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Effect of design parameters of driver's seat suspension system on mining dump truck ride comfort

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ABSTRACT: *This paper proposes a quarter-vehicle dynamic model for a mining dump truck to evaluate the effect of design parameters of driver's seat suspension system on mining truck ride comfort. To evaluate their impact on mining dump truck ride comfort, the root mean square (r.m.s) values of acceleration responses of the vertical driver's seat (a_{ws}) according to the ISO 2631:1997(E) standard are selected as objective functions. The stiffness and damping coefficients of driver's seat suspension system are analyzed respectively under various road surface conditions based on ISO 2631-1997 standard. The results show that the design parameters of driver's seat suspension system have a significant influence on mining truck ride comfort. Adjusting these parameters can help reduce the value of a_{ws} and improve ride quality. These findings provide valuable insights for optimizing driver's seat suspension systems enhancing vehicle ride comfort and protecting the health of operators in the harsh operating conditions of mining trucks.*

KEYWORDS: *mining truck, driver's seat, suspension design parameters, ride comfort*

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I. INTRODUCTION

In the mining truck industry, ensuring operator comfort is critical for maintaining both productivity and long-term health. Mining trucks often operate in demanding environments with rough terrain, subjecting operators to substantial vibrations. These vibrations not only affect comfort but can also lead to fatigue, musculoskeletal disorders, and other health complications [1], [2]. Therefore, optimizing ride comfort is essential, with particular attention given to the design of seat suspension systems, which serve as buffers against these vibrations [3]. The performance of the seat suspension system, including parameters such as spring stiffness, damping coefficients, and suspension geometry, plays a significant role in controlling vibration levels at the seat position. Proper tuning of these parameters can effectively reduce RMS acceleration, thereby improving ride comfort and reducing vibration exposure to the operator [4]. Additionally, previous research has highlighted the influence of vehicle speed and road conditions on ride comfort, noting that rougher surfaces, such as those classified under ISO Class D and E, exacerbate discomfort [5]. Various tasks in vibration analysis of mechanical and civil structures and road-vehicle-driver interaction system were proposed to compare spectrum parameters of real roads with ISO 8608 road classes [7]. A full-vehicle school bus model, which consists of a seat, vehicle body, wheels and suspension systems was proposed to evaluate vehicle seat comfort in accordance with ISO 2631-1 and Occupational Health and Safety (OHS) legislation [8]. A hybrid method of an artificial neural network (ANN) and response surface methodology (RSM) was proposed to predict the peak seat-to-head transmissibility ratio of a seating suspension system and to evaluate its ride comfort for different seat design parameters [9]. To improve the efficiency of automobile suspension systems, optimization and control methods for the systems are presented in the literatures [9-13]. A half-vehicle dynamic model of an agricultural tractor was proposed to analyze the effect of the design parameters of cab's suspension system on an agricultural tractor vehicle ride comfort [14]. The performance of novel hydrfo-pneumatic suspension system (HPSs) in comparison with traditional hydro-pneumatic fsuspension system (HPSs) of a heavy truck in the direction of improving vehicle ride comfort was proposed using a 3-D nonlinear dynamic model of heavy truck with 10 degrees of freedom under random excitation of road surface [15]. In this study, a quarter-vehicle dynamic model for a mining dump truck under different road conditions and vehicle speed conditions is proposed to evaluate the effect of design parameters of driver's seat suspension system on mining truck ride comfort.

II. QUARTER-VEHICLE DYNAMIC MODEL

In this section, the dynamic model of the mining truck's suspension system is presented. The model aims to simulate the vertical motion of the truck and its components under the influence of road irregularities, focusing on the seat suspension system and its impact on driver ride comfort. The model is based on a quarter-vehicle system, which simplifies the complexity of the vehicle's response while retaining enough detail to accurately capture the essential dynamics relevant to ride comfort. A quarter-vehicle dynamic model for a mining dump truck is developed with three degrees of freedom as shown in Fig.1. Where, m_s is driver's seat mass, m_c is the vehicle body mass, m_t is the vehicle axles; k_s and c_s are the stiffness and damping coefficients of the driver seat suspension system; k_c and c_c are the stiffness and damping coefficients of vehicle suspension system; k_t and c_t are the stiffness and damping of the tires; z_s, z_c, and z_t denote the vertical displacements of driver's seat, vehicle body and axles, respectively; and q(t) is the road surface excitation input.

