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Road and Rail Infrastructure III

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INFLUENCE OF TIRE PRESSURE ON THE VERTICAL DYNAMIC LOAD APPLIED ON THE PAVEMENT BY A TRUCK'S FRONT SUSPENSION

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Abstract

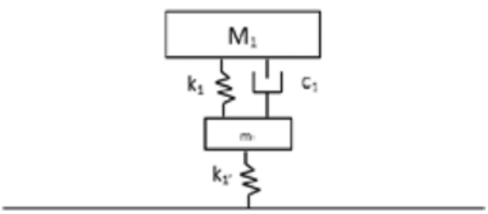
The main objective of this research study is to present the results of the influence of tire pressure, from a truck front suspension, on the vertical dynamic load applied on the pavement. For the measurements, it has been used a durability test track located in Brazil. The tire pressure was increased by 10 psi from 90 to 130 psi with a constant load of 6 tons on the front suspension, the maximum allowed load for front axle, according to Brazilian legislation. By applying relative damage concept, it is possible to conclude that the variation on the tire pressure will not affect significantly the load applied on the pavement. Although, it is recommended to repeat the same methodology, in order to analyse the influence on the variation of the other quarter car model variants.

Keywords: damage, vertical dynamic load, tire

1 Introduction

1.1 Background

Vertical dynamic load is directly related to the deterioration of the pavement [1]. Therefore, this relation can also be extended for the vehicles variants, especially for the commercial vehicles – trucks and buses. By analysing the quarter car model (Figure 1) it was expected that the tire spring rate could influence it by changing the tire pressure.



M_1 sprung mass;
k_1 primary suspension spring rate;
c_1 shock absorber damping force;
m_1 unsprung mass;
k_1' tire spring stiffness.

Figure 1 Quarter car model [2]

1.2 Scope

The main objective of this research study is to analyse the influence of the tire pressure on the vertical dynamic load applied on the pavement.

1.3 Boundaries and assumptions

In order to analyse the influence of the tire pressure, it was necessary to keep constant the other variants of the quarter car model (Figure 1):

- sprung mass and unsprung mass: set as 6 tons, the maximum allowed weight on the front axle according to the Brazilian legislation;
- primary suspension spring rate and shock absorber damping forces: set according to the manufacture specification – new components;
- pavement longitudinal profile: the tests have been performed on a proving ground located in Brazil, in order to keep the same track in all measurements;
- it has been chosen an 8x2 rigid truck (Figure 2) and all measurements reflect the loads of both front steering axles.

Figure 2 Tested truck

2 Methodology

2.1 Instrumentation and calibration

Uniaxial strain gauges were placed on the main leave spring of the 1st and 2nd steering axle (Figure 3) on the left hand side (LHS) and right hand side (RHS) of the vehicle. The recorded values given by the mentioned instrumentation were in με (micro-strain). Therefore, it was necessary to calibrate the system in order to estimate the force applied on the pavement. It has been used a weighting scale and applied different loads on the vehicle body with the objective of having the calibration curves between με and the load applied on the ground in tons (Figure 4). Due to the fact that all tested springs have the same spring rate, all calibration curves have similar characteristics.

Figure 3 Primary suspension spring leaf instrumentation

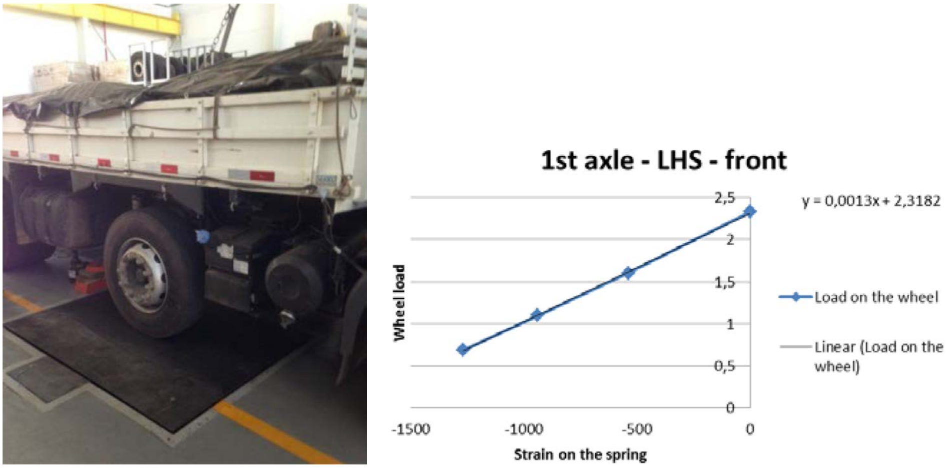


Figure 4 Weighting scale used for the calibration and example of the spring calibration

2.2 Test procedure

It has been used a pothole track in the proving ground for the measurements, with the following constant conditions: vehicle weight (6 tons per front axle), vehicle speed (40 km/h), original shock absorber setting and original primary suspension spring rate setting. The only variant was the tire pressure: 90 psi; 100 psi; 110 psi (recommended pressure for the applied vehicle weight [3]); 120 psi; and 130 psi – respectively: 621 kPa, 690 kPa, 758 kPa, 827 kPa and 896 kPa. Tire size: 295/80 R22.5.

