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Investigation of Passenger Ride Comfort in a Railway Wagon for Various Suspension Parameters

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Abstract

Comfort for passenger in rail vehicles is still currant topic. Passengers often choose the preferred kind of transport just based on the comfort level. This article is focused on the investigation of passenger ride comfort in a railway wagon for various suspension parameters. The theoretical approach comes from a description of the applied method necessary to create a virtual model of an evaluated railway wagon and it also includes the method for evaluation of the passenger ride comfort. The passenger ride comfort in a wagon is evaluated by means of the standard method, at which, the passenger ride comfort indices marked as N_{MV} in the determined locations on a wagon body floor are calculated. The calculation of the passenger ride comfort N_{MV} index requires to know values of the accelerations signals in all three directions as an input. The section of the article presents the obtained results of simulation computations. There were changed the stiffness-damping parameters of the primary and secondary suspension system and their values have been changed in three levels. The railway wagon vehicle has been running on a model of a real track section. The passenger ride indices N_{MV} have been calculated for all three variants of the wagon fifteen points located on the wagon body floor. The research results have shown, that lower values of stiffness of the secondary suspension system affects the passenger ride comfort more significantly than the lower values of stiffness-damping parameters of the primary suspension.

Keywords: rail vehicle, ride comfort, suspension system, multibody model

1 Introduction

A railway wagon represents a mechanical system with specific properties and behaviour. In the mechanics' point of view, this mechanical system is supposed to be a multi-body system (MBS). It is analysed based on the standards and defined criteria. The most important evaluated criteria relate with passengers ride comfort and running safety [1-4].

The main objective of this research is to investigate running properties of a railway wagon regarding to passengers ride comfort by means of simulation computations in a commercial MBS simulation tool. Virtual models of an investigated passenger railway wagon and a railway track have been set-up based on the available data. The goal is to found out, how the suspension parameters affect passengers ride comfort. At the same time, the passenger wagon moves on a railway track with a real geometry, which corresponds to a railway track section in the Slovak Republic. A process of assessment of passenger ride comfort needs to know the values of accelerations in a wagon body. These values are detected in that locations, which are generally given in the standard [5-7].

A MBS model of the investigated railway wagon has been created in the Simpack software. This software disposes with a specialized modelling element, which works as a standard accelerometer and allows to measure accelerations in needed directions. Resulting acceleration signals are subsequently processed in the PostProcessor of the software. Finally, the passenger ride comfort is evaluated by the ride comfort indices.

Analysing of passenger ride comfort plays a fundamental role, when railway vehicles are assessed and commissioned. Passenger ride comfort is a more complex term and it includes such factors like thermal comfort, noise propagation, quality of air in a vehicle [8-10] and definitely acting of vibrations to passengers [11, 12].

Essential factors influencing the ride comfort are a position of a passenger, time of exposure to vibrations and operational conditions. The evaluation of passengers ride comfort is a quite difficult task, because it depends on subjective character of perception of key factors influencing that. Character and effects of these factors are evaluated by means of approximate methods, which describe their influences to a human body [12-15].

2 Methods

Passengers ride comfort is quantified either by a direct method or by an indirect method. The direct method means, that passengers in a real vehicle are exposed to effects of vehicle running on a track and they evaluate comfort by their subjective feeling. The indirect method comes from knowing the measured data. The data are the values of accelerations in certain locations. Then, these signals of accelerations are processed (weighed and statistically calculated) and finally, ride comfort indices are calculated [16-18]. The process of processing and calculation of the comfort indices are described in [5, 19]. This standard recognizes average comfort (indices N_{MV}, N_{VA}, N_{VD}), continuous comfort (CCx, CCy, CCz), comfort during a rail vehicle running in a curve (P_{CT}) and comfort during discrete events (P_{DE}).

This research is aimed at investigation of average passengers ride comfort on a wagon body floor. It is marked by the N_{MV} index.

The research has been performed on a wagon in a MBS simulation software. This vehicle consists of two two-wheelsets bogies. A guidance of wheelsets in bogies is ensured by two swinging arms. Wheelsets are suspended by means of steel coil springs and hydraulic dampers (a primary suspension system) and the body of wagon is suspended against bogies also by means of steel coil springs and hydraulic dampers (a secondary suspension system). The MBS model of wagon includes only rigid bodies and they are interconnected by means of massless force elements described above.

