



Evaluation of Effects of Wheel Loader Load Condition on Driver Ride Comfort

Nguyen Van Liem¹, Vi Thi Phuong Thao², Ngo Thanh Trung^{3*}

¹ Faculty of Vehicle and Energy Engineering, Thai Nguyen University of Technology, Thai Nguyen, Vietnam

² Faculty of International Training, Thai Nguyen University of Technology, Thai Nguyen, Vietnam

³ Faculty of Basic and Applied Sciences, Thai Nguyen University of Technology, Thai Nguyen, Vietnam

* Corresponding Author: **Ngô Thanh Trung**

Article Info

ISSN (online): 3049-1215

Volume: 02

Issue: 03

May - June 2025

Received: 21-04-2025

Accepted: 23-05-2025

Published: 12-06-2025

Page No: 187-190

Abstract

Wheel loader ride comfort is a critical factor affecting operator safety, productivity, and long-term health. This study systematically investigates the influence of different operating load conditions using a half-vehicle dynamic model. The ride comfort is evaluated based on the root mean square (r.m.s) values of acceleration responses of the vertical driver's seat (a_{ws}) and pitch angles of cab (a_{wc}), in accordance with ISO 2631:1997(E) standards. The simulation results demonstrate that variations in operating loads significantly affect ride comfort when the machine operates under an ISO class D road surface at a speed of 10 km/h. These findings provide a theoretical basis for optimizing the load configuration of wheel loaders to ensure acceptable ride comfort during operation.

DOI: <https://doi.org/10.54660/IJFEI.2025.2.3.187-190>

Keywords: Wheel Load, Acceleration Response, Operating Load Condition, Ride Comfort

1. Introduction

Construction machinery is a type of machinery that frequently operate on deformable road surfaces, where all vibration sources transmitted to the cab significantly affect the ride comfort of the driver. Le *et al.* [1] developed a nonlinear dynamic model of a single-drum vibratory roller operating on deformable soil grounds to evaluate operator ride comfort under realistic excitation conditions. The study integrates a 3-DOF system with elastic-plastic soil interaction and ISO 2631-1 vibration criteria, simulated in Matlab/Simulink to quantify seat and cab responses across varying terrain types. Doan *et al.* [2] proposed an analytical evaluation of the effects of cab isolation parameters on ride comfort in single-drum vibratory rollers using a half-vehicle dynamic model. The study, conducted under ISO 2631-1 criteria, demonstrates that increased damping improves comfort, whereas increased stiffness reduces it. Optimal parameters were identified for varying working conditions. Nguyen *et al.* (2018) [3] developed and validated a nonlinear dynamic model of a vibratory roller to evaluate the low-frequency ride comfort associated with three different cab isolation mount types under off-road conditions. Their results reveal that hydraulic mounts significantly reduce cab vibration compared to traditional rubber and pneumatic mounts. Le Van Quynh *et al.* (2019) [4] developed a 3D nonlinear dynamic model of a single-drum vibratory roller to analyze the influence of stiffness and damping parameters of the cab's isolation system on ride comfort under deformed ground surfaces. The study identified optimal design values using MATLAB/Simulink simulations and ISO 2631-1 objective functions. Quynh *et al.* (2020) [5] conducted an experimental modal analysis and optimal design of a cab's isolation system for a single-drum vibratory roller. The study integrates LMS dynamic testing and FEA simulation to address low-frequency cab shaking in the forward motion direction, aiming to minimize resonance and improve ride comfort. Quynh *et al.* (2011) [6] proposed a dynamic modeling and optimization approach to reduce low frequency shaking of the cab in the forward motion direction of vibratory rollers. Their study applies harmonic response and finite element analysis to identify the optimal isolation parameters for enhanced ride comfort and vibration control. Le Van Quynh *et al.* (2018) [7] proposed a multi-objective optimization approach using the NSGA-II algorithm to improve ride comfort of a single-drum vibratory roller. A nonlinear dynamic model was developed to analyze the effects of stiffness and damping parameters of the cab's isolation system under varied working conditions.