The equations of motion are as follows:

With diver's seat, m_s

$$m_s\ddot{z}_s = -[(k_s(z_s - z_c) + c_s(\dot{z}_s - \dot{z}_c)] \quad (1)$$

With vehicle body, m_c

$$m_c\ddot{z}_c = [(k_s(z_s - z_c) + c_s(\dot{z}_s - \dot{z}_c)] - [k_c(z_c - z_t) + c_c(\dot{z}_c - \dot{z}_t)] \quad (2)$$

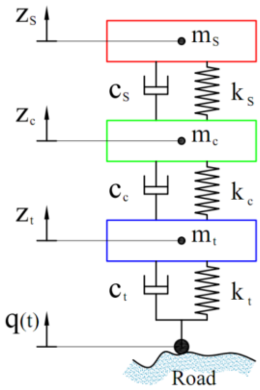

Fig 1.1. A quarter- verhicle dynamic model for a ming truck

With vehile axles, m_t

$$m_t\ddot{z}_t = [(k_c(z_c - z_t) + c_c(\dot{z}_c - \dot{z}_t)] - [k_t(z_t - q) + c_t(\dot{z}_t - \dot{q})] \quad (3)$$

The excitations of the road surface roughness: The off-road vehicle often operates under bad road surface conditions. However, the random road surface roughness is chosen as the vibration-input excitation functions for the vehicle dynamic analysis in this paper. Road surface roughness is assumed to be a Gaussian stochastic process, which is generated through an inverse Fourier transformation. The random excitation function of road surface roughness according to ISO 8068 (1995) [7] is shown by equation (4).

$$q(t) = \sum_{i=1}^{N}\sqrt{2G_q(n_i)\Delta n}\cos(2\pi n_k t + \varphi_i) \quad (4)$$

where, N is the number of intervals, $\Delta n = 2\pi / L$ with L as the length of the road segment, φ_i is a random phase uniformly distributed from 0-2π.

generated between 0 and π..

III. VEHICLE RIDE COMFORT EVALUATION CRITERIA

The time-domain method can be applied to evaluate the vehicle ride comfort according to ISO 2631-1 (1997) [1], in this study, the vibration evaluation based on the basic evaluation methods including measurements of the weighted root-mean-square (r.m.s.) acceleration defined as:

$$a_{wz} = \left[\frac{1}{T}\int_0^T a_z^2(t)dt\right]^{1/2} \quad (5)$$

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.

IV. RESULTS AND DISCUSSION

The simulation was developed and executed in MATLAB/Simulink to solve the equations of motion of a quarter-vehicle dynamic model with reference parameters [16]. The stiffness and damping coefficients of driver's seat suspension system are analyzed respectively under different road surface and vehicle speed conditions based on ISO 2631-1997 standard with two Cases such as Case1: c_s =constant, k_s=[0.5 1 1.5]k_{s0} and Case 2: k_s =constant, c_s=[0.5 1 1.5]k_{s0} (c_{s0} and k_{s0} are the original stiffness and damping coefficients of driver's suspension system).

Case 1: Effect of stiffness of driver's suspension system, k_s on vehicle ride comfort

Three k_s values, k_s= [0.5 1 1.5] ks_0 selected to evaluate their influence on the a_s value which determined by Eq. (5) when vehicle moves on the different road surface and vehicle speed conditions. The a_s values with changing value of k_s when vehicle moves on road surface ISO class C, ISO class D, and ISO class E at v= 5 km/h, v=10 km/h, v=15km/h and full load are illustrated in Fig.2, Fig.3 and Fig.4. From the results in Fig.2, Fig.3 and Fig.4, we see that (i) at v=5 km/h: When $k_s = 0.5\, k_{s_0}$ (soft stiffness), the a_s value with ISO Class E is 0.1097 m/s^2, but when $k_s = 1.5\, k_{s_0}$ (stiff stiffness), the a_s increases by 0.4034 m/s^2; (ii) At v=10 km/h: The a_s values with ISO Class E increases from 0.2202 m/s^2 with $k_s = 0.5\, k_{s_0}$ to 0.8086 m/s^2 with $k_s = 1.5\, k_{s_0}$; (iii) At 15 km/h: The a_s value with ISO Class E increases from a_s= 0.3308 m/s^2 with $k_s = 0.5\, k_{s_0}$ to a_s=1.2067m/s^2 with $k_s = 1.5\, k_{s_0}$. The obtained results show that the k_s value increases, the a_s also increases, vehicle ride comfort becomes worse when vehicle moves on all road surface conditions.

