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EVALUATION OF RIDE COMFORT FOR PASSENGERS OF A MULTIPLE-UNIT TRAIN WITH DIFFERENT TYPES OF POWERTRAIN

Ján DIŽO[1] [0000-0001-9433-392X]
Alyona LOVSKA[2] [0000-0002-8604-1764]
Miroslav BLATNICKÝ[3] [0000-0003-3936-7507]
Vadym ISHCHUK[4] [0000-0003-2024-382X]

Abstract *– Multiple-unit trains belong to quite widely used passenger railway vehicle, which transport passengers usually for medium long distances. There is suburban and intercity passenger railway transport. Multiple-unit trains with independent traction are applied on railway lines, where electrification is not available. Current diesel multiple units (DMU) are exposed to stricter and stricter requirements for their carbon footprint. Therefore, producers of DMUs are forced to think about alternative fuels and power sources, which are more environmentally friendly during operation. A hydrogen powertrain system of a DMU is one of perspective ways to reduce negative effects of operation of conventional diesel combustion engines. As an installation of new source of power to an existing DMU design represents a significant change of its structure, it is important to evaluate the main running properties of a modified vehicle. The goal of the presented research is to evaluate the dynamic properties of a DMU with different types of powertrains. The dynamic properties are assessed by means of the indices of ride comfort passengers. This requires knowing values of accelerations on chosen location in a DMU body. The research was conducted in a commercial multibody software. The results have shown that an installation of the hydrogen powertrain does not significantly influence the dynamical properties of the investigated DMU.*

Keywords – suburban train unit, railway vehicle, powertrain, multibody system, dynamics.

1. INTRODUCTION

Current demands to the emission reduction of transport means force producers to find new and innovative technical solutions, which allow to reduce a production of harmful exhaust emissions during operation. These demands also relate with railway transport. Electrification is one of a possible way. However, there are locations and regions, where electrification of railway lines is not possible, or it is not effective. Therefore, rail vehicles with an independent powertrain are used [1]. These rail vehicles are powered by a diesel combustion engine, and they form train-sets consisting of a locomotive and wagons or they are complete units called multiple units (MU). The second variant often appears, because it provides several advantages. However, they are also powered by diesel combustion engine producing unwanted exhaust emissions including CO_2.

Recently, there are way of reduction of gas emissions production. An application of batteries does not provide a sufficient running range of a rail vehicle [2]. More modern and current way is an application of hydrogen fuel cells as a source of energy for a rail vehicle [3-6]. A rail vehicle, namely the MU with an installation of hydrogen fuel cells is a subject of this research. Originally, the solved MU is a DEMU (it means, diesel-electric multiple unit) (Fig. 1). The modified vehicle includes an installation of a new, modern and ecological powertrain, which uses fuel cells as a source of energy. However, this modification requires a significant change of the DEMU design. It is a change of unnecessary

[1] University of Žilina, Faculty of Mechanical Engineering, Department of Transport and Handling Machines, Žilina, Slovakia, jan.dizo@fstroj.uniza.sk
[2] University of Žilina, Faculty of Mechanical Engineering, Department of Transport and Handling Machines, Žilina, Slovakia, alyona.lovska@fstroj.uniza.sk
[3] University of Žilina, Faculty of Mechanical Engineering, Department of Transport and Handling Machines, Žilina, Slovakia, miroslav.blatnicky@fstroj.uniza.sk
[4] University of Žilina, Faculty of Mechanical Engineering, Department of Transport and Handling Machines, Žilina, Slovakia, vadym.ishchuk@fstroj.uniza.sk

components of an original diesel-electric powertrain and an installation of new components, which will ensure flawless operation of the unit with the hydrogen fuel cells.

Fig.1. An illustration of the solved multiple unit train

The point of the solved issue consists in a fact, that the component of the multiple-unit with the hydrogen fuel cells have higher mass. Therefore, it is assumed a significant influence on the running properties. Based on this fact, it is necessary to perform needed analyses which reveal the results about the running properties. From the running properties point of view, running safety and ride comfort for passenger is assessed. The analysis of running safety is an object of other research, which results are also included in this proceeding. The ride comfort of passengers is a parameter, which belongs to the vehicle dynamics. The fuel cells components increase the total weight of the multiple unit train. This fact is evaluated form the ride comfort point of view.

2. RIDE COMFROT FOR PASSENGERS

Ride comfort for passengers in rail vehicles is one of the most important dynamic properties of these transport means. It can influence passengers, whether they choose that which vehicle and then, a producer an operator (or the transport company) can choose a product of the particular producer. Ride comfort for passengers is a complex of factors, which a passenger is exposed, such as noise, light, and mainly vibration [7, 8].

Regarding to dynamics, the ride comfort for passengers is affected by vibrations, which arise during rail vehicle running on a railway track [9, 10]. These vibrations are generated mainly by track irregularities as well as due to running through other parts of track (e.g. through turnout).

together with the method of evaluation of the ride comfort for passengers.