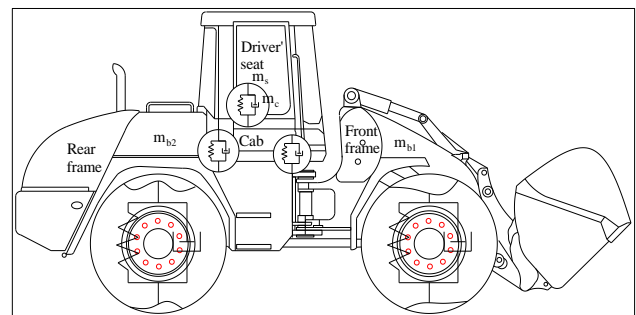
Simulation results confirmed that the optimized design significantly reduced cab vibration based on three objective indices. Le Van Quynh *et al.* (2022) [8] developed a nonlinear half-vehicle model to compare the ride comfort of liquid-filled and rubber cab mount systems on a double-drum vibratory roller. Their analysis demonstrates that the liquid-filled mounts significantly reduce RMS and PSD acceleration responses, enhancing low-frequency vibration isolation. The findings highlight the superior damping performance of LCMs under varied operating conditions. Vu Ngoc Quynh *et al.* (2025) [9] developed a half-vehicle dynamic model to evaluate the influence of cab isolation design parameters on the ride comfort of a wheel loader. Based on ISO 2631-1, stiffness and damping coefficients were assessed through vibration-related objective functions to optimize isolation performance. The results highlight the critical role of cab isolation design in improving ride comfort for construction machinery. Nguyen Dinh Tan *et al.* (2024) [10] provided a comprehensive review of cab isolation systems for construction machinery, analyzing the evolution from traditional rubber mounts to semi-active hydraulic-pneumatic systems, and highlighting their impact on ride comfort performance under various working conditions. Le Van Quynh *et al.* (2021) [11] developed and evaluated a semi-active hydraulic cab isolation system (SHCIS) to enhance ride comfort of earth-moving machinery. A vehicle-road coupled dynamic model was established, and PID control was employed to regulate damping under random excitations. Simulation results demonstrated that SHCIS significantly outperforms passive systems under large-amplitude and low-frequency disturbances. Nguyen Tien Duy *et al.* (2021) [12] proposed and validated a semi-active hydraulic cab mount system (SHCM) using a fuzzy logic controller to enhance ride comfort of a double-drum vibratory roller. A nonlinear dynamic model and MATLAB/Simulink simulations demonstrated significant improvements in RMS-based comfort indices under varying operating conditions. Tan *et al.* (2023) [13] developed a fuzzy self-tuning PID controller to enhance the ride comfort of a wheel loader equipped with a semi-active cab isolation system. A dynamic model was established under ISO 2631-1 conditions, and simulation results demonstrated superior performance of the proposed SCIS compared to passive systems. The study provides foundational insights for optimizing semi-active control strategies in heavy machinery applications. Doan Thanh Binh *et al.* (2024) [14] provided a comprehensive overview of semi-active isolation systems for earth-moving machinery cabs, emphasizing their ability to reduce harmful vibrations and enhance ride comfort. The study synthesizes modeling, simulation, and experimental research to highlight the advantages of semi-active systems over conventional passive solutions. This study focuses on analyzing the influence of various load conditions of a wheel loader on the driver ride comfort. A dynamic model of the machine is developed to simulate various loading conditions, and the evaluation is conducted based on ISO 2631-1:1997 criteria. The findings are expected to provide valuable insights into optimizing vehicle design parameters, contributing to improved ride comfort, operational safety, and overall working efficiency for earth-moving machinery.

2. Machine Dynamic model

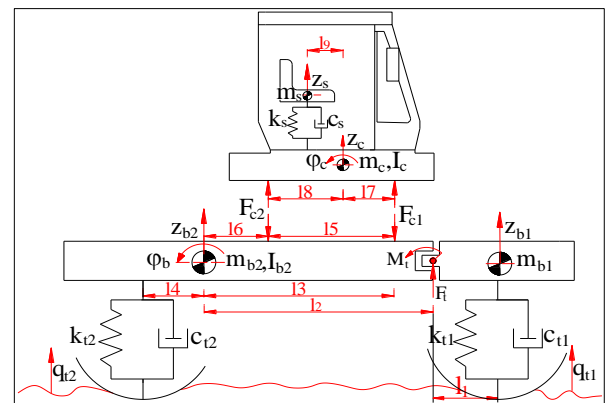
2.1 Half- machine Dynamic model [13, 16]

