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Innovative two-axle vehicle with improved ride comfort via blended active vibration control

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Abstract

In the project Pivot2 of the European Research Program Shift2Rail an innovative passenger vehicle with single axle running gear and one suspension step is proposed, drastically reducing the vehicle weight. The concept also features active suspension to overcome the deficiency in vibration attenuation the omitted suspension step brings. A composite material running gear frame will be used both as structural and suspension element. The vehicle is meant to be an alternative to the existing Metro Madrid class 8000 vehicles expecting 400 kg/m ([1]) vehicle weight saving.

Different approaches are possible to actively improve passenger comfort [2]. Modal sky-hook control, being among one of the most simple and effective strategies, finds application in field tests ([3]). Modal control is also considered here as a starting point for the development of the blended control. Due to the strong interaction between running gear frame and carbody, the performance of modal control can be further improved by taking a percentage of the frame acceleration as control variable. A similar concept was introduced by Alujević et. al. in [4] for a 3 d.o.f. system. The concept is modified to fit the purpose of the modal controller selected for our case.

The vehicle is modelled in the multibody simulation (MBS) tool SIMPACK. The composite material frame is incorporated into the model with a simple but effective representation. To simulate the anti-roll bar, the required torsional stiffness (250 kNm/rad) connects two rigid halves of the frame (Figure 1 (Left)). A rigid carbody with a mass of 13 tons is considered. The hydraulic actuators are modelled in MATLAB/Simulink to increase the trustworthiness of the results in the study. The actuator scheme is shown in Figure 1 (Right). A complete description of the modelled actuator can be found in [1].

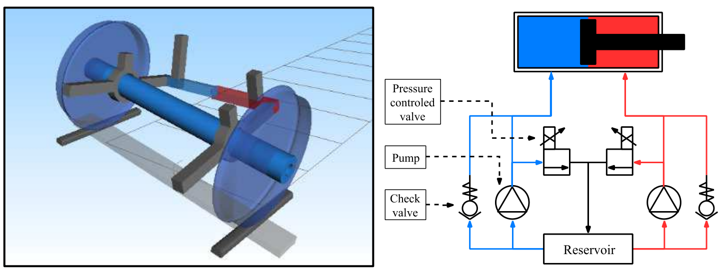

Figure 1: Running gear SIMPACK implementation (Left) and actuator schematic (Right)

Modal and blended control algorithms are compared. In the first one, carbody accelerations (co-located with the actuators actuation points) are used as feedback signals for a modal sky-hook controller. The blended control measures accelerations from the end extremities of the connection frame to consider a more complete behaviour of the vehicle before feeding it back to the modal sky-hook controller.

The multiplicative dimensional reduction method sensitivity analysis ([5]) is applied to investigate which control parameter is effective. Subsequently, the two control algorithms are optimized with the same optimization procedure (genetic algorithm).

The comfort is evaluated in vertical direction with the EN12299 standard [6] with the vehicles running at constant speed on a 1000 m tangent track with stochastic track irregularities. The vehicle speeds are chosen to be from 10 km/h to the allowable speed of 120 km/h with an interval of 10 km/h.

The comfort evaluation resulting from the optimization procedure for both controllers is given in Figure 2. In average, the blended controller provides an improvement of 5.4 %, with 6.9 % in the front part of the vehicle and 3.9 % in the rear one.

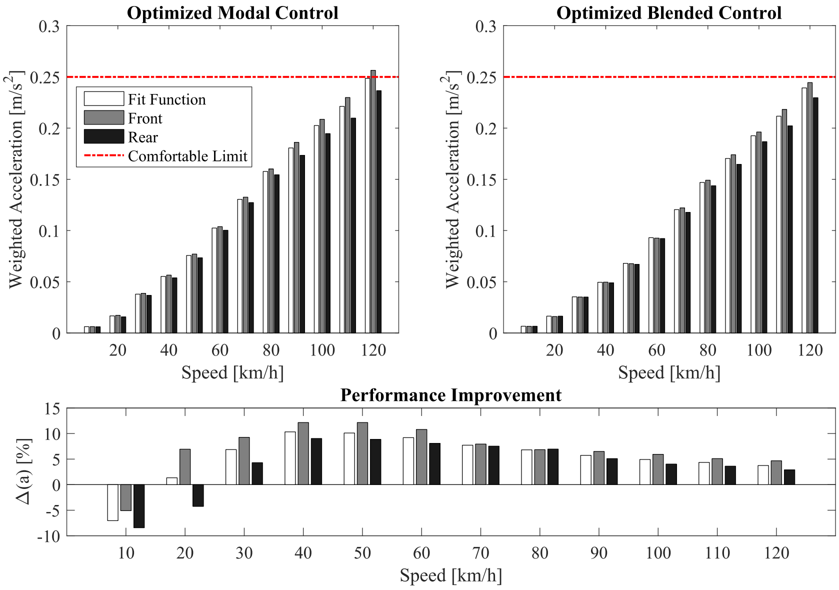

Figure 2: Comfort results: Modal control (Top-Left), Blended control (Top-Right) and their comparison (Bottom)

Despite the improvement of the proposed blended control with regard to ride comfort, other aspects must be taken into consideration. These are the maximum used force, the actuator displacement and the rms value of the power. The results given in Table 1 show that the two controllers from these aspects are similar, and do not provide further guidance in the choice controller.

Table 1: Comparison between force, displacement, rms power and energy consumption between modal and blended control

	Max Force [kN]	Max Displacement [mm]	Max rms Power [W]	Energy Cons. [kJ]
Modal	2.15 (@120 km/h)	20.1 (@120 km/h)	83.9 (@30 km/h)	495.8
Blended	2.16 (@100 km/h)	19.5 (@120 km/h)	68.1 (@120 km/h)	493.5

The comfort evaluation shows that active vertical suspension significantly improves ride comfort making it possible to introduce a vehicle with single axle running gears and only one suspension step instead of conventional bogies, promising substantial weight and cost savings.
Blended control improves the passenger comfort further compared to the standard modal approach at the expense of a more complex system. This involves more measurement sensors and more knowledge of the vehicle behaviour.

References

[1] "Innovative Running Gear Solutions for New Dependable, Sustainable, Intelligent and Comfortable Rail Vehicles, Deliverable 3.2 – New actuation systems for conventional vehicles and an innovative concept for a two-axle vehicle," 2019.

[2] B. Fu, R. L. Giossi, R. Persson, S. Stichel, S. Bruni, and R. Goodall, "Active suspension in railway vehicles: a literature survey," *Railw. Eng. Sci.*, Mar. 2020.

[3] Y. Sugahara, A. Kazato, R. Koganei, M. Sampei, and S. Nakaura, "Suppression of vertical bending and rigid-body-mode vibration in railway vehicle car body by primary and secondary suspension control: Results of simulations and running tests using Shinkansen vehicle," *Proc. Inst. Mech. Eng. Part F J. Rail Rapid Transit*, vol. 223, no. 6, pp. 517–531, 2009.

[4] N. Alujević, H. Wolf, P. Gardonio, and I. Tomac, "Stability and performance limits for active vibration isolation using blended velocity feedback," *J. Sound Vib.*, vol. 330, no. 21, pp. 4981–4997, 2011.

[5] X. Zhang and M. D. Pandey, "An effective approximation for variance-based global sensitivity analysis," *Reliab. Eng. Syst. Saf.*, vol. 121, pp. 164–174, 2014.

[6] CEN ; EN 12299, *Railway Applications - Ride Comfort for Passengers - Measurement and Evaluation*. 2009.