The evaluation of vibrations, which act to a passenger and affect its feelings, is performed based on the standard [5]. The N_{MV} comfort index is calculated. It quantifies ride comfort level in a wagon on a floor. It requires to know accelerations in all three directions, i.e. in the longitudinal (x-axis), lateral (y-axis) and vertical direction (z-axis). Accelerations are during evaluation process weighted by the W_b and W_d weight functions for frequency range of 0.4 to 100 Hz [5, 12].
The final calculated value of the N_{MV} passenger ride comfort index is compared with values given in the standard (Table 1).

Value of the N_{MV} comfort index	A level of the passenger rice comfort
$N_{MV} < 1.5$	Very comfortable
$1.5 \leq N_{MV} < 2.5$	Comfortable
$2.5 \leq N_{MV} < 3.5$	Medium comfortable
$3.5 \leq N_{MV} < 4.5$	Uncomfortable
$N_{MV} \geq 4.5$	Very uncomfortable

Table 1: MBS model eigenvalues.

3 Results

An investigated passenger railway wagon (Figure 1) has been running on a real track section model with defined track irregularities.

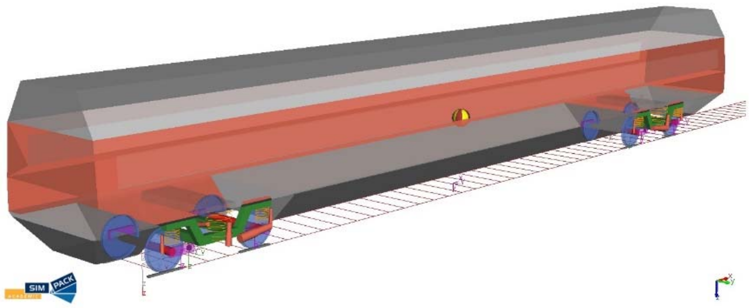

Figure 1. A view of the model of the investigated wagon in the software

The suspension parameters (stiffness and damping coefficients of vertical dampers in the primary and secondary suspension systems) have been changed within chosen range. These parameters have been changed together. It means, lower values of stiffness-damping parameters of the primary suspension have been combined with higher stiffness-damping parameters of the secondary suspension. A set of simulations have been performed for the described conditions and passenger ride comfort has been evaluated. Table 2 includes marking of the wagon with defined various stiffness-damping parameters, at which, this short paper presents only results limited values of stiffness-damping coefficients. As it can be seen, the spring and dampers parameters have been changed in several levels. The reference values correspond to the "Wagon O" (wagon original). Others are marked "Wagon H3" and "Wagon L3".

	Stiffness		Damping	
Name	k_P	k_S	b_{PV}	b_{SV}
Wagon O	0%	0%	0%	0%
Wagon L3	-45%	+45%	-45%	+45%
Wagon H3	+45%	-45%	+45%	-45%

Table 2: Values of components of the suspension system.

Percentages in Table 2 means, by what percentage are lower values of the springs and dampers lower (higher) compared to the original values (Wagon O). The wagon with springs and dampers with lower values of stiffness-damping parameters of the primary suspension system is marked Wagon L3 and the wagon with spring and damper with higher values of stiffness-damping parameters of the primary suspension system is marked as Wagon H3.

The N_{MV} comfort index has been evaluated in fifteen points on the body floor.

Following figures (Figure 2 to Figure 4) bring results of distribution of the N_{MV} indices for selected running conditions. These figures show only some of results for this short paper, namely for the running speed of 60 km/h and 120 km/h.

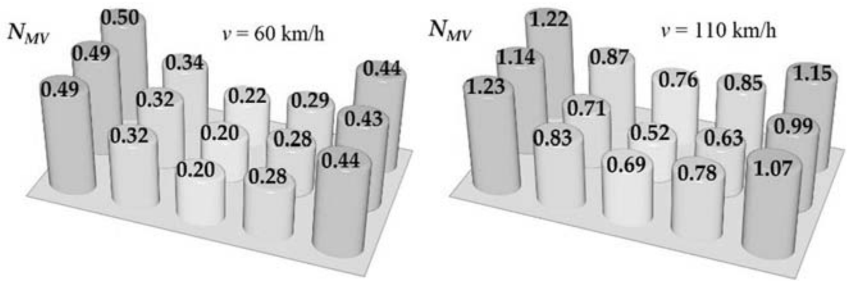

Figure 2. Resulting N_{MV} index for the speed of 60 km/h and 110 km/h for the Wagon O.

