

## Effects of Cab Isolation System Damping Coefficients on Vibratory Roller Ride Comfort

To Ngoc Thien <sup>1</sup>, Bui Van Hai <sup>2\*</sup>

<sup>1</sup> Faculty of Mechanical, Automotive, and Construction Engineering, Electric Power University, Ha Noi, 100000, Viet Nam

<sup>2</sup> Faculty of Automotive Technology, School of Mechanical and Automotive Engineering, Hanoi University of Industry, Ha Noi, 100000, Viet Nam

\* Corresponding Author: **Bui Van Hai**

### Article Info

**ISSN (online):** 3049-1215

**Volume:** 02

**Issue:** 04

**July – August 2025**

**Received:** 06-05-2025

**Accepted:** 07-06-2025

**Published:** 02-07-2025

**Page No:** 07-10

### Abstract

This paper focuses on investigating the effects of the effects of cab isolation system damping coefficients on vibratory roller ride comfort based on a half-vehicle dynamic model of a double-drum vibratory roller based on the study results when both front and rear drums compact on the original place. The comparison results of power spectral density (PSD) acceleration responses of the vertical driver's seat ( $a_s$ ) and cab's pitch angle ( $a_{cphi}$ ) are selected as the objective functions to investigate its effects on vehicle ride comfort. The results indicate that the peak amplitude values of PSD  $a_{cphi}$  and  $a_s$  with  $c_c=0.5 c_{c0}$  respectively increase in comparison with  $c_c=1.0 c_{c0}$ . Especially, the peak amplitude values of PSD  $a_s$  with  $c_c=0.5 c_{c0}$  respectively increase by 17.05 % and 17.42% at the frequency values of 2.633 Hz and 4.33 Hz. As  $c_c$  reduces, the vehicle's ride comfort deteriorates and the peak amplitude values of PSD  $a_{cphi}$  and  $a_s$  with  $c_c=1.5 c_{c0}$  respectively reduce in comparison with  $c_c=1.0 c_{c0}$ . Especially, the peak amplitude values of PSD  $a_s$  with  $c_c=1.5 c_{c0}$  respectively reduce by 21.34 % and 20.15% at the frequency values of 2.633 Hz and 4.33 Hz. As  $c_c$  increases, the vehicle's ride comfort improves significantly.

**DOI:** <https://doi.org/10.54660/IJFEI.2025.2.4.07-10>

**Keywords:** Double-Drum Vibratory Roller, Cab Rubber Isolation System, Peak Amplitude, PSD, Damping Coefficient, Ride Comfort

### 1. Introduction

Vibratory rollers are a type of construction machine that operates in harsh environments. Vibration sources from the ground surface, the engine, and roller's own vibration mechanism are transmitted to driver's body through cab's isolation system and driver seat suspension. Doan Thanh Binh, *et al.* (2021) <sup>[1]</sup> proposed a half-vehicle dynamic model of a single-drum vibratory roller to investigate the effects of parameters of cab's isolation system on vehicle ride comfort under various operating conditions and the results indicate that vehicle ride comfort was greatly influenced by the parameters of cab's isolation system. Bui Van Cuong, *et al.* (2022) <sup>[2]</sup> proposed a half-vehicle dynamic model of a double-drum vibratory roller under the different operating conditions to analyze the ride comfort performance of cab' hydraulic isolation system of a double-drum vibratory roller and the study results indicated that performance of drum's isolation systems was better than the original vehicle in improving the vehicle ride comfort. Nguyen V, *et al.*, (2018) <sup>[3]</sup> proposed a dynamic model of the vibratory roller interacting with the off-road deformed terrain to analyze the low-frequency performance of three different cab's isolation mounts under the different operating conditions and the study results shown that cab hydraulic isolation had an obvious effect on mitigating the cab vibration and improving the ride comfort in comparison with the traditional rubber and pneumatic isolation systems. Le V. Q., *et al.*, (2019) <sup>[4]</sup> proposed a 3D nonlinear dynamic model of a single drum vibratory roller based on the analysis of nonlinear geometric characteristics of wheel-deformation of soil ground contact to analyze the effects of parameters of the stiffness and damping coefficients of cab's isolation system on vehicle ride comfort. To improve vehicle ride comfort, optimization and control techniques have been applied to cab's isolation system.

