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Design and Validation of a Rail Vehicle Propulsion Concept With a Traction Unit Powered by a Hydrogen Fuel Cell

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INTRODUCTION

Given the growing trend towards the implementation of alternative propulsion systems in the transport sector, hydrogen represent one of the most promising options. By using hydrogen obtained from renewable or nuclear energy sources, it is possible to develop transport vehicles with zero emissions.

The research focuses on creating the necessary conditions for implementing hydrogen technologies in railway transport. The article presents the results of a feasibility study focusing on the conceptual design, safety and related industrial research aimed at the replacement of a diesel rail vehicle with a hydrogen powertrain.

The most important outputs are the definition of the range of design changes and the validation of the traction unit powertrain change concept, the complex set of required technical parameters of the individual nodes of the new powertrain and their impact on driving characteristics and energy balances in a wide range of operating modes.

MATERIALS, METHODS & IMPLEMENTATION

When simulating the driving of a railway vehicle equipped with a hydrogen fuel cell drive, we assumed the replacement of the original propulsion system with an internal combustion engine, with an asynchronous motor whose nominal power is defined by the vehicle manufacturer. In this context, it was necessary to modify the parameters of the unit, especially the traction characteristics. The power Pem = 400 kW is required for a single driving bogie. Taking into account the characteristics of the asynchronous traction motor, we assumed that this motor would provide constant power over the entire speed range. Based on these parameters, we have calculated the traction characteristic for specific speeds.
When installing a hydrogen fuel cell powertrain, weight changes and distribution must be considered. Many components are placed on the roof, affecting vehicle dynamics. The hydrogen system is more complex than diesel, leading to a weight increase.

RESULTS

For the rebuild itself, it is still difficult at this stage to accurately determine the total weight of the vehicle after the modification; therefore, driving simulations were carried out with different percentage increases in weight. The results are shown in Fig. 1,2,3, - track section with a rugged track profile and in Fig. 4,5,6 - track section with a higher speed. The simulation results for the driving of the hydrogen fuel cell-powered multiple units are presented graphically to show the evolution of speed at different weight increase levels. On a track with a rugged profile, it can be seen that the vehicle reaches the desired track speed without any weight increase without any problems. This trend continues even with a slight weight increase of 5% or 10%.Simulating driving on a track allowing higher speeds, it is shown that at unchanged mass, the hydrogen-powered vehicle exhibits similar behavior to the diesel-powered vehicle. This finding is confirmed by the comparison of the traction characteristics. On the other hand, when the weight is increased, there are situations where the vehicle is unable to reach the desired track speed on certain sections of the track. For these reasons, it is necessary to investigate further possibilities to optimize and reduce the overall weight of the modified hydrogen unit.

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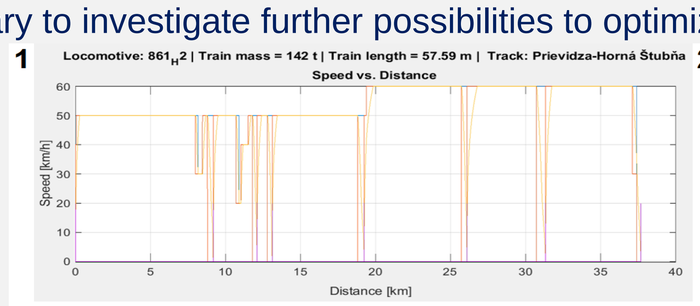

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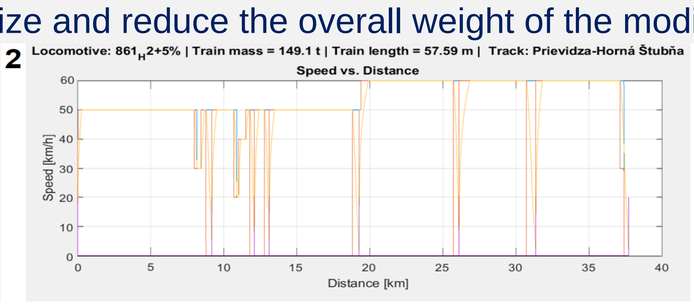

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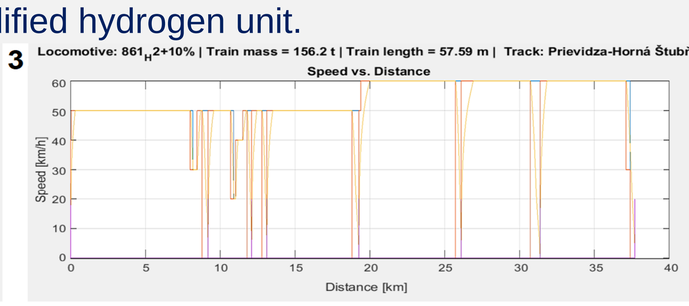

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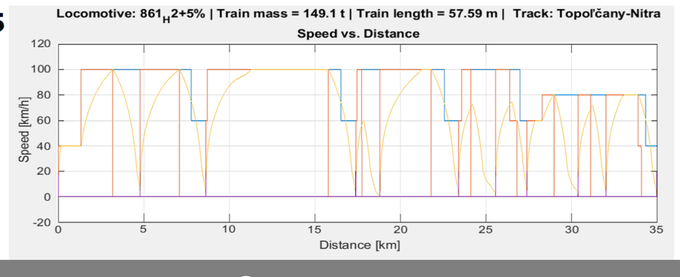

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CONCLUSION & IMPLEMENTATION PATH

Simulation analyses were used to verify the possibilities of changing the powertrain system and evaluate the impacts on driving characteristics and energy balances in different modes. The vehicle was analyzed on two representative lines. Based on the input parameters, computational simulations were carried out, and the results enabled a comparison of the vehicle's performance with the original propulsion and hydrogen fuel cells (an analysis of the original design was presented in an earlier publication).
The results show that the increased weight of the hydrogen propulsion system causes problems at higher speeds. Competing hydrogen vehicles use aluminum car-bodies, which reduces the overall weight. The 861 unit has a steel car-body, which increases weight and makes it more difficult to achieve the prescribed speeds when converted to hydrogen propulsion. A reduction in the number of hydrogen tanks and cells is also a possible option, but this will reduce the range of the vehicle. Therefore, further research and design of alternative concepts for hydrogen propulsion to this type of vehicle is needed.

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