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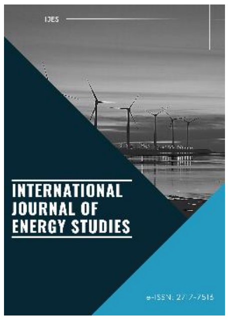

Erratum Article

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Erratum to: Effect of conventional and additive manufacturing reactors on hydrogen charging process

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In the article titled "Effect of conventional and additive manufacturing reactors on hydrogen charging process", published in Volume 10, Issue 4 of the International Journal of Energy Studies, a formatting problem occurred in the published version of the manuscript.

During the typesetting process, some bibliographic and publication information fields in the manuscript were incorrectly rendered due to formatting issues in the source document. In particular, the page number range in the article header section was displayed incorrectly as placeholder text in the published version.

The editorial office reviewed the article and corrected the header information, in accordance with the journal's template.

The scientific content of the article remains unchanged. The correction concerns only header information.

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Original article file can be found here: dergipark.org.tr/en/download/article-file/5067510

The corrected version of the article is provided below.

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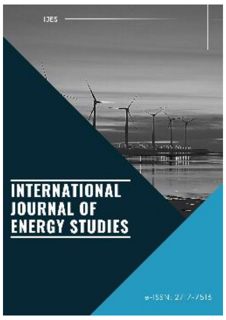

Research Article

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Effect of conventional and additive manufacturing reactors on hydrogen charging process

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Highlights

- Hydrogen charging and storage experiments utilized both conventionally manufactured and additively manufactured reactors.
- The additively manufactured reactor significantly reduced the number of charge/discharge cycles.
- Heat transfer was improved thanks to the lattice structure used.

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ABSTRACT

In this study, experimental studies were conducted in conventional 304 stainless steel plain reactors and AlSi10Mg reactors with a simple lattice geometry. $LaNi_5$ was selected as the hydrogen storage material. In experiments with a conventional stainless steel reactor, $LaNi_5$ activated after five charge-discharge cycles, while in the additively manufactured AlSi10Mg bed, the material was activated in a short time after just one charge-discharge cycle. The open-pore structure of the lattice improved fluid flow and heat transfer, increasing the overall efficiency of the metal hydride bed. As a result of the experiment, 0.64 g of hydrogen was stored in the conventional and simple lattice geometry reactors.

Keywords: Hydrogen storage, Metal hydride, Reactor types

1. INTRODUCTION

Hydrogen has tremendous potential to reduce greenhouse gas emissions and combat climate change [1-2]. Hydrogen is an odorless, tasteless, colorless, and lightest flammable gas [3]. As a clean energy carrier, hydrogen has a high energy content on a mass basis [4]. Hydrogen is relatively difficult to store due to its various properties; for example, conventional gas tanks are unsuitable. Hydrogen can only be liquefied with appropriate cooling and reacts violently with oxygen and chlorine [5]. Recently, metal hydride reactors that can store large amounts of hydrogen in small volumes and provide the ability to operate at high pressures have attracted great interest. The metal hydride storage method is quite simple. Hydrogen can be stored in tanks thanks to the chemical reaction between metal and gas. The hydrogen is chemically bonded or absorbed by the metal without needing to be compressed. Instead, the solid metal hydride acts like a sponge, absorbing and releasing the gas. If you want to recover hydrogen from the metal hydride, you need to add heat. Metal hydride storage systems offer a promising hydrogen storage option [6-9]. MacDonald et al. [10] focused on the heat transfer between the metal hydride reactor and the environment and investigated the effect of fins added to the metal hydride reactor in this direction. In addition, fins' importance in obtaining the desired amount of hydrogen is discussed with the developed one-dimensional resistance analysis and two-dimensional transient model. It was determined that the added fins had a significant effect on the hydrogen pressure in the reactor. After the numerical study, it was suggested that it is possible to remove the metal hydride material in the reactor center from the system to reduce both the system weight and cost, as it does not significantly affect the system performance. Chung et al. [11] designed metal hydride tanks in different configurations using heat tubes and investigated the improvement of heat transfer during hydrogen charging and discharging with the help of heat tubes. $LaNi_5$ was used as the metal hydride material. Chandra et al. [12] investigated and numerically modeled the charging process in a cylindrical metal hydride reactor using 5 kg $LaNi_5$. Conical copper fins and cooling tubes were installed inside the reactor. Different designs were examined, including 10, 13, and 19 fins, and 2, 4, and 6 cooling tubes, respectively. Hydrogen was fed to the reactor at 15 atm using a coaxial filter. The tapered fins significantly improved heat transfer by increasing the surface area. In the reactor with 19 fins and 6 cooling tubes, 80% hydrogen saturation was achieved in 290 seconds, while 90% hydrogen saturation was achieved in 375 seconds. The fins located in the reactor inlet region were found to be more efficient due to the lower temperature. The results indicated that the saturation time and the metal hydride mass in the reactor must be in balance. Gkanas et al. [13] investigated the simulation results of charging and discharging processes with two different hydride tanks and compared them. The results show that the pipes in the perforated metal hydride tanks, due to the ambient air used as cooling air, have virtually no effect on the absorption and desorption processes. The cooling medium not only positively affects the absorption process but also lowers the reaction temperature during desorption, allowing for greater controllability.

