Numerical and Experimental Investigation of Sodium Borohydride as Circular Fuel for Marine Vessels

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Numerical and Experimental Investigation of Sodium Borohydride as Circular Fuel for Marine Vessels

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Abstract

The maritime sector accounts for approximately 3% of the global emissions, and to limit these emissions, a transition towards alternative fuels is ongoing. In this work, a novel circular bunkering process for marine vessels is considered, such that a renewable fuel economy for the maritime industry can be realised. The proposed bunkering process is shown in Figure 1, and uses sodium borohydride ($NaBH_4$) as the fuel, due to its favourable gravimetric and volumetric energy density compared to other alternatives [1]. $NaBH_4$ is fed into a reactor during vessel operation, where it reacts with water to form hydrogen and sodium metaborate (NaBO2). While the hydrogen can be used in e.g. fuel cells to power the ship, the $NaBO_2$, also referred to as spent fuel, has to be stored for the remainder of the voyage. Both $NaBH_4$ and $NaBO_2$ are bulk solids with a particle size distribution ranging from a hundred micrometres to several millimetres.

To this moment, $NaBH_4$ has predominantly been used in the chemical industry as a reducing agent [2], and consequently the mechanical characteristics and the effects of operational conditions such as humidity, temperature, and stress on the behaviour of the material are virtually unknown. However, this knowledge is essential to be able to design the required storage and handling equipment to realise the aforementioned circular bunkering process. Therefore, this work focuses on acquiring the relevant data using experiments. While most experiments show that $NaBH_4$ is initially free-flowing, particular combinations of operational conditions show a significant change in the materials flow characteristics, some results showing very cohesive material or even non-flowing characteristics. Using the acquired experimental data, the Discrete Element Method (DEM) will be used to calibrate, verify, and validate material models, such that the flow characteristics of this novel fuel can be captured numerically. These models can then be used to conceptualise the bunkering process in a virtual environment. Finally, an outlook on how to use the gained insights to develop and design the storage and handling equipment for the proposed circular bunkering process is presented.

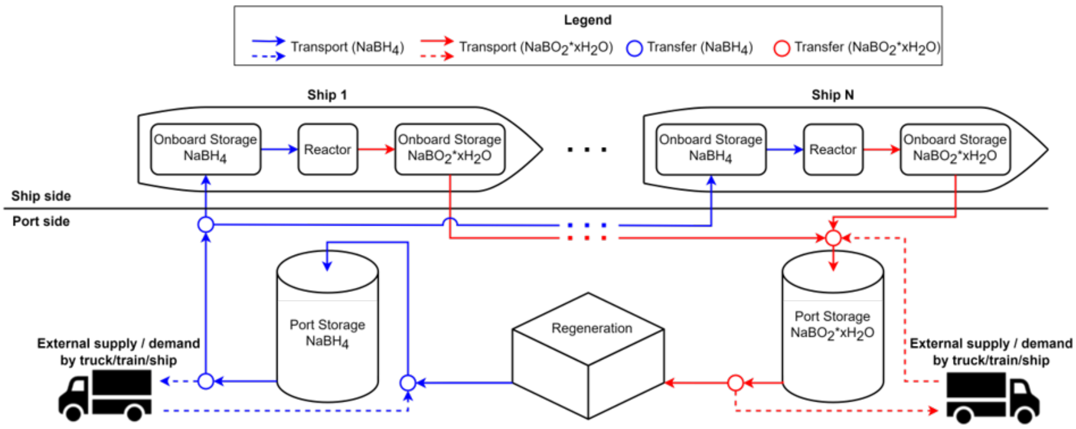

Figure 1: Circular bunkering process for marine vessels using $NaBH_4$

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[2] Kaiqiang Zhang et al. "Recent Advances in the Nanocatalyst-Assisted NaBH $_4$ Reduction of Nitroaromatics in Water". In: *ACS Omega* 4.1 (Jan. 2019), pp. 483–495. ISSN: 2470-1343, 2470-1343. DOI: 10.1021/acsomega.8b03051.