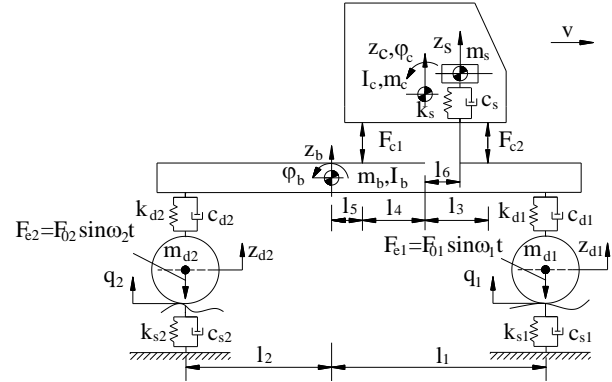
L. V. Quynh, *et al.*, (2020) <sup>[5]</sup> proposed a modal test for a single-drum vibratory roller to solve problems about cab's low-frequency shaking in the direction of forward motion when vibratory roller operates. Quynh, L.V., (2011) <sup>[6]</sup> proposed an auxiliary vibrations isolator for solving the low-frequency sloshing in the direction of forward motion based on the dynamic test and simulations analysis. Le V.Q. and Nguyen K.T., (2018) <sup>[7]</sup> proposed a 3D nonlinear dynamic model of a single drum vibratory roller to optimize the design parameters of cab's isolation system when vehicle operates under the different conditions. N.T. Duy, *et al.*, (2001) <sup>[8]</sup> proposed a Fuzzy - PID controller to control the value of damping coefficient for a semi-active hydraulic cab isolation system (SHCIs) for enhancing the ride comfort of a wheel loader using a vehicle - road coupled interaction model including vehicle body, cab body and driver seat masses under the random excitation of ground surface. Sim K. Lee, (2017) <sup>[9]</sup> proposed cab's hydro-pneumatic suspension model with a semi-active suspension control using a quarter-car model and optimal control theories. Hoang Anh Tan, (2023) <sup>[10]</sup> proposed a fuzzy self-tuning of PID controller o control the damping coefficient of Semi-active cab isolation system (SCIS) for a wheel loader. Ni D, *et al.*, (2022) <sup>[11]</sup> proposed a novel design of the seat suspension equipped with the quasi-zero stiffness (QZS) and hydraulic mount (HM) of the cab isolation system to improve the off-road vibratory roller ride comfort. In addition, several analyses have been conducted on other types of construction equipment. Quynh, V.N., (2025) <sup>[12]</sup> proposed a half-vehicle dynamic model to analyze and evaluate the effects of design parameters on the wheel loader ride comfort. Zhuang C, (2022) <sup>[13]</sup> proposed a multi-target regression forests (MRFs) method in the design and optimization design of the mount system to achieve multi-point mount stiffness prediction. Doan, T.B., (2024) <sup>[14]</sup> proposed an overview of semi-active isolation systems of earthmoving machinery cab. Nguyen, D.T., (2024) <sup>[15]</sup> proposed an overview of passive isolation systems of earthmoving machinery cab. Sun X, *et al.*, (2012) <sup>[16]</sup> proposed a six-degree-of-freedom (DOF) model of the cab to explore the low-frequency advantages and characteristics of the hydraulic mounts used for vibration isolation of an earthmoving machinery cab. This study aims to investigate the effects of cab isolation system damping coefficients on vibratory roller ride comfort. The comparison results of power spectral density (PSD) acceleration responses of the vertical driver's seat ( $a_s$ ) and cab's pitch angle ( $a_{cphi}$ ) are selected as the objective functions to investigate its effects on vehicle ride comfort.