For the purposes of the presented research, the N_{MV} ride comfort index in a chosen places of the multiple unit train is calculated and evaluated. The N_{MV} comfort index related with the locations on a floor and it is calculated based on the following formulation [11-13]:

$$N_{MV} = 6 \cdot \sqrt{\left(a_{xP95}^{W_d}\right)^2 + \left(a_{yP95}^{W_d}\right)^2 + \left(a_{zP95}^{W_b}\right)^2} \tag{1}$$

where a_x, a_y and a_z are accelerations in the x, y and z directions, respectively, $P95$ means the 95-percentage and W_d, W_b are weight functions.

Hence, the investigated multiple-unit train were analysed for specific operational conditions (track geometry, running speeds, track irregularities), at which, both an original version (with a diesel-electric powertrain) and a modified version (with a hydrogen fuel cells powertrain) were assessed.

3. A MULTIBODY MODEL OF THE MULTIPLE-UNIT TRAIN

A multibody model (MBS model) of the solved multi-unit train was created in the Simpack software in order to perform the needed simulation computations. The set-up MBS model interprets all specific characteristics of the rail vehicle. As it can be seen in Fig. 1, the vehicle consists of three articles, which rest on four bogies. Two bogies belong to end articles and two bogies, so-called Jacobs bogies, are mutual for middle and end articles. The primary suspension connects wheelsets axle boxes with the bogies frames and includes coil springs and hydraulic dampers. The secondary suspension is located between articles bodies and bogies frames. It includes air-springs and additional hydraulic dampers. Used air-springs improve the ride comfort for passengers and allow to maintain the constant floor height independently on the load. The created multibody model of the solved multiple-unit train is shown in Fig 2. In this figure, five pints are marked. These points

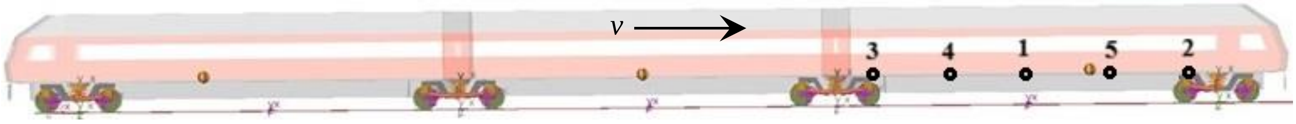

Fig.2. An illustration of the MBS model of the solved multi-unit train with marked measured points

Based on described above, the ride comfort for passengers takes into account the intensity and level of track irregularities as an input to the mechanical systems of a rail vehicle. The evaluated and assessed output from the mechanical system are accelerations. These acceleration signals are measured in specified locations of a rail vehicle. There are recognized several main locations of accelerations detection

were selected for evaluation of the ride comfort for passengers. Surely, all tree articles serve for transport of passengers. However, the range of the paper does not allow to present the findings for the entire vehicle. On the other hand, the performed research has shown, that the most unfavourable response to the excitation seems to be in the first article in the running direction.

Simulation computations were performed on a track model, which corresponds to the real railway track section Prievidza - Chrenovec in the Sovak Republic. The track model included the track irregularities and with the Fastsim wheel/rail contact. The total length of this track section is of 9.8 km. The track profile together with the curvatures is shown in Fig. 3.

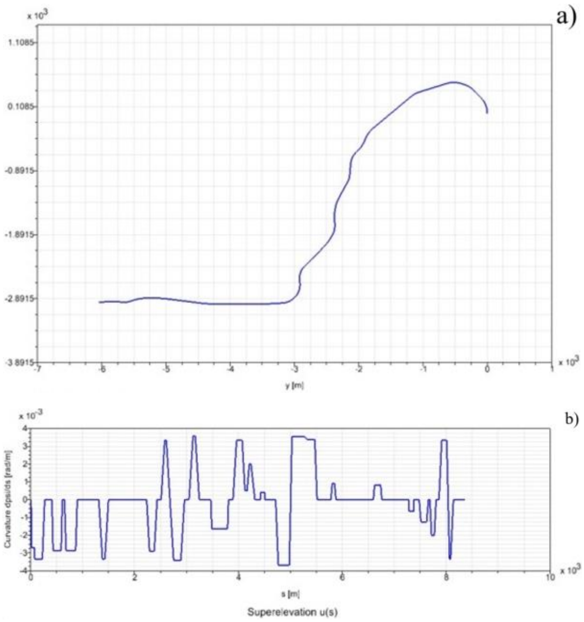

Fig.3. A horizontal profile of the track a) and the track curvature b)

The next section includes the results of the simulation computations. There are evaluated the results of the multiple-unit train running at the two speed of 50 km/h and 70 km/h on the railway track described above for both original and modified version.

4. RESULTS AND DISCUSSION

The presented results include bar graphs of the ride comfort index N_{MV} for five points (Fig. 2) in the original vehicle (with the diesel-electric powertrain) and in the modified vehicle (with the hydrogen fuel cells powertrain).

Fig. 4 shows the distribution of the N_{MV} index for the original vehicle at the speed of 50 km/h. As it can be seen, the highest values of the index are in the ends part of the vehicle article and the smallest values are in the middle part - point 1. From the human sense, it is “very comfortable”.

