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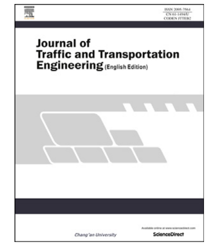

Original Research Paper

Influence of shock absorber condition on pavement fatigue using relative damage concept

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ARTICLE INFO

Article history:
Available online 9 October 2015

Keywords:
Vertical load
Pavement
Relative damage
Shock absorber

ABSTRACT

Considering the importance of the road transportation nowadays, concerns related to pavement deterioration and maintenance have become relevant subjects. Especially for commercial vehicles, the vertical dynamic load (characterized by the tire-road interaction) is directly related to wear on the road surface. Given this, the main objective of this paper is to analyse effects of vertical loads applied on the flexible pavement, considering the variation of the condition of shock absorbers from a truck's front suspension. The measurements were performed on a rigid truck, with 2 steering front axles, in a durability test track located in Brazil. With a constant load of 6 tons on the front suspension (the maximum allowed load on front axles according to Brazilian legislation), 3 different shock absorber conditions were evaluated: new, used and failed. By applying the relative damage concept, it is possible to conclude that the variation of the shock absorber conditions will significantly affect the vertical load applied on the pavement. Although the results clearly point to a dependent relationship between the load and the condition of the shock absorbers, it is recommended to repeat the same methodology, in future to analyse the influence of other quarter car model variants (such as spring rate, mass and tire spring stiffness).

1. Introduction

Besides the direct impact on the vehicle dynamic behaviour (rolling resistance, ride & handling, fuel economy, NVH), the tire-road interaction is also a factor that compromises the pavement integrity. As larger loads and vehicles appear in the road transportation system, pavement damage concerns become an increasingly relevant issue in road construction and maintenance activities (Fabela-Gallegos et al., 2010; Oliveira et al., 2008).

Vertical dynamic load is directly related to the deterioration of the pavement (Sayers et al., 1986). Therefore, this

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Peer review under responsibility of Periodical Offices of Chang'an University.
http://dx.doi.org/10.1016/j.jtte.2015.10.001

relation can also be extended to vehicles variants, especially for commercial vehicles (trucks and buses). However, not all vehicles could cause equivalent damage because of the differences in wheel loads, number and location of axles, types of suspensions and tires, and other aspects (Gillespie et al., 1991).

By analysing a quarter car model (Fig. 1), it was expected that the shock absorber damping forces could be influenced by the natural wear of this system.

In Fig. 1, M_1 is sprung mass, Z is displacement of the sprung mass, K_1 is primary suspension spring rate, C_1 is shock absorber damping force, m_1 is unsprung mass, Z_u is displacement of the unsprung mass, K_1' is tire spring stiffness, Z_r is displacement of the ground.

The equations of motion for the quarter car model in Fig. 1 are shown as below (Simms and Crolla, 2002).

$$m_1\ddot{Z}_u = K_1'(Z_r - Z_u) - K_1(Z_u - Z) - C_1\left(\dot{Z}_u - \dot{Z}\right) \quad (1)$$

$$M_1\ddot{Z} = K_1'(Z_u - Z) + C_1\left(\dot{Z}_u - \dot{Z}\right) \quad (2)$$

Besides the fact that the damping forces (C_1) is a parameter of the quarter car model, it is not often considered in some studies regarding vertical load $m_1\ddot{Z}_u$ applied on the pavement (Che et al., 2011; Sun et al., 2011; Zhang and Zhang, 2011), or it is considered as a constant (Liu and Wang, 2008). In reality, the shock absorber damping forces varies in terms of compression and extension speed (Causemann and Kelchner, 2000).

The main objective of this paper is to analyse the influence of the shock absorber conditions on the vertical load damage on the pavement, using a simple instrumentation (metal-foil strain gauges) and the concept of relative damage.

2. Methodology

2.1. Metal-foil strain gauge

The metal-foil strain gauges (Fig. 2) are sensors made up of a thin resistive foil, fixed on an electrical insulation material called base (Andolfato et al., 2004) or matrix (Hannah and Reed, 1992). The main advantages and characteristics of the metal-foil strain gauges are their high precision and linearity, low cost and good dynamic and static response (Lima et al., 2008).

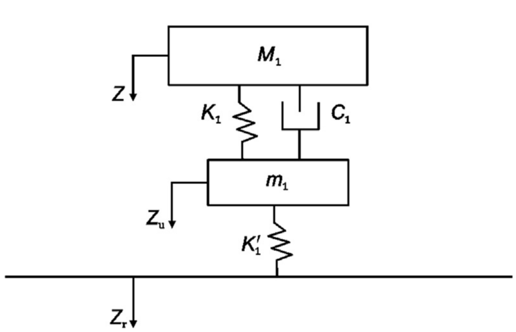

Fig. 1 – Quarter car model (Gillespie, 1992).

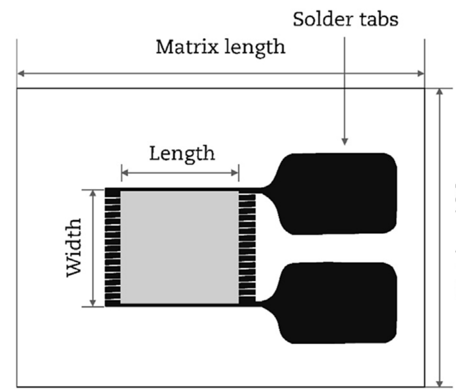

Fig. 2 – Illustration of a metal-foil strain gauge (Hannah and Reed, 1992).

The working principle of this gauge is based on the fact that all electrical conductors change their resistance when elongated (Gallina, 2003). This characteristic is stated in the Second Ohm's Law, which relates the resistance (R) of a conductor to its length (L), cross-sectional area (A) and resistivity (ρ).

$$R = \frac{\rho L}{A} \quad (3)$$

Considering a generic elongation in an electrical conductor, Eq. (3) can be rewritten as follow

$$\frac{\Delta R}{R} = \frac{k\Delta L}{L} \quad (4)$$

where the factor k is defined as the sensitivity of the strain gauge, corresponding to a constant that varies with the resistive material used (Andolfato et al., 2004; Gallina, 2003). Considering that the giving strain is measured as the total elongation per unit length of the material, the following equation is obtained.

$$\frac{\Delta R}{R} = k\epsilon \quad (5)$$

The Eq. (5) indicates that the magnitude of the measured strain (ϵ) is proportional to a relative change of resistance, which is the working principle of this type of sensor (Andolfato et al., 2004; Doebelin, 1990).

2.2. Damage calculation

As structures and mechanical components are regularly subjected to oscillating loads and fatigue is one of the major causes in component failures, fatigue life prediction has become a relevant subject (Liou et al., 1999). If a test specimen is subjected to a sufficiently severe cyclic stress, a fatigue crack or other damage will develop, resulting in the complete failure of the component/system (Dowling, 2012).

Through a stress-life (Wöhler) curve, as shown in Fig. 3, it is possible to estimate the number of cycles for component to failure on a determined magnitude of cycle stress. Unfortunately, only a few applications present such behaviour (regular and sinusoidal stress loads).