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Comparison of multiphase modelling and simplified single-phase modelling of Polymer Electrolyte Fuel Cell (PEFC) ejector for anodic recirculation / Mansourkiaei, M., Arabbeiki, M., Ferrero, D., Santarelli, M.. - (2025). (EFCF 2025 Lucerne, Switzerland July 2025).

Availability:
This version is available at: 11583/3014888 since: 2026-08-26T13:13:14Z

Publisher:
EFCF

Published
DOI:

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20 November 2026

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Comparison of multiphase modelling and simplified single phase modelling of Polymer Electrolyte Fuel Cell (PEFC) ejector for anodic recirculation

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Abstract

Ejectors play a crucial role in PEM fuel cell systems by recirculating hydrogen from the anode outlet to the inlet, enhancing overall fuel utilization and system efficiency. They provide a passive, reliable, and energy-efficient alternative to mechanical pumps, making them particularly advantageous for compact and robust fuel cell designs. However, their performance is highly sensitive to operating conditions and geometry. consequently, it is inevitable to use modelling approaches to have a thorough understanding of the ejector performance particularly considering variations in the flow of hydrogen. This study investigates the difference between a simplified single phase dry gas modelling of the ejector and multiphase multiphysics modelling especially including the phase transport and heat transfer physics and presents a correlation between the KPIs of the two approaches in an effort to reduce the modelling calculation cost.

Using COMSOL software, the impact of humidified hydrogen on ejector performance is modelled, focusing on its two main performance indicators i.e.: entrainment ratio and Mach number distribution in comparison with the simplified model. Furthermore, different ejector sizes adapt to 10-100kW power range of fuel cell stacks were considered in the Computational fluid dynamics (CFD) simulations study as well. For the higher sized ejector, results indicate that the presence of humidified hydrogen leads to an approximately 7% decrease in the entrainment ratio even with a minimum relative humidity of 80%. On the other hand, the local Mach number in the nozzle and mixing chamber was observed to differ by 8%, as a result of the influence of humidity on flow acceleration and choking conditions within the ejector. At the diffuser outlet, the humidity of hydrogen decreases to around 20%, which influences the pressure and temperature recovery process. Humidified hydrogen alters the flow dynamics by increasing the effective density and viscosity of the recirculation flow stream, which affects momentum exchange and mixing efficiency. As a summary, this study proposes a simplified solution in modelling while recognizing the importance of accounting for multiphase multiphysics simulations when designing ejectors.

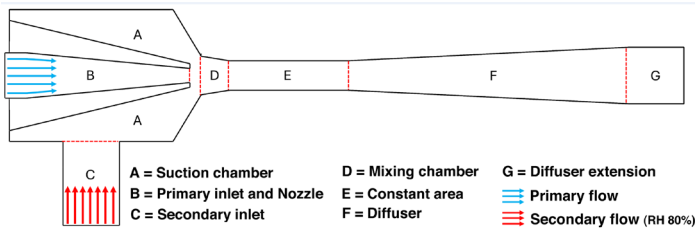


Figure 1. 2D section of the simulated ejector with the indicated sections