International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 13, Issue 6 [June. 2024] PP: 14-17

Vibration analysis of double-drum vibratory vibrations Part 2: Effects of operating conditions

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ABSTRACT: *In order to analyze effects of operating conditions on ride comfort of a double-drum vibratory roller, based on the physical model and mathematical model presented in part 1 of this study. Operating conditions such as the elasticities of the compressed ground surface and vehicle speeds are analyzed for their influence on the vehicle's ride comfort according to the ISO 2631:1997(E). The study results have shown that operating conditions have a great influence on vehicle ridecomfort, especially the condition of the vehicle compressing on hard ground conditions.*
KEYWORDS: *Double-drum vibratory roller, Vibration, Operating conditions, Ride comfort*

Date of Submission: 25-05-2024 Date of acceptance: 06-06-2024

I. INTRODUCTION

The effects of the operating conditions of onvehicle ride comfort and road surface friendliness presented reference [1]. 3-D full-vehicle vibration model of a mining dump truck with 10 degrees of freedom was set up to analyze the performance of the hydro-pneumatic suspension system (HPSs) of a mining dump truck on ride comfort under operating conditions such as vehicle and road surface conditions [2]. A half-vehicle ride dynamic model was established based on the drum-ground interactions to analyze the effect of the operating conditions of a double-drum vibratory roller on vehicle ride comfort [3]. A dynamic model of quarter vehicle was established under the combination of in-wheel motor and road surface roughnessr to evaluate the influence of the operating conditions on electric vehicle ride comfort [4]. A three-dimensional nonlinear dynamic model of heavy with 15 DOF (degree of freedom) based on Zhou Changfeng mode was established to evaluate influence of heavy truck operating condition on dynamic load coefficient [5]. A three-dimensional vehicle-pavement coupled model with 14 degrees of freedom is established to analyze the influence of semi-trailer truck operating conditions on road surface [6]. A 3D nonlinear dynamic model of a single drum vibratory roller was developed based on Adam D. and Kopf F’s elastic-plastic soil model and Bekker hypothesis of the soft soil ground to simulate the nonlinear dynamic models and calculate the objective functions according to the ISO 2631: 1997 (E) standard such as the weighted r.m.s acceleration responses of the vertical driver’s seat, pitch and roll angle of the cab and an experiment was set up to measure ride comfort for vibratory roller when vehicle compacts and moves under four different operating conditions. The numerical simulation results for ride comfort analysis were compared with the experimental results whicle have verified the validity of models [7].

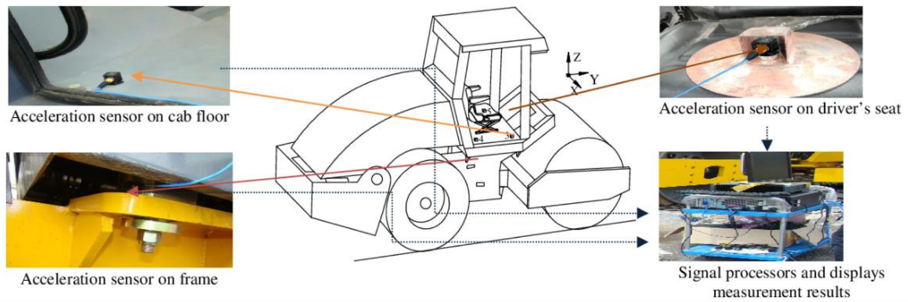

Fig.1. Arrangement of measuring points and acceleration sensors [7]

The aim of this paper is to analyze the influences of the elasticities of the compressed ground surface and vehicle speeds on the vehicle's ride comfort according to the ISO 2631:1997(E) [8] based on the modeling and simulation results in part 1 of the research team.

