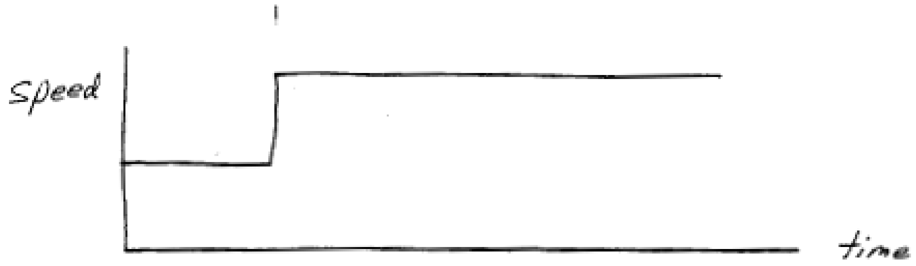


Rolling Resistance at Low Speeds

P195/60R14 XGT @ 2 bars



Increasing Speed at High Loads



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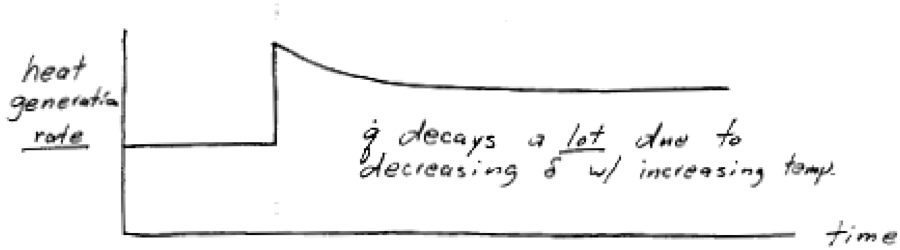
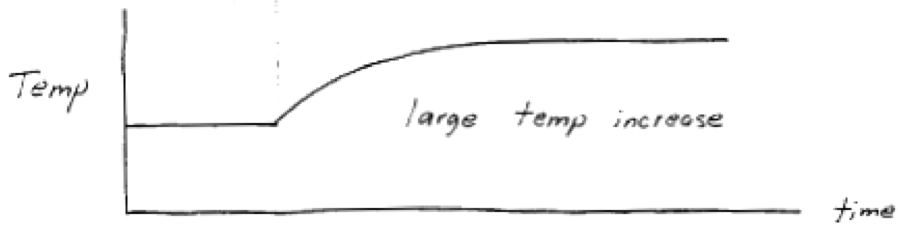
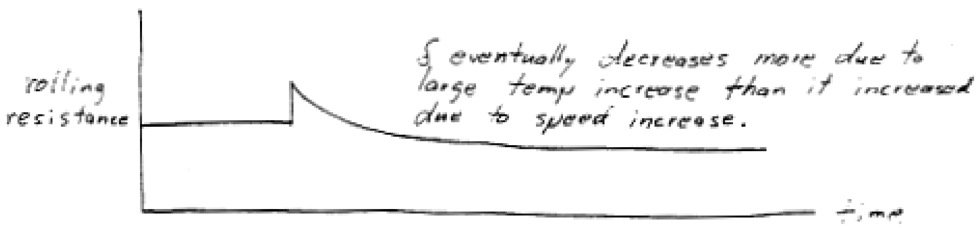
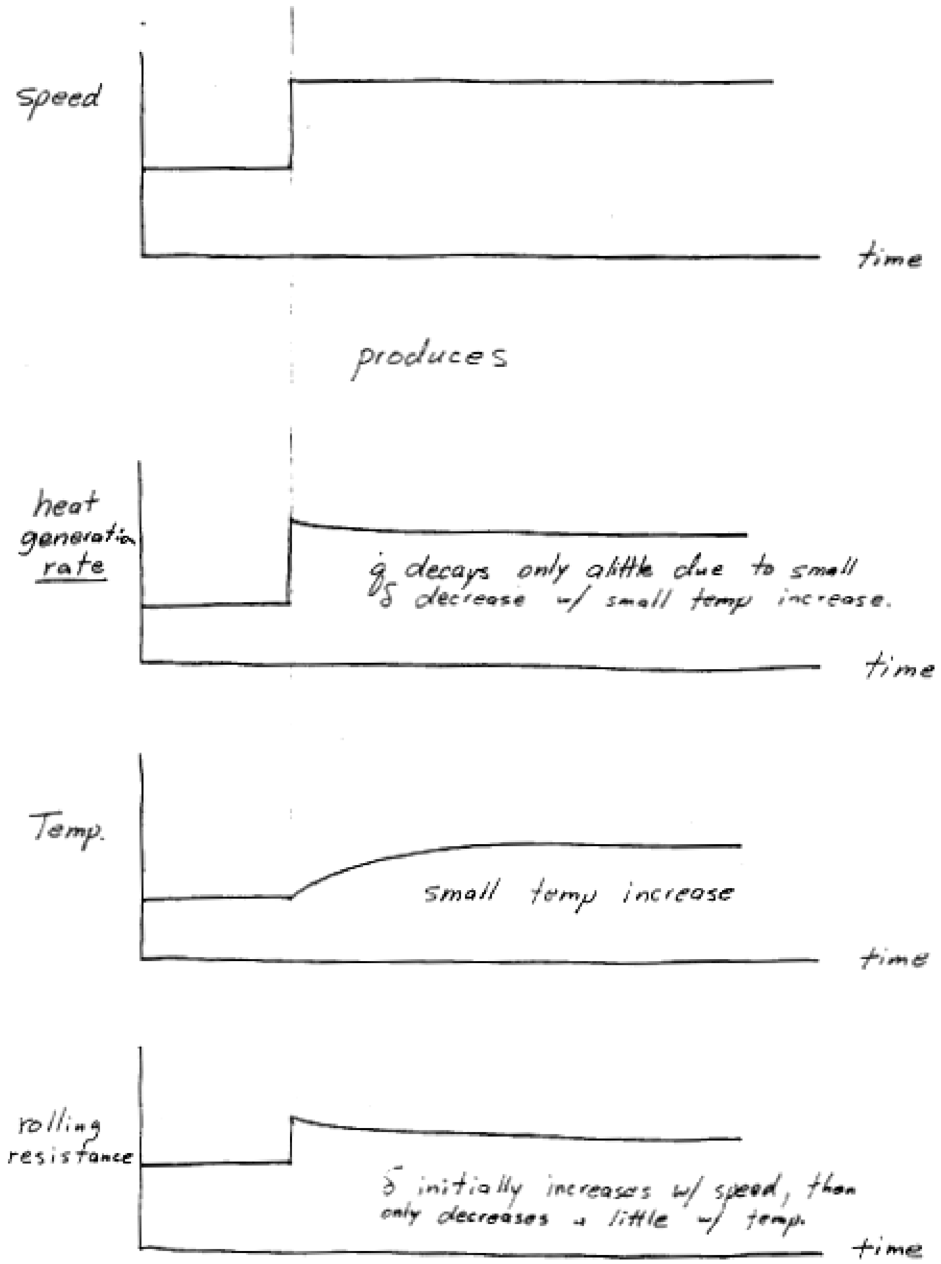