In the study, two reactors were produced using the traditional and additive manufacturing methods. Additive manufacturing (AM) is a method in which digital designs of 3D objects are physically produced layer by layer. This method involves adding materials to build objects in layers, increasing design freedom and facilitating the production of complex geometries [14-15]. AM is used across many different industries due to its advantages, such as prototyping, customized production, the production of complex geometries, and design freedom. It has significantly impacted areas such as automotive, aerospace, healthcare, fashion, consumer products, and education [16-17].

In this study, experimental studies were carried out in two different materials, 304 stainless steel with flat geometry and AlSi10Mg with simple lattice geometry reactors.

2. EXPERIMENTAL

$LaNi_5$ used as storage material was supplied by Shanghai Yuyi Chemical Technology Co. Ltd., China. $LaNi_5$ was subjected to a 5-hour grinding process. Grinding was carried out in a glove box under nitrogen gas in a 60 mm diameter and 80 mm height grinder. Approximately 55 g of $LaNi_5$ material was used for each reactor in the experiments. The ground material was filled into the reactors under nitrogen gas. A schematic representation of the experiments is given in Figure 1.

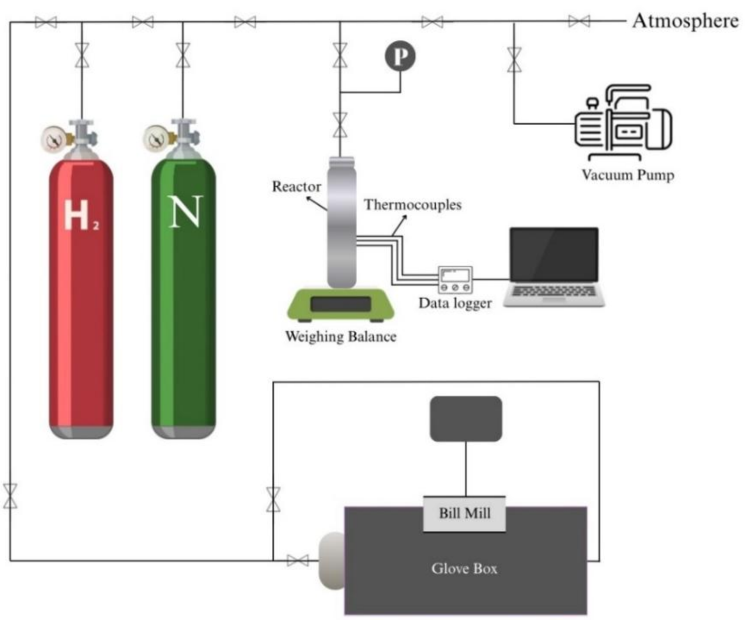
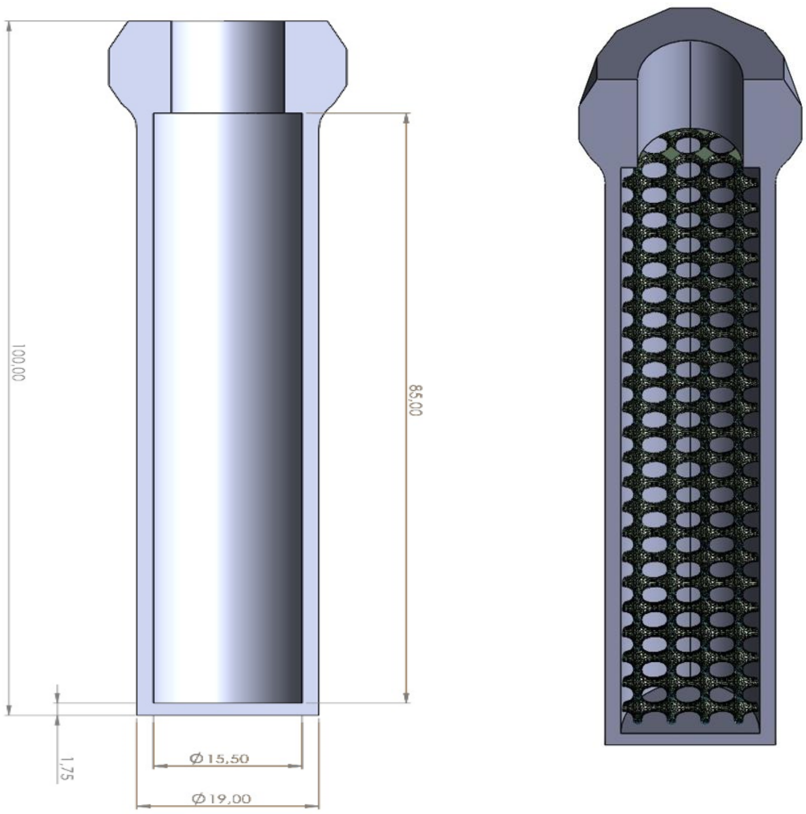


