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Long Short-Term Memory Time Series Modelling of Pressure Valves for Hydrogen-Powered Vehicles and Infrastructure

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ABSTRACT

In hydrogen-powered vehicles and hydrogen infrastructure, the long-term reliability and precision of pressure valves are critical, particularly under extreme weather conditions such as cold winters and hot summers. This study evaluates pressure valves following the Endurance Test outlined in European Commission Regulation (EU) No 406/2010, which implements Regulation (EC) No 79/2009 for the type-approval of hydrogen vehicles. To streamline the development and validation process, a machine learning-based approach utilizing long short-term memory (LSTM) networks is employed to simulate valve endurance testing. The LSTM model, configured with three inputs and one output, predicts the outlet pressure patterns of these valves. It is trained on experimental data collected at 25°C, 85°C, and -40°C to simulate a 20-year valve life cycle comprising 75000 cycles. For data at 25°C, the model achieves optimal performance with 40000 training cycles, corresponding to 55% of the total, while accurately predicting the remaining 45%. This reduces experimental validation time by nearly half without compromising accuracy, achieving an R^2 of 0.969. Robust performance is demonstrated across all tested temperatures, with R^2 values exceeding 0.960, highlighting the model's adaptability and accuracy. By leveraging LSTM models, the development process for pressure valves is significantly accelerated, and the potential for real-time onboard diagnostics and monitoring is enhanced. These findings underscore the capacity of machine learning to expedite development, enhance reliability, and facilitate the widespread adoption of hydrogen technologies, thereby advancing sustainable energy solutions.