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# Tests on $LmNi_{4.91}Sn_{0.15}$ based solid state hydrogen storage device with embedded cooling tubes – Part B: Desorption process

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ABSTRACT

In this Part B manuscript, the performance tests on $LmNi_{4.91}Sn_{0.15}$ based two solid state hydrogen storage devices with 36 and 60 embedded cooling tubes (ECT) during desorption of hydrogen are presented. The results of a systematic investigation of these reactors during hydrogen desorption process at different operating conditions are discussed while the absorption characteristics are reported in part A of this manuscript. The desorption characteristics of the hydrogen storage devices are studied by varying the hot fluid temperature (30 °C–60 °C), and the heat transfer fluid flow rate (2.2 l/min–30 l/min). In the reactor with 36 ECT and 60 ECT, with oil flow rate of 3.2 l/min, at 60 °C hot fluid temperature, the hydride bed attains the initial hot fluid temperature rapidly. At the desorption condition of 50 °C desorption temperature, 30 l/min of water flow rate, the reactor with 60 ECT completes the desorption of hydrogen within 8 min.


## 1. Introduction

In the recent times, much research attention has been paid towards the development of energy efficient and carbon free energy conversion technologies for ensuring the long-term energy security. Hydrogen is one of the most promising carbon free energy sources as it is simple, non-polluting and abundant in nature etc. [1]. The use of hydrogen is gaining remarkable attention since it can be used in variety of applications. Hydrogen storage is a critical issue as it is less dense and hence, several options are being devised to store hydrogen effectively. Metal hydride (MH) based hydrogen storage system enriches the use of hydrogen energy as it offers various advantages such as high volumetric storage density, capable of storing hydrogen at ambient temperature and pressure, utilizes low grade thermal inputs for storage, etc.

Many experimental [2–11] and numerical [12–21] studies have been carried out for investigating the heat and hydrogen transfer characteristics of MH bed and also studying the performances of the system during charging/discharging processes. Previous works reported in the literatures enlightened the desorption characteristics mainly influenced by heat transfer fluid (HTF) temperatures and its fluid flow rates of metal hydride based hydrogen storage devices (MHHSD). Gopal and Murthy [2] reported the experimental interpretation of $MmNi_{4.5}Al_{0.5}$ based MHHSD during absorption and desorption processes at different HTF temperatures and highlighted the need for enhancing the effective thermal conductivity of the hydride bed. Employing $LaNi_5$, Jemni et al. [3] carried out both experimental and numerical

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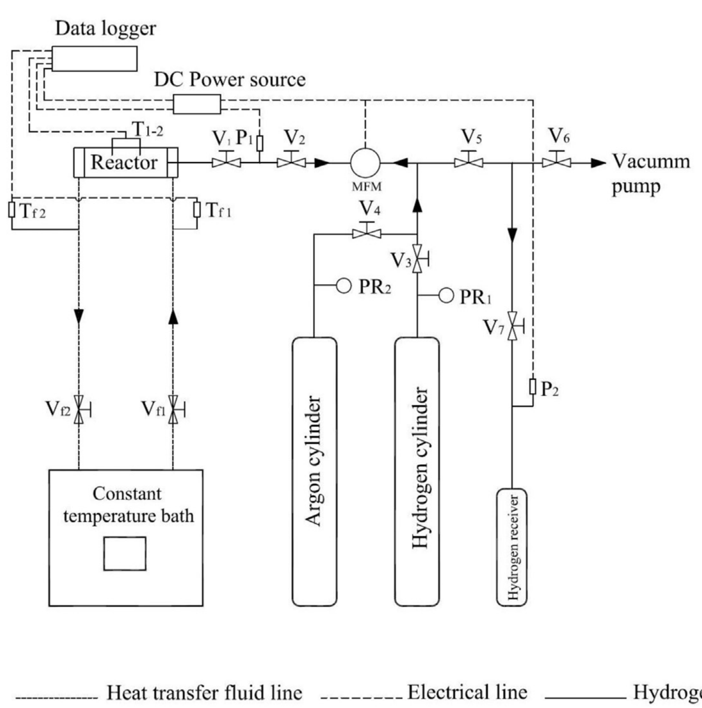
investigations to study the absorption and desorption characteristics of the hydride bed.

To enhance the rate of hydrogen desorption, different heat transfer augmentation techniques such as using different types of heat exchangers [5,6,10,17] and multi - tubular configuration [18] have been proposed by several researchers. Dhaou et al. [4–6] studied both experimental and numerical investigations of the dynamic behaviour of $LaNi_5$ based MHHSD during discharge process at different operating parameters. They also reported the temperature and pressure evaluations of the hydride bed. Later, the same research group tested the heat and hydrogen transfer characteristics of $LaNi_5$ based MHHSD with spiral finned heat exchanger during the absorption and desorption processes. Then, similar study was performed by adding copper fins in the spiral heat exchanger. Muthukumar et al. [7] studied the performance of $AB_5$ alloys viz., $MmNi_{4.6}Fe_{0.4}$ and $MmNi_{4.6}Al_{0.4}$ based MHHSD during hydriding and dehydriding processes at different operating parameters. It was observed that high desorption rate was achieved at higher hot fluid temperature.

Melnichuk et al. [8,9] tested the desorption characteristics of $MmNi_{4.7}Al_{0.3}$ based MHHSD at different HTF temperatures. Later, the same research group reported both experimental and numerical investigations of hydrogen discharge behaviour at different HTF flow rates. Visaria and Mudawar [10] reported the results of both experimental and theoretical evaluations on $Ti_{1.1}CrMn$ based MHHSD with modular – tube pin and simpler coiled – tube heat exchangers during hydrogen discharge process. It was found that the dehydriding rate was faster in modular tube pin heat exchanger which accelerated the rate of desorption by increasing the HTF temperature. Sekhar et al. [11] presented the performance tests on the lab-scale prototypes of MHHSD filled with $MmNi_{4.08}Co_{0.2}Mn_{0.62}Al_{0.1}$ and Mg + 30% $MmNi_5$ alloys during both absorption and desorption of hydrogen at various operating parameters.

Jemni and Nasrallah [12] developed a 2-D mathematical model to determine the dynamic heat and mass transfer in $LaNi_5$ based MHHSD during desorption process. Neglecting the convection term in transport equation, they observed that the increase in bed thermal conductivity lead to more desorption rate. Gambini et al. [13] examined the lumped model for predicting the charging and discharging characteristics of $MmNi_{4.6}Fe_{0.4}$ based MHHSD at different operating parameters. Mellouli et al. [14,15] developed a 2-D mathematical model to estimate the transient heat and hydrogen transfer process during desorption of hydrogen in $LaNi_5$ based MHHSD with Al foam. Later, the same authors developed three different models to estimate the performance of the MHHSD filled with $LaNi_5$ during absorption and desorption processes. The obtained numerical results were validated with their experimental data.

Chung and Ho [16] investigated the influence of expansion volume and convective heat transfer term in the energy equation on the hydriding and dehydriding characteristics of $LaNi_5$ based MHHSD. Later, the same research group extended

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| MFM | Coriolis mass flow meter | $T_{f1-f2}$ | Heat transfer fluid inlet and outlet temperature |
| $P_1$ | Pressure transducer | $V_{1-2}$ | Bellow sealed valve |
| $PR_{1-2}$ | Pressure regulators | $V_{f1-f2}$ | Ball valve |
| $T_{1-2}$ | Metal Sheathed "K" type thermocouples | | |

**Fig. 1 – Experimental test setup of the hydrogen storage device.**