2006-01-1680

Measurement of Changes to Vehicle Handling Due To Tread-Separation-Induced Axle Tramp

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ABSTRACT

Tests were conducted to evaluate the effects of the tire-induced vibration caused by a tread separating rear tire on the handling characteristics of a 1996 four-door two-wheel drive Ford Explorer. The first test series consisted of a laboratory test utilizing a 36-inch diameter single roller dynamometer driven by the rear wheels of the Explorer. The right rear tire was modified to generate the vibration disturbance that results from a separating tire. This was accomplished by vulcanizing sections of retread to the prepared surface of the tire. Either one or two tread sections covering 1/8, 1/4, or 1/2 of the circumference of the tire were evaluated. The results demonstrated that a tire modified with two bonded-on tread sections driven at half speed replicated axle tramp characteristics of a modified tire with a single bonded-on tread section at the peak axle tramp speed. A second test series consisted of low speed vehicle handling tests with a right rear tire modified with two bonded-on tread sections. The on-road testing showed that the modified right rear tire caused axle tramp and associated vehicle skate at the peak axle tramp speed during quasi-steady state and dynamic maneuvers. A 1999 four-wheel drive Ford F-250 truck was tested with a tire modified by cutting away 1/4 of the tread and outer belt at two locations. The modified tire was placed at the left front position and low speed vehicle handling tests were conducted at the peak axle tramp speed. Test results show front-axle tramp induced an increase in steer gradient and significantly reduced turning capability.

INTRODUCTION

Road-induced vibrations in vehicle suspension systems are a topic of considerable interest in motor vehicle design. Dixon, in his book The Shock Absorber Handbook (1), describes a tire discomfort value derived from the r.m.s. value of the vertical force fluctuations divided by the mean vertical force. Dixon states, "a high tire discomfort value causes significant deterioration of the tire mean shear-force capability and therefore [causes significant deterioration] of the vehicle['s] cornering and handling capability." Hop, according to SAE J670e - SAE Vehicle Dynamics Terminology (10), is the vertical oscillatory motion of a wheel between the road surface and the sprung mass. Axle tramp occurs when the right and left side wheels oscillate out of phase (10). Axle tramp as a self-exciting oscillation under conditions of acceleration and braking was studied by Sharp (2, 3). It was also studied by Kramer (4) who linked axle tramp to the occurrence of vehicle skate. Kramer stated that "skate occurs when the rear of the vehicle moves laterally while traveling over rough road surfaces." Skate is described in materials provided for the Monroe® [shock absorber] Ride Control Seminar as "A condition where the rear of the vehicle moves laterally over rough surfaces. Typically caused by wheel shake which reduces the traction of the wheel…" (5). Skate is typically associated with rough roadway conditions and is not defined by SAE J670e - Vehicle Dynamics Terminology (10). Search of the SAE Handbook yielded no hits for the word skate. For the purpose of this paper skate will be defined as: a condition where the rear of a vehicle moves from a straight line direction without change to the steering wheel angle made possible by rear wheel hop (or a form of rear wheel hop) oscillation. A vehicle motion called "dart" is described as identical to skate but related to the front end of the vehicle.

A tire-tread separation event results when the tread either partially or completely peels away from the carcass of the tire while driving. Noise, vibration, and the vehicle pulling to the side of the separating tire have been a consistently reported vehicle response by researchers conducting tread separation event tests. The vibration is caused by a number of factors including: 1) a tire which is no longer round, 2) an imbalance of the tire, and 3) the vertical step that occurs as the tire rolls from a position on the tire surface where there is tread to a position where the tread has peeled off and back to where there is tread again. The step described in three (3) above is also influenced by flailing detached tread folding under the tire as it rolls. All of these factors tend to occur at the rotational frequency of the tire. The