Institut de Robòtica i Informàtica Industrial

CSIC

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Model Modification and Calibration of Metal Hydride Tanks

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Reduced-order model of metal hydride tanks

A **reduced-order model** of the metal hydride (MH) tank is proposed which considers the tank temperature as a system input:

$$\dot{\breve{\mathbf{x}}} = \begin{bmatrix} \dfrac{\breve{u}_2 - f_r}{V_g} \\ \dfrac{f_r}{V_s} \end{bmatrix},$$

$$\breve{y} = \breve{x}_1 \frac{\breve{u}_1 R}{M_{H_2}},$$

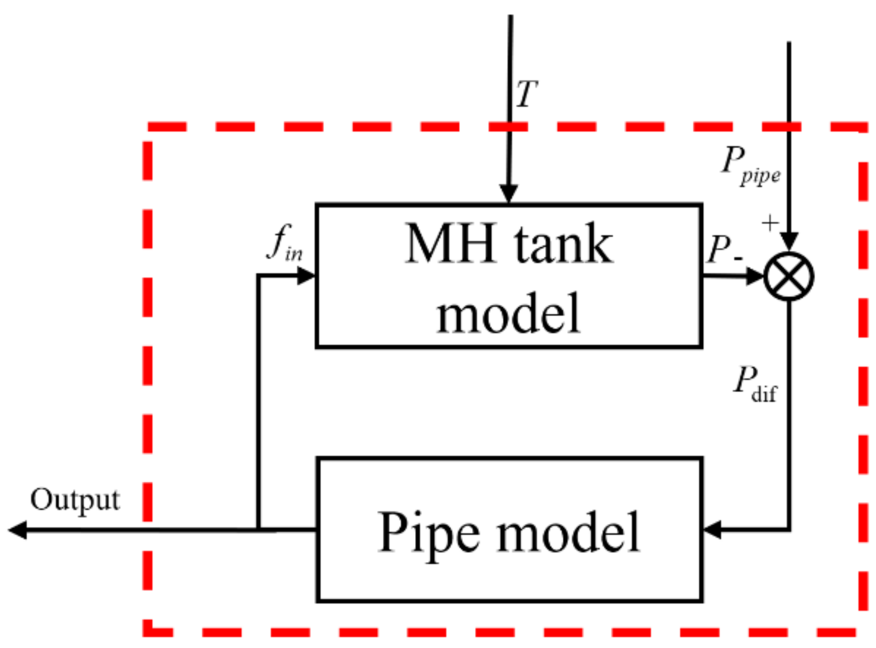
where

$$\breve{\mathbf{x}} = \begin{bmatrix} \breve{x}_1 \\ \breve{x}_2 \end{bmatrix} = \begin{bmatrix} \rho_g \\ \rho_s \end{bmatrix}, \breve{\mathbf{u}} = \begin{bmatrix} \breve{u}_1 \\ \breve{u}_2 \end{bmatrix} = \begin{bmatrix} T \\ f_{in} \end{bmatrix}, \breve{y} = P$$

are the states, inputs and output of the system, respectively. ρ_g is the density of hydrogen, ρ_s is the density of the MH, T is the temperature of MH, f_{in} is the normalized mass flow rate of hydrogen, P is the pressure of hydrogen, f_r is the normalized sorption mass flow rate of hydrogen, R is universal gas constant and M_{H_2} is the molar mass of hydrogen.

Modification of model input and output

The strategy for modifying the reduced-order model is shown in the following Figure:



Model modified

$P_{dif} = P_{pipe} - P$ is the pressure difference between the pressure inside of the MH tank and pipe pressure. When the pressures on the two sides of the entrance of the MH tank are different, the pressure difference drives the flow of hydrogen from the side with the higher pressure to the side with the lower pressure. Consider the proportional pipe model to reflect this relationship, i.e. when the normalized mass flow rate f_{in} is proportional to the pressure difference:

$$f_{in} = k_p \cdot P_{dif} \cdot 10^{-5},$$

where k_p is the proportionality coefficient.

Reduced-order modified model of MH tanks

The **reduced-order modified model** can be expressed as:

$$\dot{\mathbf{x}} = \begin{bmatrix} \dfrac{k_p \cdot (u_2 - \frac{x_1 u_1 R}{M_{H_2}}) \cdot 10^{-5} - f_r}{V_g} \\ \dfrac{f_r}{V_s} \end{bmatrix},$$

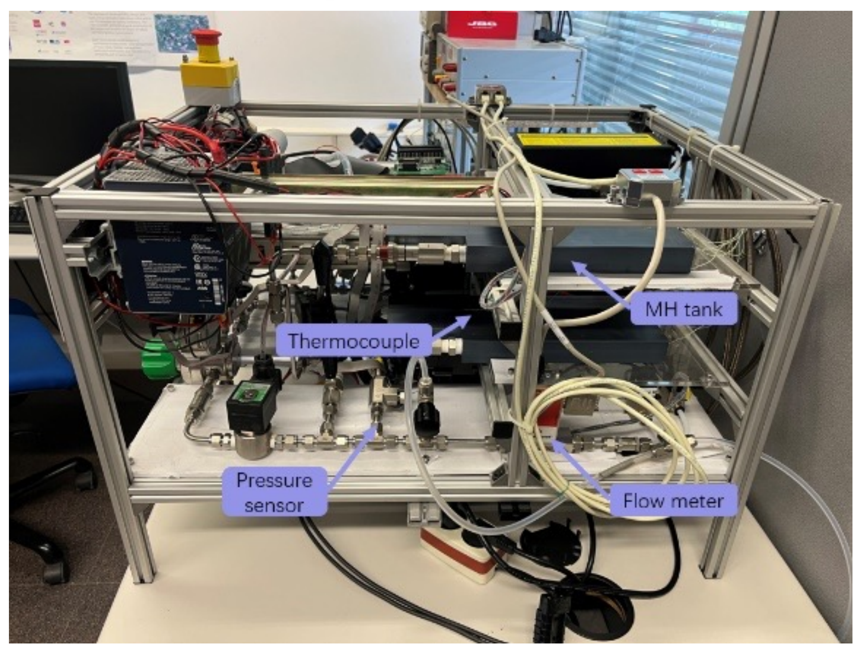
$$y = k_p \cdot (u_2 - \frac{x_1 u_1 R}{M_{H_2}}) \cdot 10^{-5},$$