Figure 5 Detail of the pothole track

3 Results Analysis

3.1 Overview

Figure 6 presents an example of the time signal of each front spring for a tire pressure of 110 psi. The mentioned figure refers to the load applied to the pavement on each front axles tires, in tons. By analysing the time signal data, it is not possible to find a conclusion. Therefore, it was necessary to use others statistical analysis.

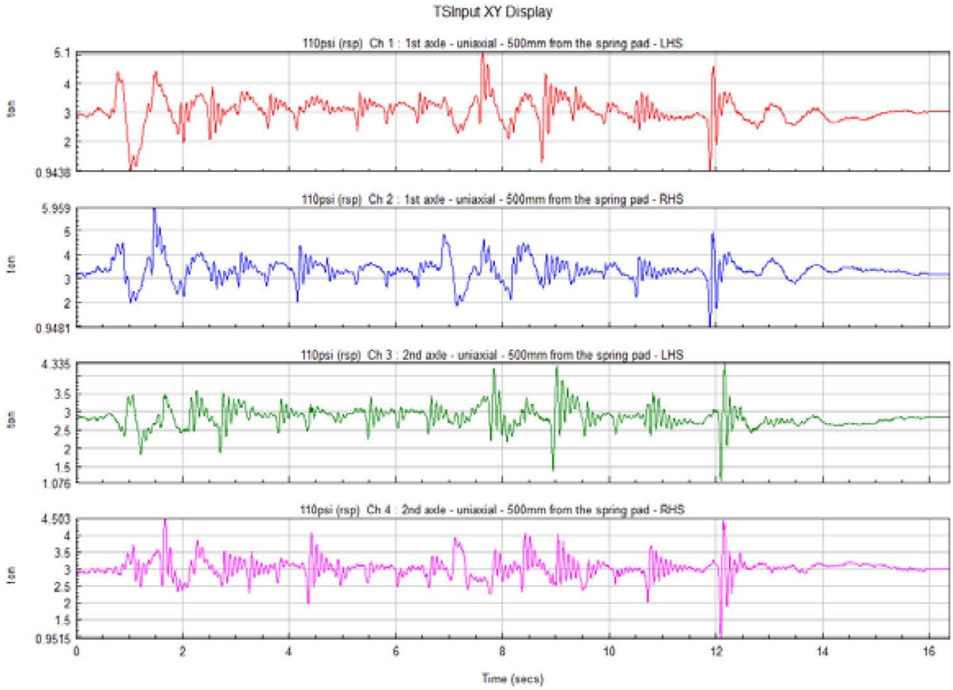


Figure 6 Time signal – load applied on the pavement – 110 psi

3.2 Histograms

Figures 7 to 10 present the histograms for the tested tire pressures. It is possible to visualize on these Figures that the counting cycles close to the static load (3 tons) are the mandatory values. Nevertheless, with this statistical tool, it is not possible to analyse the behaviour of the other loads to the pavement.