A half-machine dynamic model of wheel loader is developed

based on reference [13, 16] as shown in Fig.1, where, m_{b1} is the masses of the bucket, front axle, front frame and other parts above the front wheel, m_{b2} and I_{b2} are the masses and mass inertia moments of the engine, powertrain, rear axle and other parts above the rear wheel, respectively, m_c and I_c are the mass and mass inertia moment of cab body, k_{ti} are the stiffness coefficient of the tires, c_{ti} are the damping coefficient of the tires, k_s is the stiffness coefficient of driver seat suspension system, c_s is the damping coefficient of driver seat suspension system, F_{ci} are the vertical forces of cab isolation system, l_j are the calculated distances for determining the coordinates, F_t and M_t are the replacement force and moment for the front vehicle body mass assembly, respectively, z_{bi} , z_c and z_s are the vertical displacements of the vehicle body, cabin and driver's seat and q_{ti} are road surface excitations ($i=1 \div 2, j=1 \div 9$)



(a) Structural diagram



(b) Half-machine dynamic model of a wheel loader

Fig 1: Structural diagram of a wheel loader

2.2 Equations of motion

The motion equations of m_{b2} are written as follows

$$m_{b2} \ddot{z}_{b2} = \sum_{i=1}^2 F_{ci} - F_{t2} + F_t \tag{1}$$

$$I_{b2} \ddot{\phi}_{b2} = F_{t2} J_3 - F_t J_2 + \sum_{i=1}^{i=2} F_{ci} J_{i+3} - M_t \tag{2}$$

The motion equations of m_c are written as follows

$$m_c \ddot{z}_c = F_s - \sum_{i=1}^2 F_{ci} \tag{3}$$

$$I_c \ddot{\phi}_c = \sum_{i=1}^{i=2} (-1)^{i+1} F_{ci} J_{i+5} - F_s J_8 \tag{4}$$

The motion equation of m_s is written as follows

$$m_s \ddot{z}_s = -F_s \tag{5}$$

2.3 Ground surface excitations

In off-road applications, wheel loaders frequently encounter irregular ground surfaces characterized by large-amplitude and low-frequency excitations. To simulate these adverse road conditions, the present study employs an excitation model based on ISO 8608:2016 [17], which describes the stochastic nature of road roughness through its spectral characteristics. The road input $q(t)$ for the coupled vehicle–terrain dynamic interaction is generated using the following expression:

$$q(t) = \sum_{i=1}^N \sqrt{2G_d(n_i) \Delta n_i} \cos(2\pi i \Delta n t + \beta_i) \tag{6}$$

Here, $G_d(n_i)$ denotes the power spectral density (PSD) of the road surface at spatial frequency n_i corresponding to ISO roughness classes from A (smooth) to H (very rough). The term Δn_i represents the frequency bandwidth, while β_i is the randomly assigned phase angle within the interval $[0, \pi]$, ensuring a realistic representation of random surface profiles.

3. Vehicle Ride Comfort Evaluation Criteria [19-25]

To evaluate the ride comfort of the vehicle in the time domain, the approach outlined in ISO 2631-1:1997 [15] is

adopted in this study. Specifically, the evaluation is based on the calculation of the frequency-weighted root mean square (r.m.s.) acceleration, which reflects the cumulative effect of vibrations over a given measurement interval. The weighted acceleration response, denoted as

$$a_{wz} = \left[\frac{1}{T} \int_0^T a_z^2(t) dt \right]^{1/2} \tag{7}$$

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

4. Results and discussion

To evaluate the effect of wheel loader load on the drive ride comfort, the differential equations of motion of Fig.1 are simulated when the machine operates on an ISO class D road surface at a speed of 10 km/h by the MATLAB/Simulink with design parameters in the Reference [15].

Increased load condition: $m_{b1}=1.5 m_{b10}$ (m_{b01} is the load value of original machine) is chosen to evaluate [15] of wheel loader load on the drive ride comfort. The evaluation results of acceleration responses of the vertical driver’s seat (a_s) and cab’s pitch angle (a_c) with $m_{b1}=1.5 m_{b10}$ compared to the $m_{b1}=1.0 m_{b10}$ condition are shown Fig.2.

