Influence of Road Roughness Wavelengths on Bus Passengers’ Oscillatory Comfort

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This paper analyses the effect of the waviness parameter \( w \) on the oscillatory comfort of bus passengers for one road in good condition. The analysis is carried out by a validated nonlinear oscillatory 16 degrees of freedom (DOF) bus model defined in the software Matlab/Simulink and procedure from ISO 2631/1997 standard. The root-mean-square (RMS) values of the weighted vertical accelerations from the passengers’ seats increase with the increase in the parameter \( w \). On the other hand, the RMS values of the weighted vertical accelerations from bus floor decreased with the increase in the parameter \( w \). The best oscillatory comfort has a passenger in the middle part of the bus, and the worst has a passenger in the rear part of the bus. The intensities of the vertical accelerations from the bus floor are mainly concentrated into two frequency ranges, \( 0 \div 2.5 \) Hz and \( 5 \div 10 \) Hz. The passenger seats are dampened with vertical vibrations above 4 Hz. For the narrow range \( w = 1.5 \div 2.3 \), nominal value of the waviness parameter \( (w = 2) \) is sufficiently precise in assessment of the bus passengers’ oscillatory comfort.

1. INTRODUCTION

The oscillatory movement of the bus negatively affects bus users’ oscillatory comfort, road surface, and the vehicle itself. Although bus oscillatory motion is excited from a number of sources, the dominant excitation originates from road roughness. Longitudinal road roughness comprises of a number of different unevenness, wavelengths, and amplitudes. Spectrum composition and unevenness amplitude, and their effect on the vibration intensity, depend on the type/condition of the road roughness and on vehicle speed.

There are a considerable number of direct and indirect parameters for the description of the longitudinal road roughness. Direct parameters come from vertical road elevation data processing. Two of these parameters refer to road elevation power spectral density (PSD) - unevenness index \( \Phi_z (n_0) \) and waviness parameter \( w \). Standard ISO 8608 analytically defines PSD and presents a classification of road roughness according to different unevenness index \( \Phi_z (n_0) \) values and one constant waviness \( w \) value \( (w = 2) \).

The unevenness index defines road roughness quality. Higher values of the unevenness coefficient indicate a worse state of the road. The waviness parameter expresses distribution of short/long wavelengths in road elevation spectrum. According to the ISO 8608 standard, the nominal value of parameter \( w \) is 2 and indicates a similar proportion of short/long wavelengths in the road spectrum. However, studies have shown that the values of the parameter \( w \) lie within the limits of 1.5 to 3.5. Standard shape of the PSD with waviness of \( w = 2 \) correspond to 60% of analysed road profiles. Long wavelengths \( (w > 2) \) prevailed in 20%, and for the remaining 20%, short wavelengths \( (w < 2) \) dominated.

Muˇcka analysed influence of the longitudinal road unevenness on the dynamic tire forces using the quarter model of a commercial heavy vehicle with 2 DOF. Dynamic tyre forces in function of random road profiles with different waviness using longitudinal planar model of three axle heavy vehicle with 8 DOF were analysed by Muˇcka. Four different spatial mathematical models of heavy vehicles are used for simulation when analysing influence of different roads roughness and waviness on dynamic load stress factor by Steinauer and Ueckermann. To the author’s knowledge, influence of road waviness on the bus vertical dynamics, especially on passengers’ ride comfort, is not a sufficiently investigated area.

The aim of this paper is to determine the influence of the waviness parameter \( w \) on bus passengers’ whole-body vibration (WBV) considering vertical accelerations from their seats. The aim is also to determine the effect of the parameter \( w \) on vertical acceleration from bus floor acting on the passengers’ legs. The main goal of this work is to determine passengers’ ride comfort in the function of the parameter \( w \). In order to achieve these goals, a validated nonlinear in-plane bus model with 16 DOF was considered. The model was defined in the Matlab/Simulink software. Longitudinal road roughness in good condition was modelled by road elevation PSD defined in ISO 8608 standard. Ride comfort was determined by procedure and criteria prescribed by ISO 2631/1997 standard. This standard is the most frequently used one when assessing human response to WBV.

2. BUS OSCILLATORY MODEL

Figure 1 shows intercity bus IK-301 for passengers transport. Elementary geometry parameters are shown in Fig. 1(a). Position of the passengers’ seats \((1 \div 3)\), considered in the oscillatory comfort analysis are denoted in Fig. 1(a, b).

A sixteen DOF plane model of the intercity bus IK-301 was used in the study (Fig. 2). The DOF included mass \( m_{hi}, (i = 1 \div 3) \) bouncing \((zh_i, (i = 1 \div 3))\), mass \( m_{zi}, (i = 1 \div 3) \) bouncing \((z_{ci}, (i = 1 \div 3))\), mass \( m_{hi}, (i = 1 \div 3) \) bouncing \((zh_i, (i = 1 \div 3))\), mass \( m_{zi}, (i = 1 \div 3) \) bouncing \((z_{ci}, (i = 1 \div 3))\), mass \( m \) (vehicle body) bouncing \((z)\), mass \( m_{fi} \) (front axle) bouncing \((z_{fi})\), and mass \( m_{ci} \) (rear axle) bouncing \((z_{ci})\).

When forming the bus oscillatory model, the next assumptions were considered:

- the bus body, front and rear axles are rigid bodies;