## 2. Vehicle Dynamic model

### 2.1. Half-vehicle Dynamic model <sup>[17]</sup>

A half-vehicle dynamic model of a double-drum vibratory roller based on the study results <sup>[17]</sup> is shown in Fig.1. Explanation of the symbols for Fig. 1,  $m_{di}$ ,  $m_b$ ,  $m_c$  and  $m_s$  are the masses of the dynamic drums, frame, cab and driver's seat, respectively;  $I_b$  and  $I_c$  are the moment of inertia of the vehicle (including frame, internal combustion engine and other parts) and cab, respectively;  $k_{si}$ ,  $k_{di}$ ,  $k_s$  and  $c_{si}$ ,  $c_{di}$ ,  $c_s$  are the stiffness and damping coefficients of elastic road surfaces, front and rear mount systems of drums and driver's seat suspension system, respectively;  $z_{di}$ ,  $z_b$ ,  $z_c$  and  $z_s$  are the vertical displacements at centre of gravity of the front and rear drums, vehicle body, cab and driver's seat, respectively;  $\phi_b$  and  $\phi_c$  are the pitch angle displacements of vehicle body

and cab, respectively;  $q_i$  are the excitation of road surface roughness at drums, respectively;  $l_j$  are the distances;  $F_{ei}=F_{0i}\sin(\omega_i t)$  are the force excitations of the vibrating drums;  $F_{0i}$  are the amplitude of force excitations;  $\omega_i$  are the angular frequencies of the vibrators;  $F_{ci}$  are the vertical forces of cab rubber mount systems and  $v$  is the vehicle speed ( $i=1\div 2, j=1\div 6$ ).



**Fig 1:** Half-vehicle dynamic model of a double-drum vibratory roller <sup>[17]</sup>

### 2.2. Half-vehicle Dynamic model <sup>[17]</sup>

The equations of motion for the vertical and pitch motions of cab are written as follows

$$m_c \ddot{z}_c = F_s - \sum_{i=1}^{i=2} F_{ci} \quad (1)$$

$$I_c \ddot{\phi}_c = F_s l_6 + \sum_{i=1}^{i=2} (-1)^i F_{ci} l_{i+2} \quad (2)$$

The equations of motion for the vertical and pitch motions of vehicle are written as follows

$$m_b \ddot{z}_b = \sum_{i=1}^{i=2} F_{ci} - \sum_{i=1}^{i=2} F_{di} \quad (3)$$

$$I_b \ddot{\phi}_b = \sum_{i=1}^{i=2} (-1)^i F_{di} l_i + F_{c2} l_5 + F_{c1} \sum_{j=3}^{j=5} l_j \quad (4)$$

The equation of motion for driver's seat is written as follows

$$m_s \ddot{z}_s = -F_s \quad (5)$$

where,  $F_s$  is the vertical force of driver's seat which is determined by Eq. (6),  $F_{ci}$  are the vertical forces of cab mount system which are determined by Eq. (1) or Eq. (5) and  $F_{di}$  are the vertical forces of front and rear mount systems of drums which could be determined through two cases.

$$F_s = [k_s (z_s - z_c + l_6 \phi_c) + c_s (\dot{z}_s - \dot{z}_c + l_6 \dot{\phi}_c)] \quad (6)$$

#### Case 1: Vehicle moves into the workshop

The drum of vibratory roller in contact with the rigid road surface is the contact point which is considered in this study. The vertical forces of front and rear mount systems of drums are defined as

$$F_{d1} = k_{d1} (z_b + l_1 \phi_b - q_1) + c_{d1} (\dot{z}_b + l_1 \dot{\phi}_b - \dot{q}_1) \quad (7)$$

$$F_{d2} = k_{d2} (z_b - l_2 \phi_b - q_2) + c_{d2} (\dot{z}_b - l_2 \dot{\phi}_b - \dot{q}_2) \quad (8)$$

where,  $q_1$  and  $q_2$  are the excitation of road surface roughness at drum and tire. The road surface roughness according to the International Standards Organization (ISO 8608) [18] is road excitation which is simulated in space domain and acts as an input to the vehicle-road model.

