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An overview of semi-active cab suspension system for trucks and semi-trailer trucks

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ABSTRACT: *In order to improve the ride comfort of trucks and Semi-trailer trucks, the semi-active and active suspension systems of cab are equipped on the vehicle.An overview of research results in the field of semi-active suspension systems of cab is proposed in this study. From the dynamic vehicle of the semi-activesuspension systems of cab withcontrolling damping coefficients, these results are open to researchers who are interested in further research.Some of the analytical results obtained indicate thatride performanceof hydraulic suspensionsystems of cab is better than traditional rubber suspension systems of cab under low frequency road surface excitation.The semi-activesuspension systems of cab are more widely usedfor trucks and semi-trailer trucks because it both improves vehicle ride comfort and reduces cost.*

KEYWORDS:*Truck,Semi-trailer truck, Semi-active suspension, cab, ride comfort.*

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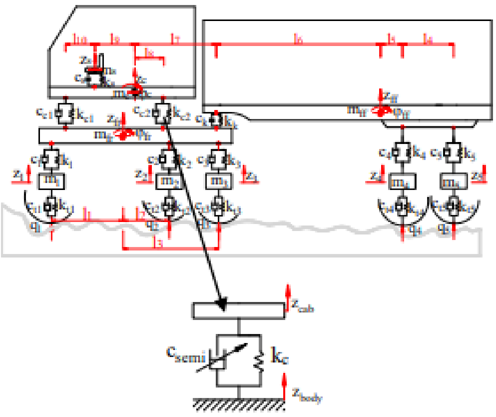
I. INTRODUCTION

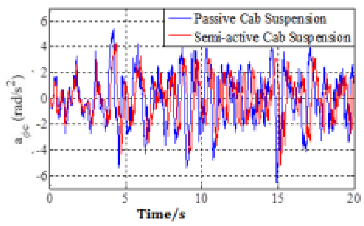
Traditional suspension systems of cab on vehicles are designed to compromise between conflicting criteria: Maintaining vehicle ride comfort and ensuring vehicle safety when moving under different conditions. Semi-active and active suspension systems ensure vehicle ride comfort, support the vehicle and provide control of vehicle motion by continuously recording parameters, processing information and controlling the actuator to change or provide additional energy to ensure smoothness of the sprung mass of the vehicles. In recent years, semi-active suspension systems have been carefully studied and widely applied by car manufacturers, and practical test results show that the working efficiency of semi-active suspension systems of cab is stable and gives much better performance than traditional passive suspension systems of cab. The effect of the design parameters of cab's suspension system on an agricultural tractor vehicle ride comfort wereanalyzed using a half-vehicle dynamic model of an agricultural tractor [1]. For semi-active suspension systems of cab that control the change in viscosity characteristics. The semi-active suspension system of the heavy truck cab with the genetic algorithm (GA-PID controller) and Fuzzy logic control combined with PID (FLC-PID controller) was proposed and controlled to improve the ride comfort of the heavy truck [2]. The control efficiency of vehicle's semi-active air suspensions(SASs)was proposed under various surfaces of soft and rigid roadsbased on the optimized rules of the fuzzy control(FC)method and vehicle dynamic model for application in SASs [3]. The cab's semi-active suspensions system of heavy truck with Fuzzy logic controller (FLC)was proposed usinga 3-D dynamic model with 13 DOF [4]. A semi active suspension system for a light commercial vehicle. The semi-active cab suspension system for trucks was proposed to investigate the effects of three control methods on improving ride comfort of semi-active cab suspension systems under random and bump road conditions: Proportional-Integral-Derivative (PID) control, fuzzy PID control, and Model Predictive Control (MPC) [5]. A combined control method of Fuzzy and PID control was proposed to control the cab isolation system of soil compactor based on the non-linear vehicle dynamic model [6]. The change of shock-absorber's damping characteristic was discussed in three ways: with the use of magneto-rheological (MR) fluids. Their properties change in dependence of a controlled magnetic field, with the use of electro-rheological (ER) fluids. Their properties change in dependence of controlled electric field, employing controlled valves, installed in the connection line between two sites of the piston in the oil-filled damper [7]. For semi-active suspension systems of cab thatchange stiffness value, a new approach for the active vibration suppression of a space truss structure by using variable-stiffness active members was proposed and investigated using a single-degree-of-freedom system [8], [9], and [10].However, it does not apply to suspension systems of vehicle cab. Semi-active systems with variable stiffness were proposed using two controllable dampers and two constant springs [11]. A variable stiffness MRF damper with two chambers and two springs was proposed through the force transmissions of the parts of the variable stiffness magnetorheological fluid (MRF) damper [12]. The aim of this paper is to discuss research results in the field of semi-active suspension systems of cab for trucks and semi-trailer trucks to improve vehicle ride comfort.