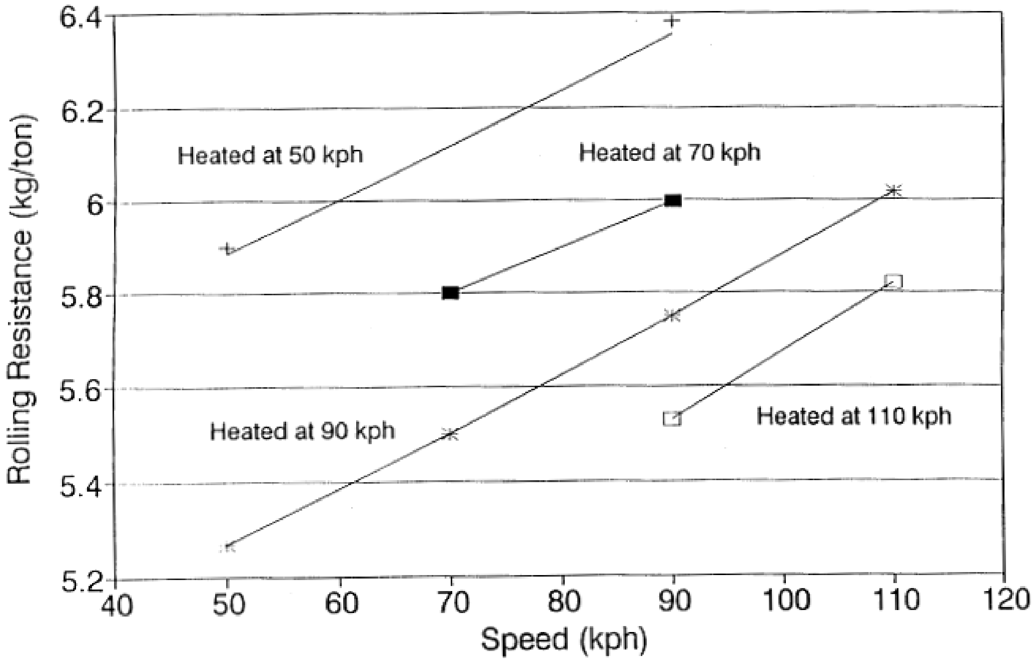




Increasing Speed at Low Loads



Effects of Speed
Ribbed Truck Tire



Rolling Resistance vs. Steer Angle

Rolling resistance increases quadratically from a minimum at the steer angle producing zero Y-force.

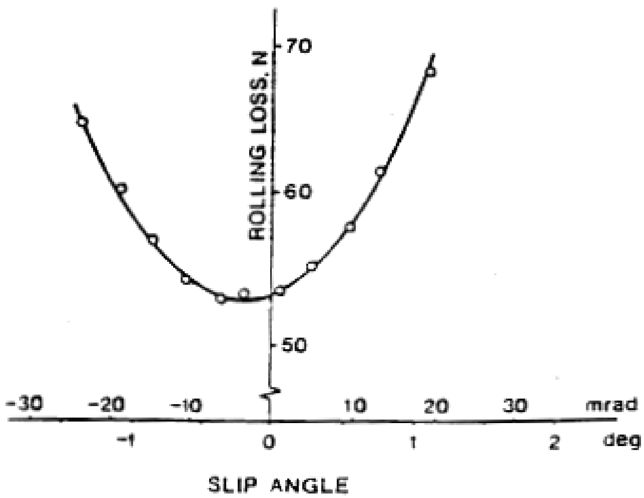
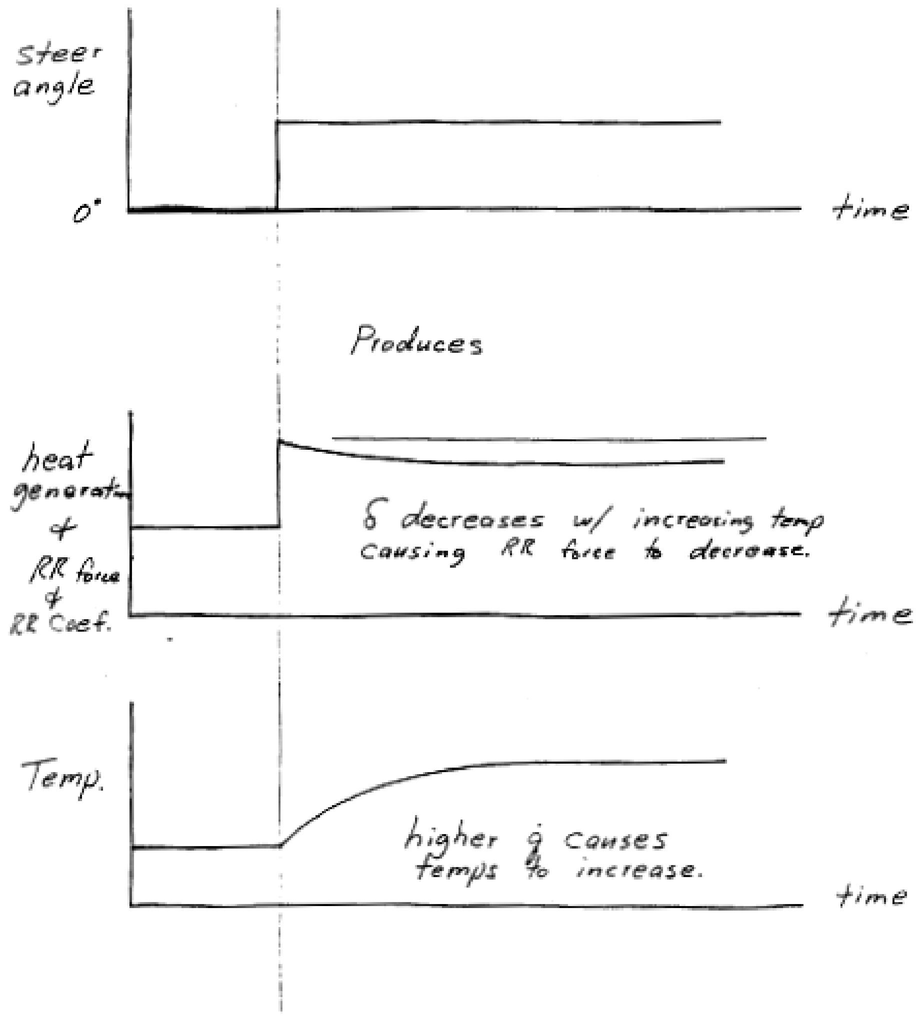