II. EVALUATION OF THE RIDE QUALITY

Currently there are many methods to evaluate the vehicle ride comfort such as frequency-domain method, time-domain method, etc. This study is based on ISO 2631-1 (1997), vibration evaluation based on the basic evaluation method including measurements of the weighted root-mean-square (rms) acceleration is defined by:

$$a_w = \left[\frac{1}{T} \int_0^T a_w{}^2(t) dt \right]^{1/2} \qquad (1)$$

where, $a_w(t)$ is the weighted acceleration (translational and rotational) as a function of time, m/s^2; T is the duration of the measurements.

In this way, for indications of likely reactions to various magnitudes of overall vibration in the public transport a synthetic index-called the weighted r.m.s acceleration, aw can be calculated from formula Eq.(1) and the r.m.s value of the vertical acceleration in vehicle would be compared with the values in Tab. 1.

Table 1 Comfort levels related to a_w threshold values

$a_w/(m.s^2)$	Comfort level
< 0.315	Not uncomfortable
0.315÷0.63	A little uncomfortable
0.5 ÷ 1.0	Fairly uncomfortable
0.8 ÷ 1.6	Uncomfortable
1.25 ÷ 2.5	Very uncomfortable
> 2	Extremely uncomfortable

III. RESULTS AND DISCUSSION

In order to simulate vibration of a double-drum vibratory roller, the differential equations of motion of Fig.3 are simulated under two operating cases by the MATLAB/Simulink with design parameters of double-drum vibratory roller in reference [9].

Effects of the elasticities of the compressed ground surface on vehicle ride comfort: The time domain acceleration responses of driver's seat (a_s) and pitching cab angle (a_{cphi}) when the front drum compacts on two elastic soil ground conditions, k_s=1.0x10^6 N/m and c_s=2.1x10^5 (Condition 1) and k_s=1.6x10^6 N/m and c_s=3.4x10^5 (Condition 2) with the excitation force of drum as F_{01}=0.128 x10^6 N, f_1=48 Hz and rear drum moves the ISO class E road surface at vehicle speed of 2.0 km/h (Case 2) are shown Fig. 2 and Fig. 3.

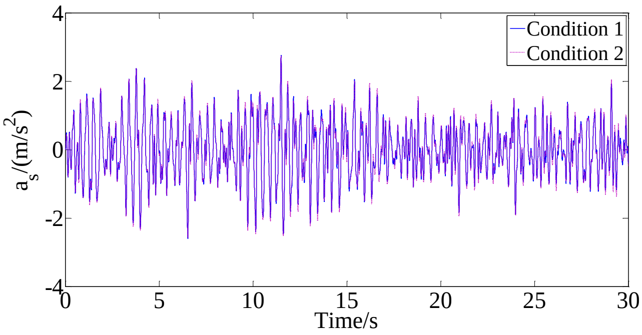

Fig.2 Time domain acceleration response of driver's seat (Condition 1 and Condition 2)

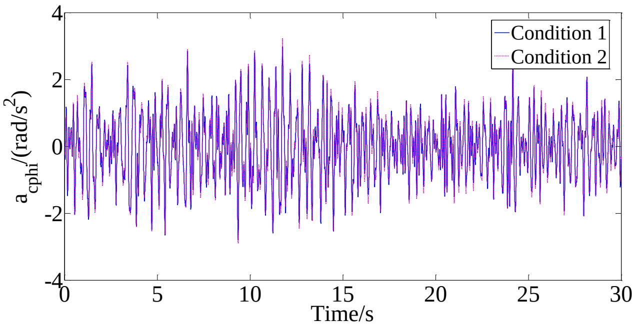

Fig. 3 Time domain acceleration response of pitching cab angle (Condition 1 and Condition 2)

From the obtained results of Fig.3 and Fig.4, we could be determined the values of a_{ws} and a_{wcphi} as a_{ws}=0.8005 m/s^2, a_{wcphi}=0.9327rad/s^2 with Condition 1 and a_{ws}= 0.8221m/s^2, a_{wcphi}= 0.9560 rad/s^2 with Condition 2. The obtained results show that the a_{ws} and a_{wcphi} values with Condition 2 respectively improve by 2.63% and 2.44% compared to Condition 1.