II. SEMI-ACTIVE SUSPENSION SYSTEM OF CAB

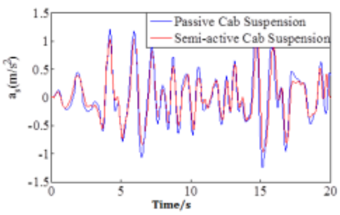
For suspension systems, controlling damping coefficients:The fuzzy logic controller (FLC) was designed to control the damping coefficient of cab suspension system using a half-vehicle dynamic model of semitrailer truck [13]. Some illustrative results are shown in Fig. 1.The results showed thatthe values of the weighted r.m.s acceleration responses of the vertical driver's seat (a_{ws}) and the cab's pitch angle($a_{w\phi c}$) with semi-active cab suspension system significantly decrease by 17.4 % and 25.4 % in comparison with passive cab suspension system when vehicle moves on the ISO class B road surface at v=70 km/h and full load.



(a) Half-vehicle dynamic model of a semi-trailer truck



(b) The vertical acceleration of driver's seat



(b) The acceleration of cabin pitch angle

Fig. 1 Some illustrative results [13]

A dynamic model for a heavy truck including the seat of the driver, cab, vehicle's floor, and two front/rear wheel axles of the heavy truck was used to evaluate the performance of the semi-active suspension system of the heavy truck cab using FLC-PID and GA-PID controller [14]. The obtained results show that the ride comfort of the vehicle using FLC-PID is better improved in comparison with using GA-PID under different operating conditions. Especially, when the vehicle moves at a speed of 72 km/h, the values of the RMS accelerations of the driver's seat and cab pitch angle are greatly reduced by 26.45 % and 26.07 % respectively. Therefore, the FLC-PID control should be applied to the suspension system of the vehicles to improve the vehicle's ride comfort.a 3-D dynamic model with 13 DOF was establishedto investigate the effectiveness of the semi-active cab suspension systems using Fuzzy logic controller (FLC) [15]. The semi-active cab suspension system for trucks was gaining increasing importance due to its economic advantages, low energy consumption, and significant enhancement of ride comfort [5]. The effects of three control methods on improving ride comfort of semi-active cab suspension systems under random and bump road conditions: Proportional-Integral-Derivative (PID) control, fuzzy PID control, and Model Predictive Control (MPC) were recommended to analyze their effectiveness on vehicle ride comfort.Schematic diagram of the truck cab suspension model is shown in Fig.3.In addition, some research results related to semi-active cab suspension systems for special vehicles are presented in the references [16], [17].