**Case 2: Vehicle operates in the workshop**

*Condition1:* When both front and rear drums compact on the original place, the equations of motion for the dynamic drums are written as follows

$$m_{d1}\ddot{z}_{d1} = F_{e1} + F_{d1} - k_{s1}z_{d1} - c_{s1}\dot{z}_{d1} \tag{9}$$

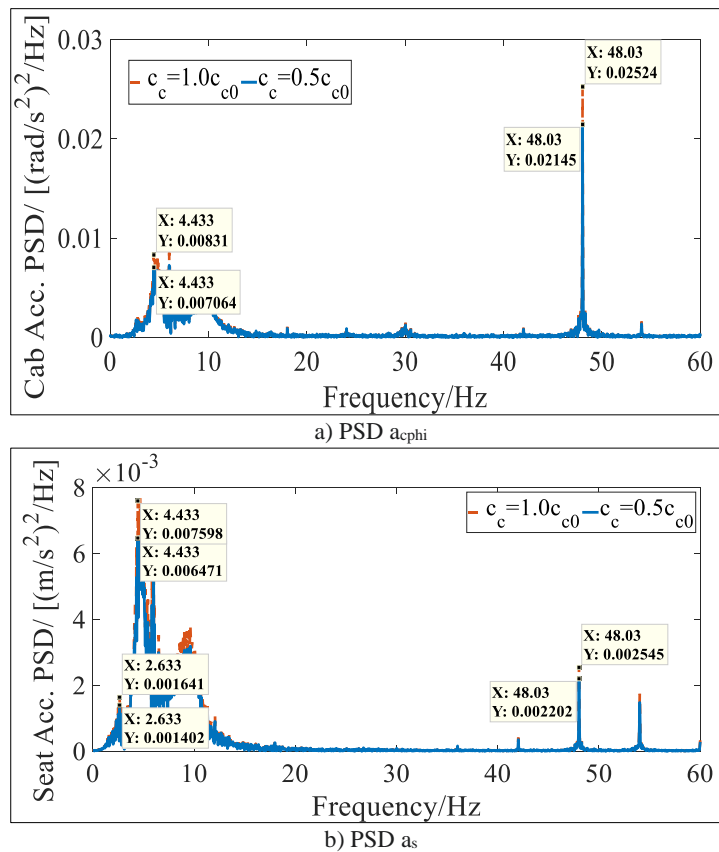
$$m_{d2}\ddot{z}_{d2} = F_{e2} + F_{d2} - k_{s2}z_{d2} - c_{s2}\dot{z}_{d2} \tag{10}$$

*Condition 2:* When front drum compact on the elastic soil grounds, and rear drum moves on the rigid ground surfaces, the equation of motion for front drum is determined by Eq. (9) and the vertical forces of rear mount systems of drum is determined by Eq. (8). However, the condition1 in Case 2 were selected to investigate the effects of cab isolation system damping coefficients on vibratory roller ride comfort.

**3. Results and Discussion**

To investigate the effects of cab isolation system damping coefficients on vibratory roller ride comfort, the differential equations of motion of Fig.1 are simulated under the condition 1 in Case 2 by the MATLAB/Simulink with design parameters and cab’s rubber isolation systems in the Reference [17].

**Reducing the damping coefficient:**  $c_c=0.5 c_{c0}$  ( $c_{c0}=[c_{c1}, c_{c2}]$  are the damping coefficient values of original isolations of cab) is chosen to investigate the effects of cab isolation system damping coefficients on vibratory roller ride comfort. The comparison results of power spectral density (PSD) acceleration responses of the vertical driver’s seat ( $a_s$ ) and cab’s pitch angle ( $a_{cphi}$ ) with  $c_c=0.5c_{c0}$  when both front and rear drums compact on the original place with the parameters of the elastic soil grounds as  $k_{s1}=1.0 \times 10^7$  N/m,  $c_{s1}=2.1 \times 10^5$  (N.s/m) and  $k_{s2}=1.2 \times 10^7$  N/m,  $c_{s2}=2.8 \times 10^5$  (N.s/m) at the front and rear drums with the excitation forces as  $F_{01}=0.128 \times 10^6$  N,  $f_1=48$  Hz and  $F_{02}=0.96 \times 10^5$  N,  $f_2=54$  Hz compared with  $c_c=1.0c_{c0}$  are shown Fig.2.