Fig. 50.—Rolling loss as function of slip angle. Radial passenger car tire (FR78-14), tested at 5.7 kN, 105 kPa, and 80 km/h.

Reference: <u>The Rolling Loss of Pneumatic Tires</u>, D. J. Schuring, Firestone

Changing Steer Angle



Rolling Resistance vs. Torque

ROLLING RESISTANCE INCREASES FROM A MINIMUM AT THE DRIVING TORQUE WHICH BALANCES THE BRAKING TORQUE CREATED BY THE ROLLING RESISTANCE FORCE.

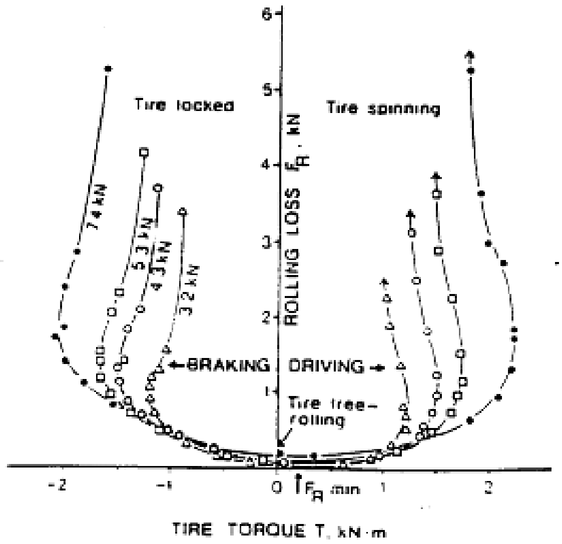


Fig. 10.—Effect of tire torque (braking and driving) on rolling loss of a passenger car tire at various loads. Adapted from Schuring[4].

REFERENCE: <u>THE ROLLING LOSS OF PNEUMATIC TIRES</u>, D. J. SCHURING, FIRESTONE

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