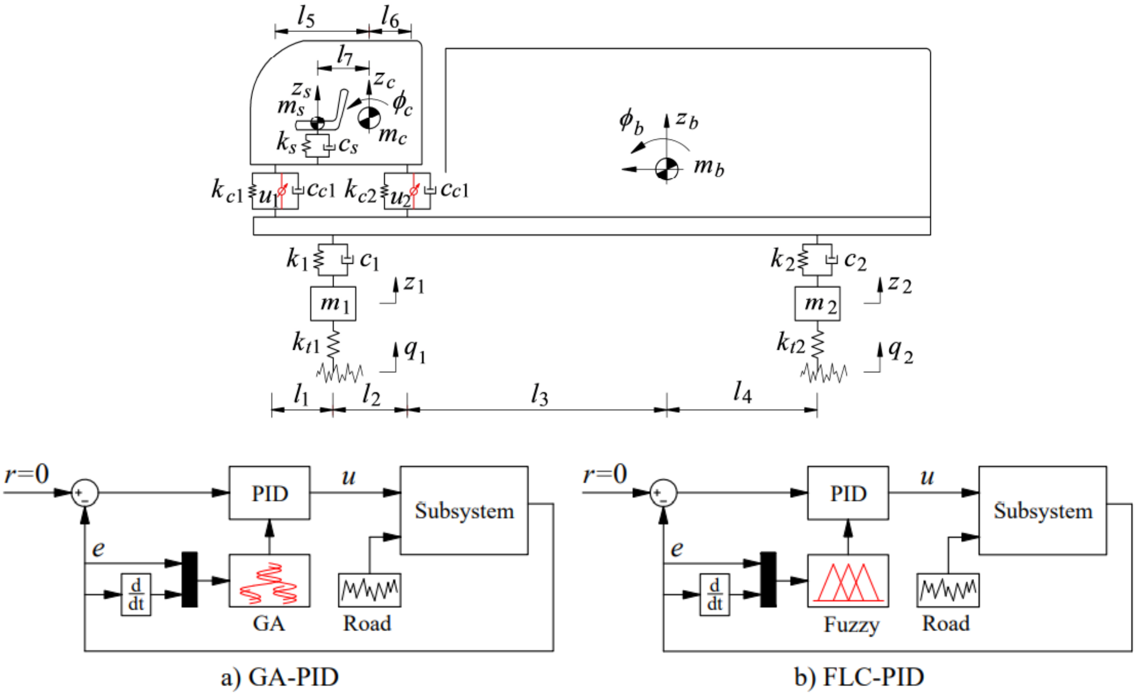


Fig. 2 A dynamic model for a heavy truck using semi-active cab suspension systems [14]

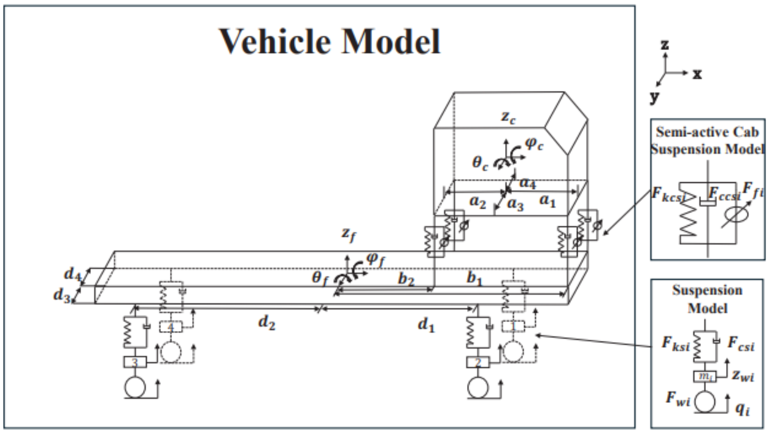


Fig.3 Schematic diagram of the truck cab suspension model [5].

*For semi-active suspension systems of cab thatchange stiffness values:*Currently, research results on this issue are still modest.

The cab suspension for passive system was represented by a parallel arrangement of a spring and damper. The research results obtained address that the active suspension system with gain scheduling strategy gave better ride improvements compared with active system in terms of vertical cab acceleration [18]. An accurate model of rolling lobe air spring (RLAS) (see in Fig.4 and Fig.5)was proposed the key to achieve the design, matching and optimization of air suspension and a refined stiffness model of RLAS with structural parameters and the stiffness characteristics of rubber bellows was developed. The refined stiffness model of RLAS also provided theoretical support for accurate performance calculation and optimization design of RLAS, which could be practically applied in parameters design and match of air suspension [19].Research results in this field are still modest, it will open a new research direction for scientists.