**Fig 2:** The comparison of PSD  $a_{cphi}$  and  $a_s$  with a reduced value of  $c_c$  at Condition1 in Case 2

From the results of Fig. 2, we show that the peak amplitude values of PSD  $a_{cphi}$  and  $a_s$  with  $c_c=0.5 c_{c0}$  respectively increase in comparison with  $c_c=1.0 c_{c0}$ . Especially, the peak amplitude values of PSD  $a_s$  with  $c_c=0.5 c_{c0}$  respectively increase by 17.05 % and 17.42% at the frequency values of 2.633 Hz and 4.33 Hz. As  $c_c$  reduces, the vehicle’s ride comfort deteriorates.

**Increasing the damping coefficient:**  $c_c=1.5 c_{c0}$  is chosen to investigate the effects of cab isolation system damping

coefficients on vibratory roller ride comfort. Similarly, the peak amplitude values of PSD  $a_{cphi}$  and  $a_s$  with  $c_c=1.5 c_{c0}$  respectively reduce in comparison with  $c_c=1.0 c_{c0}$ . Especially, the peak amplitude values of PSD  $a_s$  with  $c_c=1.5 c_{c0}$  respectively reduce by 21.34 % and 20.15% at the frequency values of 2.633 Hz and 4.33 Hz. As  $c_c$  increases, the vehicle’s ride comfort improves significantly.

#### 4. Conclusions

In this study, the effects of the effects of cab isolation system damping coefficients on vibratory roller ride comfort were investigated using a half-vehicle dynamic model of a double-drum vibratory roller based on the study results<sup>[17]</sup> when both front and rear drums compact on the original place. The survey results have yielded the following conclusions: (i) The peak amplitude values of PSD  $a_{cphi}$  and  $a_s$  with  $c_c=0.5 c_{c0}$  respectively increase in comparison with  $c_c=1.0 c_{c0}$ . Especially, the peak amplitude values of PSD  $a_s$  with  $c_c=0.5 c_{c0}$  respectively increase by 17.05 % and 17.42% at the frequency values of 2.633 Hz and 4.33 Hz. As  $c_c$  reduces, the vehicle's ride comfort deteriorates; (ii) The peak amplitude values of PSD  $a_{cphi}$  and  $a_s$  with  $c_c=1.5 c_{c0}$  respectively reduce in comparison with  $c_c=1.0 c_{c0}$ . Especially, the peak amplitude values of PSD  $a_s$  with  $c_c=1.5 c_{c0}$  respectively reduce by 21.34 % and 20.15% at the frequency values of 2.633 Hz and 4.33 Hz. As  $c_c$  increases, the vehicle's ride comfort improves significantly. Future research directions include the development of optimized cab isolation system designs and control strategies aimed at enhancing vehicle ride comfort under harsh operating conditions.