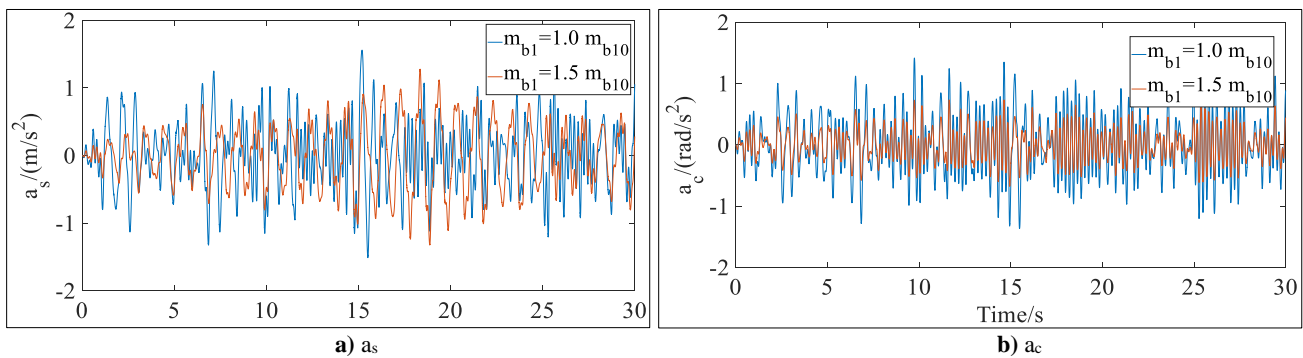


Fig 2: Acceleration responses of the vertical driver’s seat (a_s) and cab’s pitch angle (a_c) with $m_{b1}=1.5 m_{b10}$ compared to the $m_{b1}=1.0 m_{b10}$ condition

From the results of Fig. 2, the values of the root mean square (r.m.s) acceleration responses of driver’s seat and pitch angles of cab (a_{ws} and a_{wc}) are determined by Eq. (6) according to ISO 2631-1. The results in indicate that the a_{ws} and a_{wc} values with $m_{b1}=1.5 m_{b10}$ condition reduce by 6.24%, 46.94% respectively compared to the $m_{b1}=1.0 m_{b10}$ condition. This leads to a significant improvement in the machine’s ride comfort, especially by reducing the pitch vibrations of the cab

under increased load conditions.

Reduced load conditions: $m_{b1}=0.5 m_{b10}$ (m_{b01} is the load value of original machine) is chosen to evaluate of wheel loader load on the drive ride comfort. The evaluation results of acceleration responses of the vertical driver’s seat (a_s) and cab’s pitch angle (a_c) with $m_{b1}=0.5 m_{b10}$ compared to the $m_{b1}=1.0 m_{b10}$ condition are shown Fig.3.

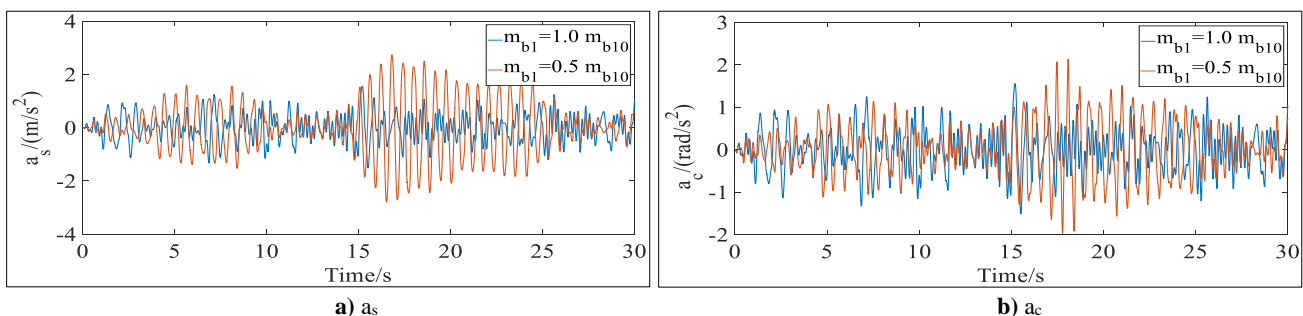


Fig 3: Acceleration responses of the vertical driver’s seat (a_s) and cab’s pitch angle (a_c) with $m_{b1}=0.5 m_{b10}$ compared to the $m_{b1}=1.0 m_{b10}$ condition

The results of Fig. 3 indicate that the a_{ws} and a_{wc} values with $m_{b1}=0.5$ m_{b10} condition increase by 32.99%, 17.04% respectively compared to the $m_{b1}=1.0$ m_{b10} condition. This leads to a significant deterioration in the machine's ride comfort under reduced load conditions.