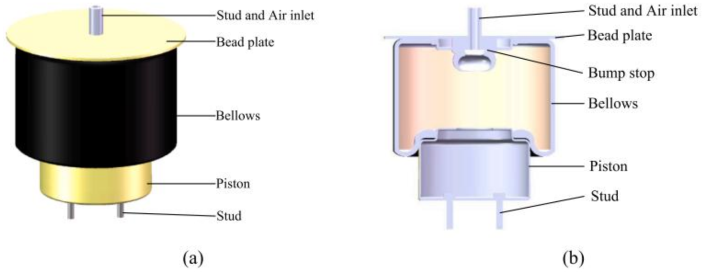


Fig.4. Physical model of a typical RLAS [19]

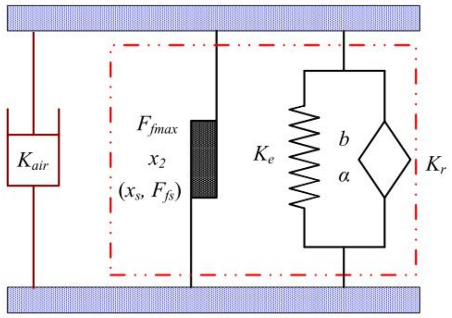


Fig.5. Schematic of the refined stiffness model of a RLAS [19]

III. CONCLUSIONS

An overview of research results in the field of semi-active suspension systems of cab was presented and analyzed and then the dynamic vehicle of the semi-active suspension systems of cab with controlling damping coefficient and change stiffness valueswas presented and analyzed in this study. The results drawn from the overview analysis are as follows: The ride performance of hydraulic suspension systems of cab is better than traditional rubber suspension systems of cab under low frequency road surface excitation. The semi-active suspension systems of cab were more commonly used for trucks and semi-trailer because it both improves vehicle ride comfort and reduces cost. In addition, the research results also give researchers an overview of the semi-active cab suspension system for trucks and semi-trailer trucks.

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REFERENCES

[1]. 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.

[2]. S. Ni and V. Nguyen, “Performance of semi-active cab suspension system with different control methods,” Journal of Mechatronics and Artificial Intelligence in Engineering, Vol. 4, No. 1, pp. 8–17, Jan. 2023, https://doi.org/10.21595/jmai.2022.23019.

[3]. S. Xu, J. Zhang, and L. Van, “Appling machine learning for car’s semi-activeair suspension under soft and rigid roads,” Journal of Southeast University, Vol. 38, pp. 300–308, 2022.DOI 10.3969/j.issn.1003-7985.2022.03.012

[4]. Nguyen van Liem, Zhang Jianrun, Le van Quynh, and Jiao Renqiang, “Study of fuzzy control for cab’s isolation system of heavy truck,” Vibroengineering Procedia, Vol. 10, pp. 309–314, 2016.

[5]. Sun, Qihao, Changcheng Yin, and Baohua Wang. 2024. "Experimental Validation of Truck Cab Suspension Model and Ride Comfort Improvement under Various Semi-Active Control Strategies" Processes 12, no. 9: 1880. https://doi.org/10.3390/pr12091880.

[6]. V. Nguyen, R. Jiao, V. Le, and A. Hoang, “Performance of PID-Fuzzy control for cab isolation mounts of soil compactors,” Mathematical Models in Engineering, Vol. 5, No. 4, pp. 137–145, Dec. 2019, https://doi.org/10.21595/mme.2019.21213.

[7]. J. Goszczak, G. Mitukiewicz, B. Radzymiński, A. Werner, T. Szydłowski, and D. Batory, “The study of damping control in semi-active car suspension,” Journal of Vibroengineering, Vol. 22, No. 4, pp. 933–944, Jun. 2020, https://doi.org/10.21595/jve.2020.20578.