Figure 1. Experimental setup

3. RESULTS AND DISCUSSION

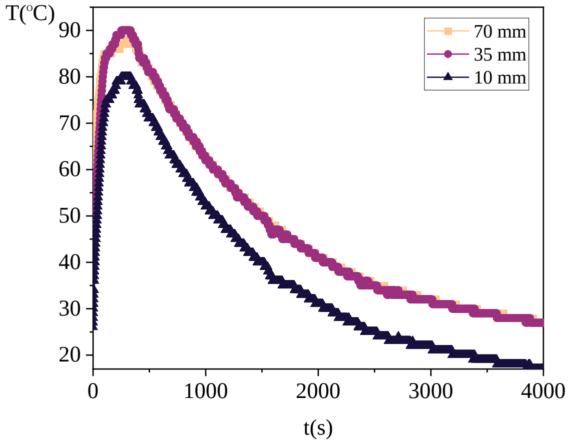
To ensure complete activation, which was performed to remove all impurities, the reactor was heated under vacuum (10^{-4} mmHg) to approximately 180 °C for 2 hours. After heating, the reactor was cooled to room temperature and charged with hydrogen at 10 bar for 60 minutes. This heating and cooling process was repeated at least five times for the stainless steel reactor, while it was reduced to one time for the lattice-structured AlSi10Mg reactor. Experiments were initiated in the activated reactors after the activation process. The temperature increases resulting from exothermic reactions following the hydrogen charge were measured for 4000 seconds using thermocouples attached to the reactors.



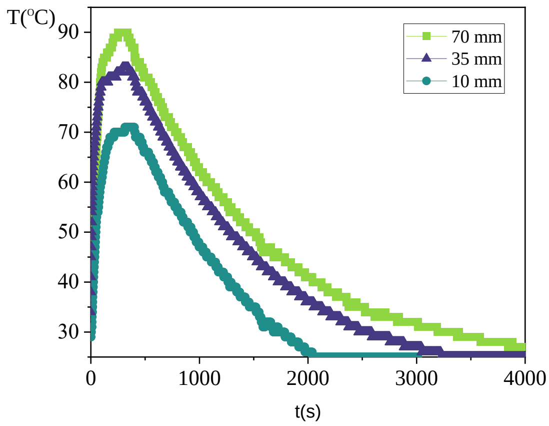
(a) (b)

Figure 2. View of reactors with simple lattice geometry made of conventional 304 stainless steel material (a) and AlSi10Mg material (b)

Two different reactor designs designed for the experimental study and manufactured from St304 and AlSi10Mg materials with a wall thickness of 1.75 mm are given in Figure 2.



(a)



(b)

Figure 3. Temperature change measured under 10 bar pressure (a) AlSi10Mg simple lattice structure reactor (b) St 304 stainless steel conventional reactor.