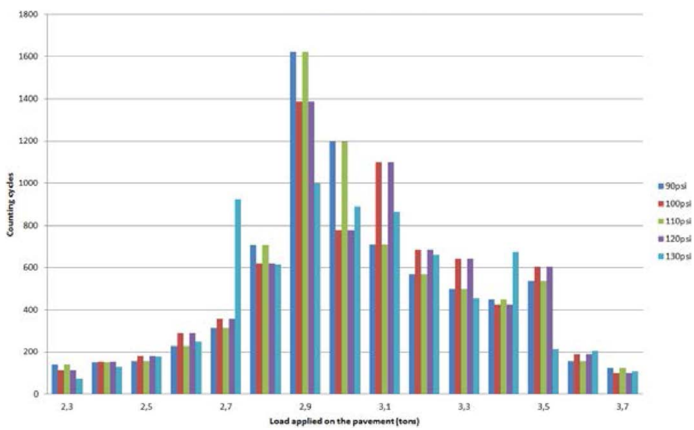


Figure 7 Histogram of the load applied on the pavement – 1st axle LHS

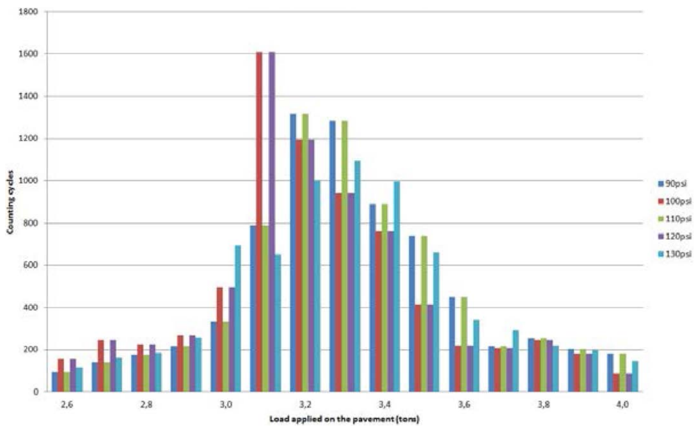


Figure 8 Histogram of the load applied on the pavement – 1st axle RHS

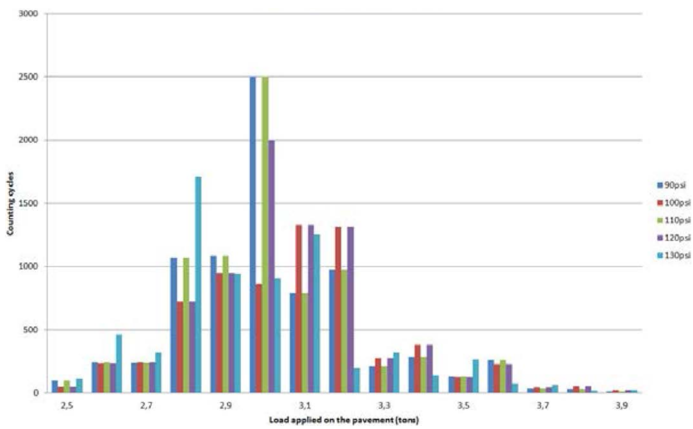


Figure 9 Histogram of the load applied on the pavement – 2nd axle LHS

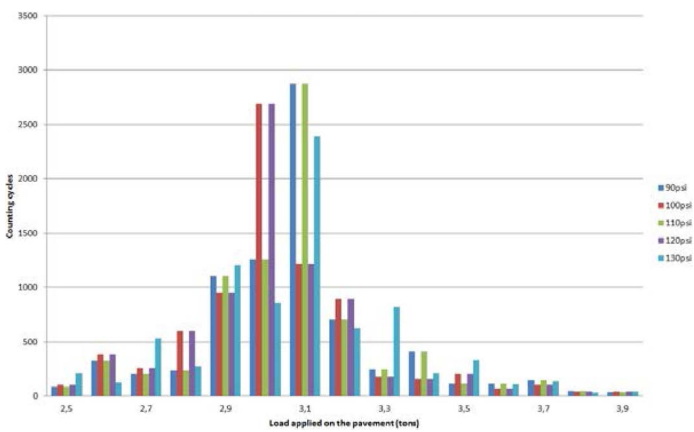


Figure 10 Histogram of the load applied on the pavement – 2nd axle RHS

3.3 Relative damage calculation

Equivalent constant amplitude stress level is calculated for making life estimates for variable amplitude loading, by using rainflow cycle counting (eqns 1 to 3), which is recommended for highly irregular variation of load with time [4].

$$\sigma_a = \frac{(\sigma_{max} - \sigma_{min})}{2} \tag{1}$$

where:

σ_a average of each rainflow cycle (σ_{max}, σ_{min});
σ_{max} max stress for each rainflow cycle counting;
σ_{min} min stress for each rainflow cycle counting;

$$N_{fj} = \frac{1}{2}\left(\frac{\sqrt{\sigma_{max} . \sigma_a}}{\sigma'_f}\right)^{\frac{1}{b}} \tag{2}$$

where:

N_{fj} absolute damage of each rainflow cycle counting;
σ'_f theoretical stress that indicates failure with zero cycles (material property);
b slope of the Stress-Life curve (material property).

$$\sum \frac{N_j}{N_{fj}} : \text{absolute damage} \tag{3}$$

where:

N_j quantity of rainflow cycle counting for each range;

Relative damage will be the ratio between a given tire pressure damage with the baseline (110 psi), Figure 11.

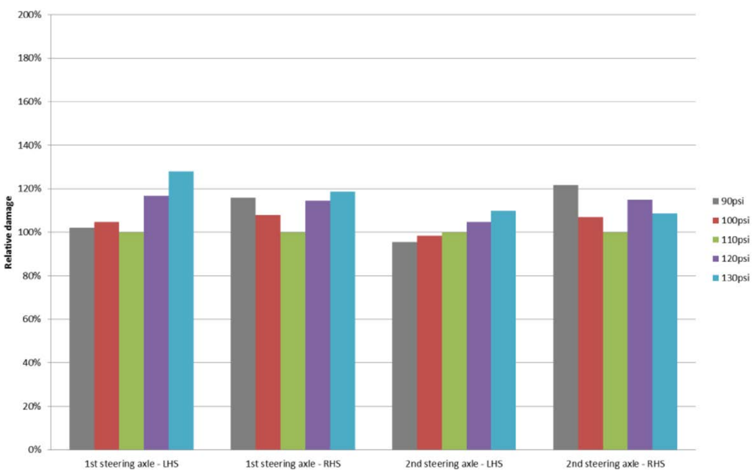


Figure 11 Relative damage among tire pressures, considering k=5

By analysing Figure 11, it is possible to observe that the relative damage, regarding tire pressure, has no significant relation with the vertical load applied on the pavement.

4 Conclusion and recommendations

By applying relative damage concept, it is possible to conclude that the variation on the tire pressure will not affect significantly the load applied on the pavement. Although, t is recommended to repeat the same methodology, in order to analyse the influence on the variation of the other quarter car model variants.

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