[8]. J. Onoda, T. Endo, H. Tamaoki, N. Watanabe, (1991)“Vibration suppression by variable-stiffness members,” AIAA J. 29 (6) (1991) 977–983.https://doi.org/10.2514/3.59943.

[9]. J. Onoda, K. Minesugi, (1996)“Alternative control logic for type-II variable-stiffness system,” AIAA J. 34 (1) (1996) 207–209. https://doi.org/10.2514/3.13049.

[10]. J. Onoda, T. Sano, K. Kamiyama, (1992)"Active, passive and semiactive vibration suppression by stiffness variation," AIAA J. 30 (12) (1992) 2922–2929.https://doi.org/10.2514/3.48978.

[11]. Yanqing Liu, Hiroshi Matsuhisa, Hideo Utsuno, "Semiactive vibration isolation system with variable stiffness and damping control," Journal of Sound and Vibration 313 (2008), pp. 16–28. https://doi.org/10.1016/j.jsv.2007.11.045.

[12]. Huaxia Deng, Mingxian Wang, Guanghui Han, Jin Zhang, Mengchao Ma, Xiang Zhong, Liandong Yu, (2017) "Variable Stiffness Mechanisms of Dual Parameters Changing Magnetorheological Fluid Devices," Smart Materials and Structures vol. 26, 2017.DOI 10.1088/1361-665X/aa92d5.

[13]. Vu The Truyen, Ho Thi Thanh Mai, (2020) "Effectiveness Evaluation of Passive and Semi-active Cab Suspension Systems for the Improvement of A Semi-Trailer Truck Ride Comfort," International Research Journal of Engineering and Technology (IRJET), Vol. 07 (12), pp. 2324- 2328.

[14]. S. Ni and V. Nguyen, "Performance of semi-active cab suspension system with different control methods," Journal of Mechatronics and Artificial Intelligence in Engineering, Vol. 4, No. 1, pp. 8–17, Jan. 2023, https://doi.org/10.21595/jmai.2022.23019.

[15]. N. V. Liem, Z. Jianrun, L. V. Quynh, and J. Renqiang, "Study of fuzzy control for cab's isolation system of heavy truck," Vibroengineering PROCEDIA, Vol. 10, pp. 309–314, Dec. 2016.

[16]. Hoang Anh Tan, Bui Van Cuong, Nguyen Dinh Tan, Nguyen Minh Chau, and Canh Chi Huan. "Improvement of Ride Quality for a Wheel Loader with Semi-Active Cab Isolation System via Fuzzy Self Tuning of PID Controller". Journal of Military Science and Technology, no. FEE, Dec. 2023, pp. 197-03, doi:10.54939/1859-1043.j.mst.FEE.2023.197-203.

[17]. Van Quynh, L., Viet Ha, D., et al, "Improvement of ride comfort quality for an earth-moving machinery with semi-active cab isolation system," E3S Web Conf. Vol.304, 02012, (2021). DOI: https://doi.org/10.1051/e3sconf/202130402012.

[18]. Soliman, Aref M. A.; Gazaly, Nouby M.; Kadry, Fatma S. . SAE Technical Paper Series [SAE International SAE 2014 World Congress & Exhibition - (APR. 08, 2014)] SAE Technical Paper Series - Parameters Affecting Truck Ride Comfort. , 1(), – ,(2014). doi:10.4271/2014-01-0147.

[19]. Chen, Jun-Jie; Yin, Zhi-Hong; Yuan, Xian-Ju; Qiu, Guang-Qi; Guo, Kong-Hui; Wang, Xiao-Li . A refined stiffness model of rolling lobe air spring with structural parameters and the stiffness characteristics of rubber bellows. Measurement, 169(), 108355–, (2021). doi:10.1016/j.measurement.2020.10.