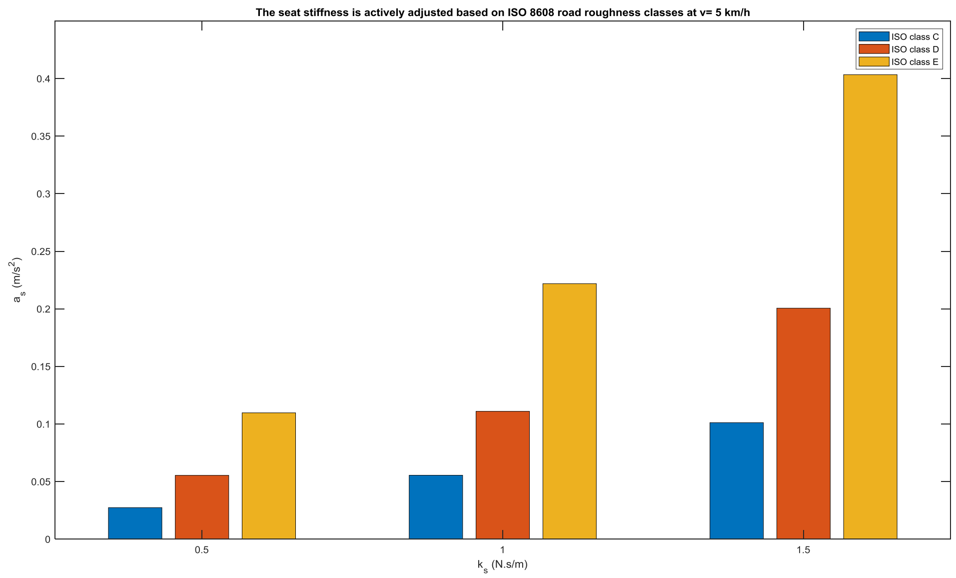

Fig 2. a_s values with changing value of k_s when vehicle moves on the different road conditions at v= 5 km/h.

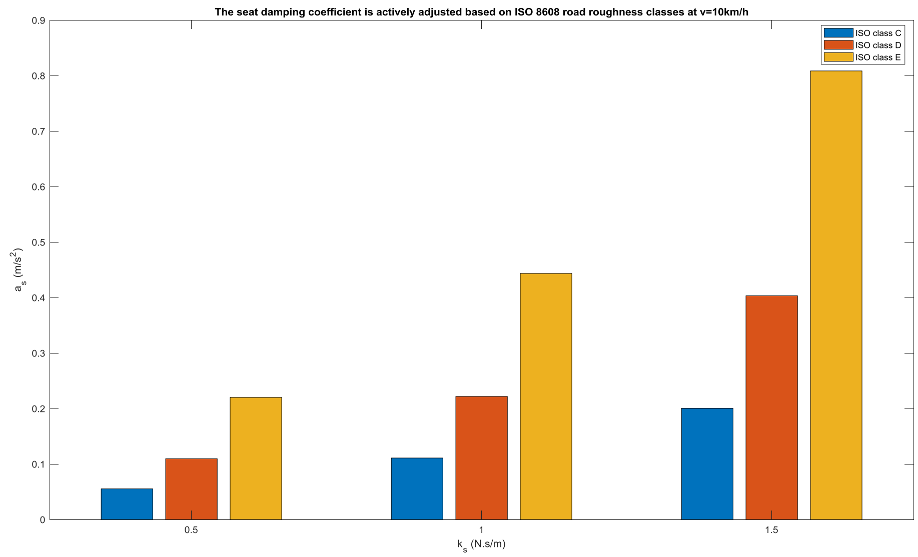

Fig 3. a_s values with changing value of k_s when vehicle moves on the different road conditions at v= 10 km/h.