#### 5. References

- Doan TB, Le VQ, Nguyen VL, Bui VC, Le XL, Hoang AT. Effects of parameters of cab's isolation system on ride comfort for a single-drum vibratory roller. *Int J Adv Res Eng Technol*. 2021;12(1):457-64. Available from: <http://iaeme.com/Home/issue/IJARET?Volume=12&Issue=1>
- Bui VC, Vi TPT, Hoang TT, Nguyen TKT. Performance analysis of cab's hydraulic isolation system on a double-drum vibratory roller ride comfort. *Int J Adv Eng Manag*. 2022;4(5):2769-74.
- Nguyen V, Zhang J, Le V, *et al*. Vibration analysis and modeling of an off-road vibratory roller equipped with three different cab's isolation mounts. *Shock Vib*. 2018;2018:1-17.
- Le VQ, Thao VTP, Cong NT. Influence of design parameters of cab's isolation system on vibratory roller ride comfort under the deformed ground surfaces. *Int Res J Eng Technol*. 2019;6(6):1974-8.
- Quynh LV, Jianrun Z, Liem NV, Cuong BV, Long LX, Phuong DT. Experimental modal analysis and optimal design of cab's isolation system for a single drum vibratory roller. *Vibroengineering Procedia*. 2020;31:52-6. <https://doi.org/10.21595/vp.2020.21325>
- Quynh LV, Zhang JR, Jiao GW, Liu XB, Wang Y. Vibration analysis and optimal design for cab's isolation system of vibratory roller. *Adv Mater Res*. 2011;199-200:936-40. <https://doi.org/10.4028/www.scientific.net/amr.199-200.936>
- Le VQ, Nguyen KT. Optimal design parameters of cab's isolation system for vibratory roller using a multi-objective genetic algorithm. *Appl Mech Mater*. 2018;875:105-12. <https://doi.org/10.4028/www.scientific.net/amm.875.105>
- Duy NT, Quynh LV, Ha DV, Cuong BV, Long LX. Ride comfort evaluation for a double-drum vibratory roller with semi-active hydraulic cab mount system. *E3S Web Conf*. 2021;304:01008. <https://doi.org/10.1051/e3sconf/202130401008>
- Tan HA, Cuong BV, Tan ND, Chau NM, Huan CC. Improvement of ride quality for a wheel loader with semi-active cab isolation system via fuzzy self tuning of PID controller. *J Mech Sci Technol*. 2023;FEE:197-203. <https://doi.org/10.54939/1859-1043.j.mst.FEE.2023.197-203>
- Sim K, Lee H, Yoon JW, Choi C, Hwang SH. Effectiveness evaluation of hydro-pneumatic and semi-active cab suspension for the improvement of ride comfort of agricultural tractors. *J Terramechanics*. 2017;69:23-32. <https://doi.org/10.1016/j.jterra.2016.10.003>
- Ni D, Jiao R, Nguyen V, Zhang J. Enhancing the ride comfort of off-road vibratory rollers with seat suspension using optimal quasi-zero stiffness. *Proc Inst Mech Eng C J Mech Eng Sci*. 2022;237(2):482-96. <https://doi.org/10.1177/09544062221119929>
- Quynh VN, Huan CC, Han NT. Effect of design parameters of cab's isolation system on a wheel loader ride comfort. *World J Res Rev*. 2025;20(5):1-4. <https://doi.org/10.31871/WJRR.20.5.3>
- Zhuang C, Wen H, Ni X, Zhang D, Bao Y, Huang H. Optimization of cab vibration comfort for construction machinery based on multi-target regression forests. *Machines*. 2022;10(12):1148. <https://doi.org/10.3390/machines10121148>
- Doan TB, Luu KO, Nguyen TT. An overview of semi-active isolation systems of earth-moving machinery cab. *Int J Eng Inventions*. 2024;13(12):89-92.
- Sun X, Zhang J. Performance of earth-moving machinery cab with hydraulic mounts in low frequency. *J Vib Control*. 2012;20(5):724-35. <https://doi.org/10.1177/1077546312464260>
- Nguyen DT, Huan CC, Trung NT. Overview of cab's isolation system in direction of improving construction machinery ride comfort. *World J Res Rev*. 2024;18(5):4-9. <https://doi.org/10.31871/WJRR.18.5.9>
- Van Quynh L, Vu LA, Van Cuong B, Tan HA, Long LX. A comparative analysis of ride performance of double-drum vibratory roller with two cab mount systems. In: *Lecture Notes in Networks and Systems*, vol 366. Cham: Springer; 2022. p. 25-38. [https://doi.org/10.1007/978-3-030-92574-1\\_3](https://doi.org/10.1007/978-3-030-92574-1_3)
- International Organization for Standardization. ISO 8608: Mechanical vibration—Road surface profiles—Reporting of measured data. Geneva: ISO; 1995.