4. Conclusions

In this study, the effect of wheel loader load on the drive ride comfort were evaluated using a half-machine dynamic model of wheel loader when the machine operates on an ISO class D road surface at a speed of 10 km/h. The evaluation results have yielded the following conclusions: (i) the a_{ws} and a_{wc} values with $m_{b1}=1.5$ m_{b10} condition reduce by 6.24%, 46.94% respectively compared to the $m_{b1}=1.0$ m_{b10} condition. This leads to a significant improvement in the machine's ride comfort, especially by reducing the pitch vibrations of the cab under increased load conditions; (ii) a_{ws} and a_{wc} values with $m_{b1}=0.5$ m_{b10} condition increase by 32.99%, 17.04% respectively compared to the $m_{b1}=1.0$ m_{b10} condition. This leads to a significant deterioration in the machine's ride comfort under reduced load conditions. In future research, the team will focus on analyzing the influence of vehicle design parameters on the ride comfort of construction machinery.

5. Acknowledgment

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

6. References

1. Le VQ, Zhang J, Liu X, Wang Y, Thoan PV. Ride comfort evaluation of vibratory roller under different soil ground. *Trans Chin Soc Agric Eng.* 2013;29(9):39-47.
2. 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.
3. 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.
4. 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.
5. 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.
6. 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.
7. 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.
8. 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: *ICERA 2021. Lecture Notes in Networks and Systems*, vol 366. Cham: Springer; 2022. p. 25-33.
9. Vu NQ, Canh CH, Nguyen TH. Effect of design parameters of cab's isolation system on a wheel loader ride comfort. *World J Res Rev.* 2025;20(5):1-4.
10. 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.
11. Le VQ, Ha DV, Cuong BV, Vu LA, Thoan TV. Improvement of ride comfort quality for an earth-moving machinery with semi-active cab isolation system. *E3S Web Conf.* 2021;304:02012.
12. Nguyen TD, Le VQ, Dang VH, Bui VC, Le XL. Ride comfort evaluation for a double-drum vibratory roller with semi-active hydraulic cab mount system. *E3S Web Conf.* 2021;304:01008.
13. Hoang AT, Bui VC, Nguyen DT, Nguyen MC, Canh CH. Improvement of ride quality for a wheel loader with semi-active cab isolation system via fuzzy self tuning of PID controller. *J Mil Sci Technol.* 2023;(FEE):197-203.
14. Doan TB, Luu KO, Nguyen TT. An overview of semi-active isolation systems of earth-moving machinery cab. *Int J Eng Invent.* 2024;13(12):89-92.
15. International Organization for Standardization. Mechanical vibration and shock-evaluation of human exposure to whole-body vibration, part I: general requirements. *ISO 2631-1.* Geneva: ISO; 1997.
16. Canh CH, Nguyen DT, Nguyen VM, Pham MT, Nguyen TH, Dam HV. Analysis of the influence of road surface conditions on wheel loader ride comfort. *Int J Eng Invent.* 2025;14(3):189-93.
17. International Organization for Standardization. Mechanical vibration—road surface profiles—reporting of measured data. *ISO 8608.* Geneva: ISO; 1995.
18. Tran TQ. Study on the ride effectiveness of hydraulic isolation system for construction machine cab [master's thesis]. Thai Nguyen: Thai Nguyen University of Technology; 2022.
19. Le VQ, Thao VTP. Effect of operating conditions on vehicle ride comfort and road surface friendliness with air suspension system. *Int Res J Eng Technol.* 2020;7(6):7671-5.
20. Long LX, Quynh LV, Cuong BV. Study on the influence of bus suspension parameters on ride comfort. *Vibroengineering PROCEDIA.* 2018;21:77-82.
21. Quynh LV, Thao VTP, *et al.* 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.
22. Wang X, Liem NV, Li S, Quynh LV. Research and optimisation of the dynamic parameters of the QZSS embedded in the seat suspension system of the vehicles. *Veh Syst Model Test.* 2023;17(1):81-99.
23. Van Cuong B, Huan CC, Van Quynh L, Binh DT. Effects of design parameters of cab's suspension system on an agricultural tractor ride comfort. In: *ICERA 2022. Lecture Notes in Networks and Systems*, vol 602. Cham: Springer; 2023.
24. Le Xuan L, Dang Viet H, Le Van Q, Bui Van C, Vu Thanh N. Effect of operating conditions on a heavy truck ride comfort with hydro-pneumatic suspension system. *E3S Web Conf.* 2021;304:02011.
25. Tan HA, Van Thoan P, Tan ND, Hien VT, Van Quynh L. Ride performance analysis of a semi-active hydraulic engine mounting system of a passenger car. In: *ICERA 2023. Lecture Notes in Networks and Systems*, vol 944. Cham: Springer; 2024.