In the study, hydrogen was charged to the reactor for 4000 s at constant pressure and temperature. The hydriding process began immediately after the application of the charge pressure. During this process, in the conventional reactor, Figure 3(b), the temperature increases suddenly within the first 500 s, then approaches each other over time and decreases to values close to ambient temperature. In the lattice structure reactor, Figure 3(a), the temperature increases suddenly within the first 350-400 s, then approaches each other over time and decreases to values close to ambient temperature. In the reactor produced using lattice structures, the temperature distribution within the reactor is more homogeneous than in the conventional reactor. The sudden increases in temperature within the reactor are due to exothermic reactions within the reactor. Three K-type thermocouples were placed at different points (z=10, 35, 70 mm) on the reactor under 10 bar charge pressure. Temperature measurements on the reactor surface were taken starting from room temperature. The measured temperature changes over time are shown in Figure 3a-b.

The reaction is rapid in the first 500 s, and then the reaction rate slows down. At higher charge pressures, the reaction is faster, and as the charge pressure decreases, the reaction rate slows down [18].

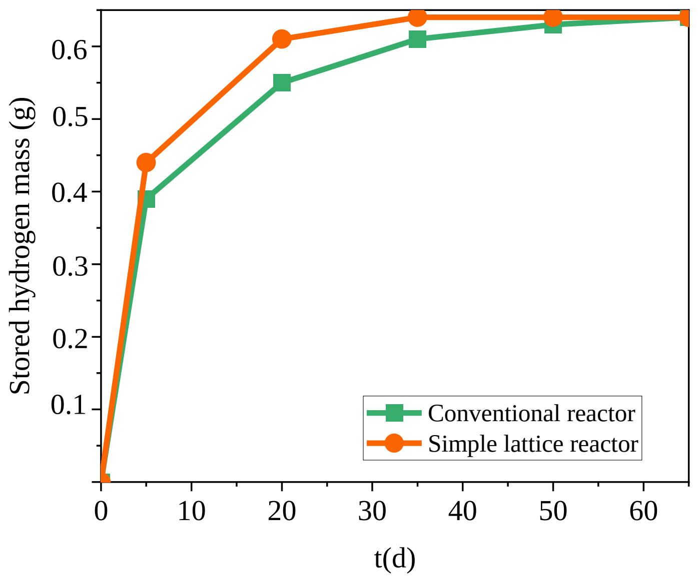


Figure 4. Superimposed graph of the change in the amount of hydrogen stored at 10 bar pressure in reactors with different geometries over time.

During the first 500 s Figure 3(b) and the first 350-400 s Figure 3(a), the reaction proceeds rapidly, and the hydrogen mass increases accordingly. After this period, the rate of mass increase slows down and remains constant after reaching maximum capacity. Mass increase occurs in parallel with temperature increase in the reactor. The amount of hydrogen stored in the reactors at a charge pressure of 10 bar was measured using a precision balance as 0.64 g. The lattice structure improves heat transfer properties. Figure 4 shows that the reactor with a lattice geometry stores hydrogen in a shorter time.

3. CONCLUSION

This study, conducted to investigate the effect of reactor design on heat transfer and hydrogen storage in metal hydride reactors using $LaNi_5$ storage material, involved fabricating reactors made of two different materials. Temperature measurements during hydrogen storage in the reactor manufactured using the conventional method revealed differences at each point. However, this situation was more homogeneous in the simple lattice reactor manufactured using the additive manufacturing method compared to the conventional reactor. Furthermore, due to the lattice structures and AlSi10Mg material used in the additive manufacturing reactor, the material was activated quickly after one charge-discharge cycle, and due to its good thermal properties, the same amount of hydrogen was stored in a shorter time. Future studies can investigate the effects of reactors manufactured using different geometries and materials on hydrogen storage and charge/discharge. Using different lattice structures with different geometries can homogenize the temperature distribution within the reactor.

NOMENCLATURE

AM	Additive manufacturing
St	Stainless steel

DECLARATION OF ETHICAL STANDARDS

The author/The authors of the paper submitted declare/declares that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHORS

Gamze Atalmis Sari: Writing – review & editing, Visualization, Resources, Methodology, Investigation.

Ruveyda Nur Kaplan: Visualization, Methodology.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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