where

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} \rho_g \\ \rho_s \end{bmatrix}, \mathbf{u} = \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = \begin{bmatrix} T \\ P_{pipe} \end{bmatrix}, y = f_{in}$$

are the states, inputs and output of the system, respectively.

Experimental setup

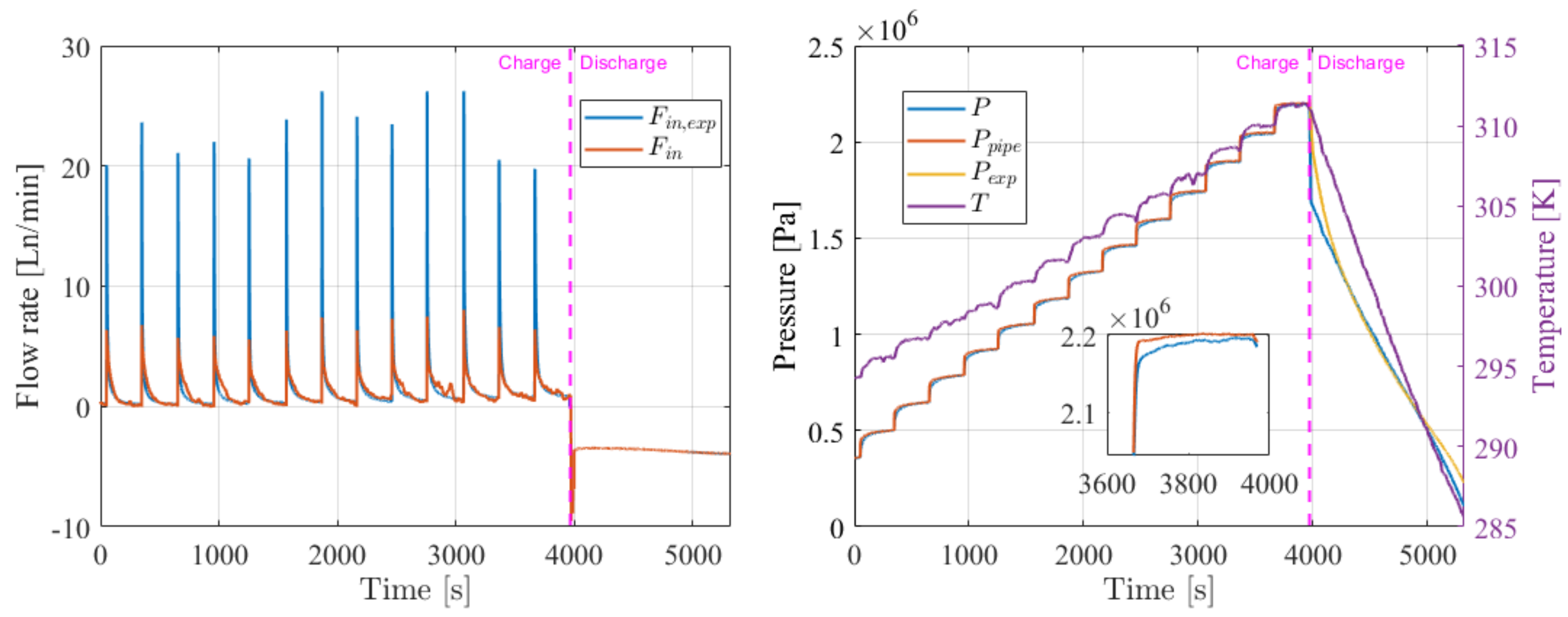


MH tank experimental setup

PSO evaluation criteria and results

$$F_{MH} = \frac{1}{N_1} \cdot \sum_{t=0}^{t=N_1 \Delta t} \left| \frac{(F_{in}(t) - F_{in,exp}(t))}{F_{in,exp}(t)} \right| + \frac{1}{N - N_1} \cdot \sum_{t=(N_1+1)\Delta t}^{t=N\Delta t} \left| \frac{(P(t) - P_{exp}(t))}{P_{exp}(t)} \right|,$$

where $F_{in,exp}$ is the experimental data of flow rate. Δt is the sampling interval, N_1 and N are the sampling times of the charge and whole experiment, respectively.



Comparison of pressure and flow rate

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Research collaborations and research stays

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Publications

[1] Chen, M., Batlle, C., Escachx, B., Costa-Castelló, R., & Na, J. (2024). ***Sensitivity analysis and calibration for a two-dimensional state-space model of metal hydride storage tanks based on experimental data***. Journal of Energy Storage, 94, 112316.