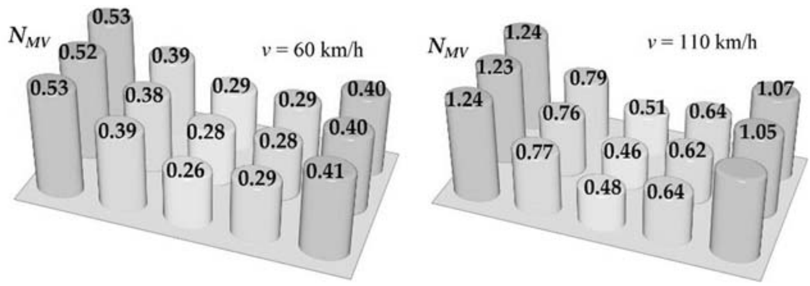

Figure 3. Resulting N_{MV} index for the speed of 60 km/h and 110 km/h for the Wagon L3.

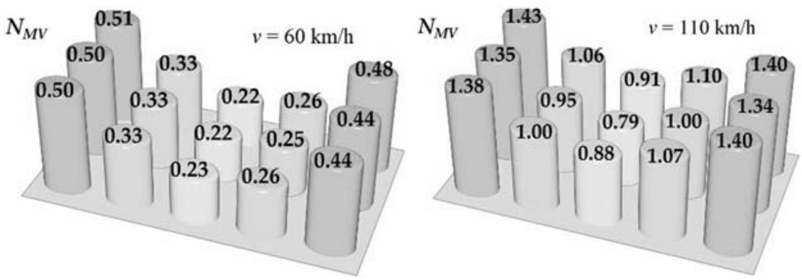

Figure 4. Resulting N_{MV} index for the speed of 60 km/h and 110 km/h for the Wagon H3.

4 Conclusions and Contributions

Results have revealed, that the passenger wagon runs on the railway track, the ride comfort depends on level of suspension parameters together with the running speed. Higher running speed causes worse passenger ride comfort. It has been reached for all three versions of suspension parameters, namely for the original values of stiffness-damping parameters (Figure 2), for softer primary suspension (Figure 3) and also for softer secondary suspension (Figure 3). It is obvious, that higher running speed leads to greater excitation of the wagon mechanical system.

When the results for the Wagon O are observed, it can be seen, that values of N_{MV} index are under the value of 1.5. The running is evaluated as very comfortable (Table 1). Together, comparing these results have shown, that higher running speed causes lower level of passenger ride comfort [20-22].

The suspension parameters of the Wagon L3, the softer primary suspension system (both springs and dampers) and the stiffer secondary suspension system (Figure 3) have caused little higher values of the ride comfort index N_{MV} on the body floor in some points. This is observed for both speeds of 60 km/h and for 110 km/h. These results are still evaluated as very comfortable (Table 1).

Greater differences are more pronounced for the Wagon H3, the stiffer primary suspension (both springs and dampers) and softer secondary suspension (Figure 4). Running of the wagon at the speed of 60 km/h results to similar values of N_{MV} comfort index as for the Wagon O. However, the N_{MV} values of passenger ride comfort for the speed of 110 km/h are higher and close to the limit 1.5. It is a limit between very comfortable and comfortable wagon. The higher values of the comfort index N_{MV} are identified for all evaluated locations. This is interesting, as the secondary suspension should to ensure mainly proper passenger ride comfort. The observed phenomenon can be explained, that lower stiffness-damping parameters of the secondary suspension cause greater tilting of the wagon body and thus, higher values of accelerations in the y-direction leads to higher values of the N_{MV} comfort index.

The introduced results are so far only a part of the more extensive and complex research, which is focused on investigation of effects of changing suspension parameters of a passenger wagon to passenger ride comfort and for running safety.

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