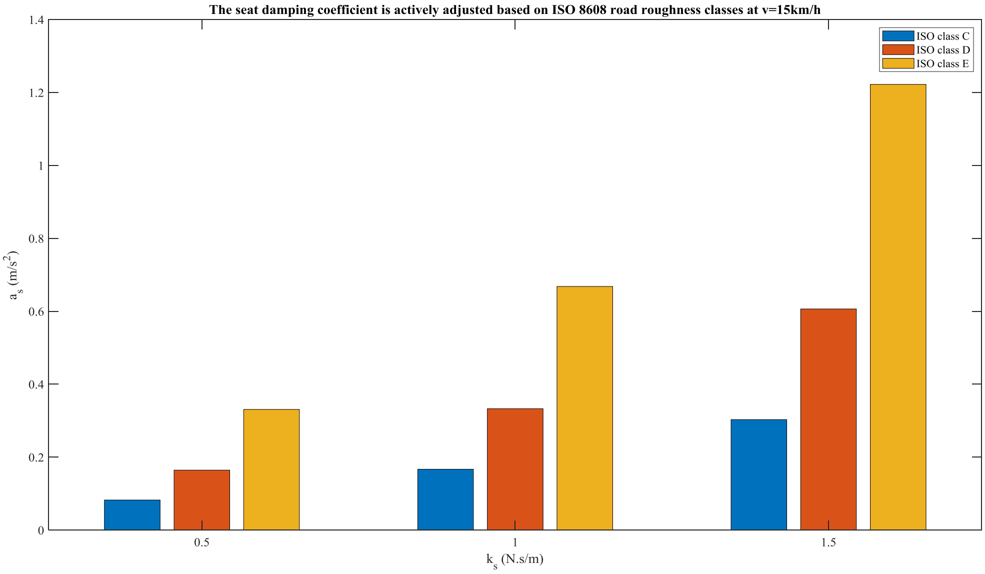

Fig 4. a_s values with changing value of k_s when vehicle moves on the different road conditions at v= 15 km/h.

Case 2: Effect of damping coefficient of driver's suspension system, c_s on vehicle ride comfort

Three c_s values, c_s= [0.5 1 1.5]c_{s0} selected to evaluate their influence on the a_s value when vehicle moves on the different road surface and vehicle speed conditions. The a_s values with changing value of c_s when vehicle moves on road surface ISO class C, ISO class D, and ISO class E at v= 5 km/h, v=10 km/h, v=15km/h and full load are illustrated in Fig.5, Fig.6 and Fig.7.

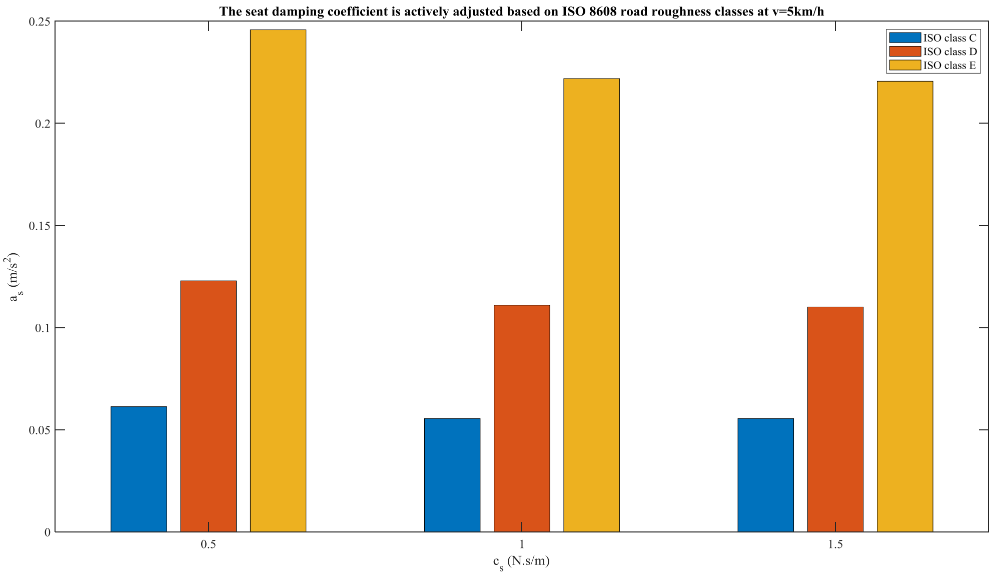

Fig 5. a_s values with changing value of c_s when vehicle moves on the different road conditions at v=5 km/h