Effects of the vehicle speeds on vehicle ride comfort: The time domain acceleration responses of driver's seat (a_s) and pitching cab angle (a_{cphi}) when the front drum compacts on elastic soil ground condition, and with the excitation force of drum as F_{01}=0.128 x10^6 N, f_1=48 Hz and rear drum moves the ISO class E road surface at vehicle speed of 2.0 km/h (Condition 3) and vehicle speed of 3.0 km/h (Condition 4) (Case 2) are shown Fig. 4 and Fig. 5.

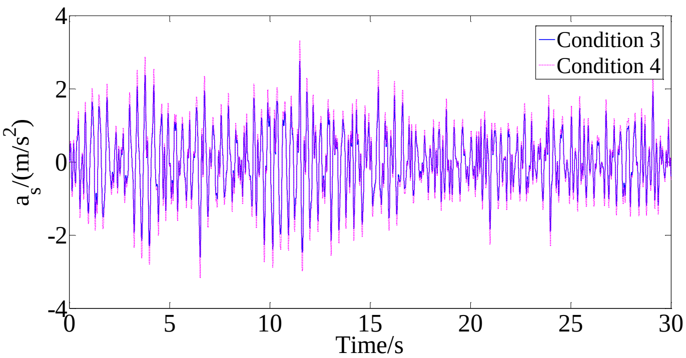

Fig. 4 Time domain acceleration response of driver's seat (Condition 3 and Condition 4)

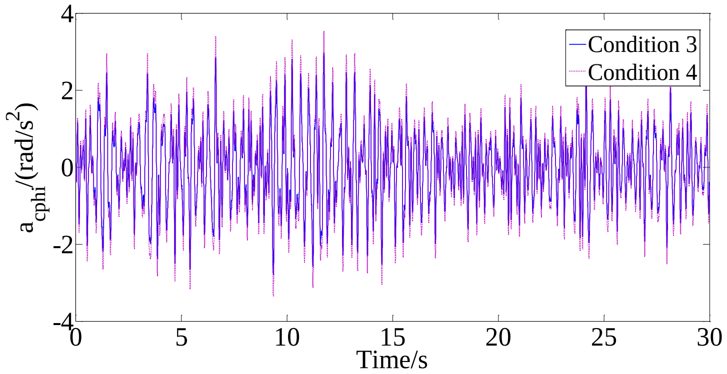

Fig. 5 Time domain acceleration response of pitching cab angle (Condition 3 and Condition 4)

From the obtained results of Fig.3 and Fig.4, we could be determined the values of a_{ws} and a_{wcphi} as a_{ws}=0.8005 m/s^2, a_{wcphi}=0.9327rad/s^2 with Condition 3 and a_{ws}=0.9700 m/s^2, a_{wcphi}=1.1262 rad/s^2 with Condition 4. The obtained results show that the a_{ws} and a_{wcphi} values with Condition 4 respectively improve by 17.47 % and 17.18 % compared to Condition 2.

IV. CONCLUSION

This study is to analyze effects of operating conditions such as from Condition 1 to Condition 4 on ride comfort of a double-drum vibratory roller. The conclusions could be drawn: (1) The values of a_{ws} and a_{wcphi} as a_{ws}=0.8005 m/s^2, a_{wcphi}=0.9327rad/s^2 with Condition 1 and a_{ws}= 0.8221m/s^2, a_{wcphi}= 0.9560 rad/s^2 with Condition 2; (2) The values of a_{ws} and a_{wcphi} as a_{ws}=0.8005 m/s^2, a_{wcphi}=0.9327rad/s^2 with Condition 3 and a_{ws}=0.9700 m/s^2, a_{wcphi}=1.1262 rad/s^2 with Condition 4. Both conditions lead to the driver feeling very uncomfortable. In addition, the results of this paper are the basis for analyzing the effects of design parameters of the driver's seat suspension system on vehicle ride comfort which will be published by our research team.

Acknowledgment

The authors wish to thank the Thai Nguyen University of Technology for supporting this work.

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