The results of the N_{MV} index for the modified vehicle and the running speed of 50 km/h is shown in Fig. 5. As it can be identified, the modified vehicle reached slightly higher values of the N_{MV} index in comparison to the original one. The vehicle is still evaluated as “very comfortable”.

The results of the simulation computations for the running speed of 70 km/h are shown in Fig. 6 and Fig. 7, at which, the N_{MV} index distribution of the original vehicle is shown in Fig. 6. The values of the N_{MV} index are higher in comparison with the running speed of 50 km/h. From the total evaluation of the vehicle, it is evaluated for all five points as “very comfortable”.

The last graph depicted in Fig. 7 shows the distribution of the N_{MV} index for the modified vehicle also at the running speed of 70 km/h. From the results, the modified vehicle reaches even slightly better values of the ride comfort index in comparison with the original vehicle. It is also ranked as “very comfortable”.

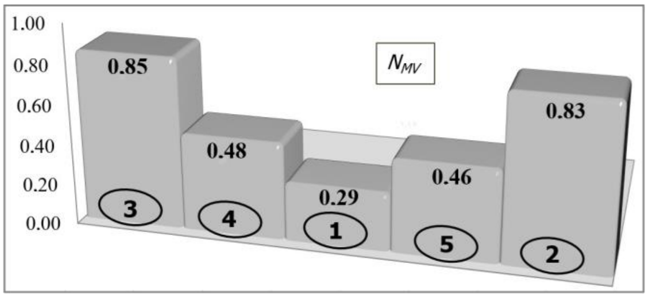

Fig.4. The ride comfort index in the original vehicle, 50 km/h

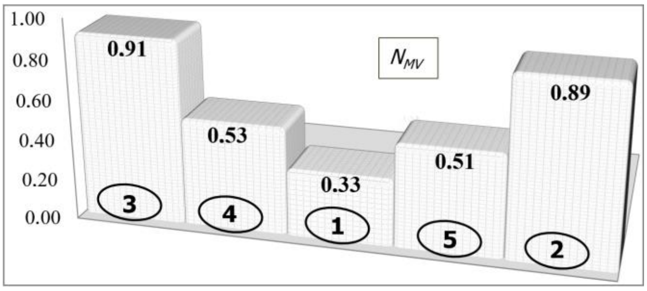

Fig.5. The ride comfort index in the modified vehicle, 50 km/h

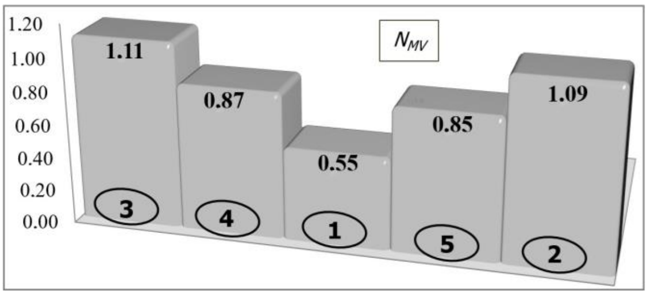

Fig.6. The ride comfort index in the original vehicle, 70 km/h

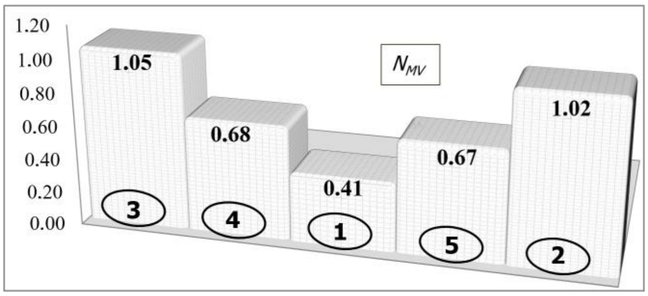

Fig.7. The ride comfort index in the modified vehicle, 70 km/h

The short discussion of the reaches results can conclude the following main findings:

- The ride comfort in the original vehicle and in the modified vehicle is comparable, the ride comfort for both vehicles is ranked as "very comfortable" for both chosen running speeds as well as for all five chosen measured points,
- All measured cases revealed that the highest quality of the ride comfort is in the middle of the vehicle article and lowest quality is at the end part of the vehicle article,
- The modified vehicle with the hydrogen powertrain does not show significant changes of the ride comfort level compared to the original one despite the changed total weight, therefore, the suspension system of the solved multiple-unit train does not need modification form the ride comfort point of view.

5. CONCLUSION

The presented research was focused on evaluation of the multiple-unit train from the ride comfort for passenger point of view. The main goal of the work was to assess, how the ride comfort for passenger is changed and influenced by the fact, that the original diesel-electric powertrain is replaced by the new hydrogen fuel cells powertrain. This modification of the powertrain changes the total weight of the multiple-unit train, therefore, it was an assumption, that this important factor will be affected. The performed simulation and calculation for the ride comfort for passengers shown, that the new powertrain does not significantly influences the comfort for passengers and form this point of view, the change of the powertrain does not require essential modifications of the suspension parameters.

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