From the results in Fig.5, Fig.6 and Fig.7, we see that (i) At v=5 km/h: With $c_s = 0.5\ c_{s_0}$ (low damping coefficient), the a_s value with ISO Class E is 0.2458 m/s^2 which decreases 0.2206 m/s^3 with $c_s = 1.5\ c_{s_0}$(high damping coefficient); (ii) At 10 km/h: the a_s value increases, v value increases, but the slight reduction when changing c_s is still observed. For example, under road surface ISO Class E, the a_s value decreases from 0.4458 m/s^2 with $c_s = 0.5\ c_{s_0}$ to 0.4097 m/s^2 with $c_s = 1.5\ c_{s_0}$; (iii) At 15 km/h: The a_s value with ISO Class E changes from 0.7373 m/s^2 with $c_s = 0.5\ c_{s_0}$ to 0.6644 m/s^2 with $c_s = 1.5\ c_{s_0}$. The obtained results show that the c_s value increases, the a_s value also decreases, improving vehicle ride comfort when vehicle moves on all road surface conditions.

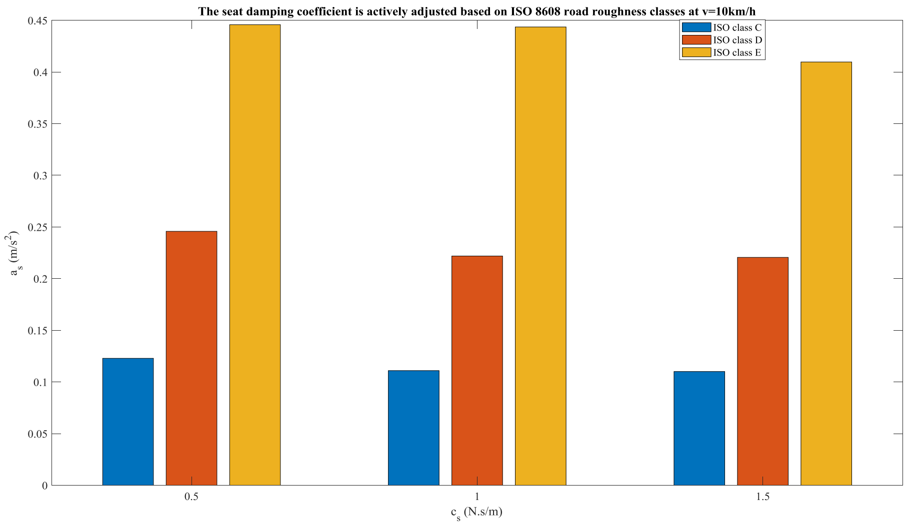

Fig 6. a_s values with changing value of c_s when vehicle moves on the different road conditions at v=10 km/h

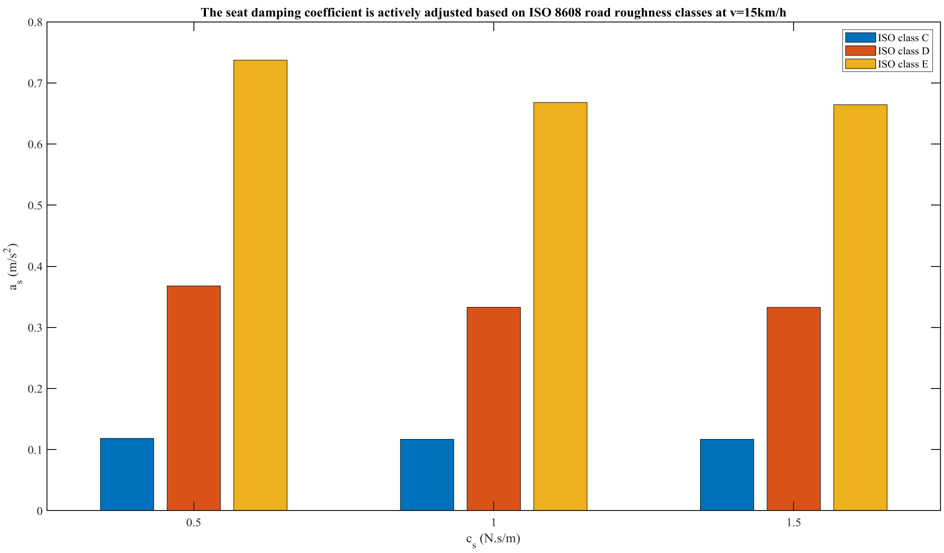

Fig 7. a_s values with changing value of c_s when vehicle moves on the different road conditions at v=15 km/h

V. CONCLUSIONS

In this study, a quarter-vehicle dynamic model for a mining dump truck under different road conditions and vehicle speed conditions was developed to evaluate the effect of design parameters of driver's seat suspension system on mining truck ride comfort. Some results obtained from some conclusions: (i) The k_s value increases, the a_s also increases, vehicle ride comfort becomes worse when vehicle moves on all road surface conditions; (ii) The c_s value increases, the a_s also decreases, improving vehicle ride comfort when vehicle moves on all road surface conditions. Additionally, the as value increases as the road surface condition deteriorates, and the vehicle speed increases which results in a deterioration of the ride comfort.

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REFERENCES

[1]. ISO 2631-1, (1997). Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-Body Vibration – Part 1: General Requirements.
[2]. Zhang, X., Li, M., & Wei, J. (2012). Study on Vibration Comfort of Vehicle Seat Suspension System. International Journal of Vehicle Design.
[3]. Morioka, M., Yamamoto, M., & Aoki, H. (2010). Optimizing Suspension Parameters for Improving Ride Comfort in Heavy-Duty Trucks. Vehicle System Dynamics.
[4]. Singh, A. (2018). Improving Ride Comfort in Mining Trucks: The Role of Suspension Control. Journal of Vehicle Engineering
[5]. Hutchinson, M., & Jacobs, L. (2007). Vibration and Human Health: The Role of Vehicle Suspensions. Journal of Vehicle Design.
[6]. ISO 8608:2016. (2016). Mechanical vibration – Road surface profiles – Reporting of measured data. International Organization for Standardization.
[7]. P. Múčka, (2018). Simulated Road Profiles According to ISO 8608 in Vibration Analysis. J. Test. Eval., vol. 46, no. 1, pp. 405–418.
[8]. A. Yavuz and S. E. Hacibektasoglu, (2023). Evaluation of Road Roughness and Vehicle Speed Effects on Vibration Comfort of School Bus Driver Seats following the ISO 2631-1 Standard and Occupational Health and Safety Legislation. Bitlis Eren Univ. J. Sci. Technol., vol. 12, no. 4, pp. 1171–1184.
[9]. Zhao, Yuli, Mohamed Khayet, and Xu Wang, (2024). A Study of Seating Suspension System Vibration Isolation Using a Hybrid Method of an Artificial Neural Network and Response Surface Modelling. Vibration 7, no. 1: 53-63. https://doi.org/10.3390/vibration7010003.
[10]. Morioka, M., Yamamoto, M., & Aoki, H. (2010). Optimizing Suspension Parameters for Improving Ride Comfort in Heavy-Duty Trucks. Vehicle System Dynamics, 48(5), 467-481.
[11]. Singh, A. (2018). Improving Ride Comfort in Mining Trucks: The Role of Suspension Control. Journal of Vehicle Engineering, 35(2), 112-121.
[12]. Hutchinson, M., & Jacobs, L. (2007). Vibration and Human Health: The Role of Vehicle Suspensions. Journal of Vehicle Design, 35(2), 132-141.
[13]. He, L., Liu, X., & Zhao, W. (2014). Optimization of Suspension System Parameters for Heavy Vehicles Based on Ride Comfort and Handling Performance. Journal of Sound and Vibration, 333(22), 5915-5928.
[14]. Van Cuong, B., Huan, C.C., Van Quynh, L., Binh, D.T. (2023). Effects of Design Parameters of Cab's Suspension System on an Agricultural Tractor Ride Comfort. Lecture Notes in Networks and Systems, vol 602. Springer, Cham. https://doi.org/10.1007/978-3-031-22200-9_93.
[15]. Ha, D.V., Van Cuong, B., Hien, V.T., (2021). Performance evaluation of a novel hydro-pneumatic suspension system of a heavy truck on ride comfort. In: E3S Web of Conferences, vol. 304, p. 01009