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Dynamic study of a new design of a tanks based on metallic hydrides

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ABSTRACT

It is known that the hydrogen has a very high mass energy density, in fact, that it is a lightest gas; therefore, its storage is a great problem. The aim of the hydrogen storage technologies is thus to reduce the volume that hydrogen occupies in its thermodynamically stable state under conditions close to ambient salt. Recent work on hydrogen storage is mainly based on the use of metal hydrides. These metal hydrides have a high capacity for the hydrogen storage in the operating conditions. The effecting parameters on the performance of such a metal-hydrogen reactor are its design and configuration. In this case, there are a number of problems that need to be considered in designing a reactor. Among these parameters are the reactor configuration, the thermal and the mechanical strength, the kinetics of hydrogen storage and the security. Our study is concentrated on the problem of the thermal and the mechanical strength while focusing on the nature of the metal makes the reactor. In this work, the experimental studies of the hydrogen absorption phenomenon in different reactors, based on metal hydrides, were evaluated. The characteristics of the reaction kinetics in three different reactors using the same measurement conditions were compared. A numerical model describing the reaction kinetic of the H_2 absorption by $LaNi_5$ alloy validates the results were obtained. Of these results, it is found that the rate constant varies from one reactor to another. Moreover, the activation energy of the absorption kinetics were identified.

Introduction

Great number of research study have been launched to use hydrogen as an energy carrier for many exploit renewable energy resources and to develop fuel cell technology. That also preserve environment by reducing discharges of pollutants and the emission of greenhouse gases caused by the strong growth in demand for energy. If hydrogen were prevailed in the long term as an energy, the researchers and engineers challenge is to know how to produce, distribute, store and use it [1–5]. Hydrogen has several applications in energy area. It has undergone significant interest in order to meet the demand in terms of industrial development [6].

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Nomenclature

C_p	Specific heat, J kg^{-1} K^{-1}
E_a	Activation energy, J mol^{-1}
E_{ap}	Apparent absorption energy, J mol^{-1}
λ	Thermal conductivity, W m^{-1} K^{-1}
P	Pressure, bar
T	Temperature, K
t	time, s
R	Gas constant, J mol^{-1} K^{-1}
ρ	Density, kg m^{-3}

Subscripts

[H/M]	Hydrogen-to-metal-atomic ratio
G	Gas
E	Equilibrium
Ss	Saturated

We know that the hydrogen has a low energy capacity per volume, but it offers a good energy capacity per mass compared to others fossil fuels. The only way to make the hydrogen more efficient is to store it in high-density metals, which have small volumes and low masses. However, it is necessary to develop new designs and geometries of hydrogen storage reactors based on metal hydride, which exhibit high volumetric capacity and fast sorption kinetics. Many physical, chemical and dynamic challenge need to be considered for hydrogen storage systems. In particular, the properties of hydrogen gas and heat transfer of the hydride bed are the major problems for a high-dynamic tank operation. Hydrogen must be stored in a small, lightweight system due to the size and weight constraints in vehicles. This is particularly challenging because this gas has the lowest energy density of common fuels. Therefore, many researches are focusing on the performance of storage system such as; high thermal conductivity, favorable equilibrium pressure, high hydrogen absorption capacity, fast reaction kinetics and simple activation process [7,8].

It has been recognized for a long time that the hydrogen storage in the form of hydride has the advantage of safety and easy recovery than the other types of storage. Much larger quantities of hydrogen can be stored per unit volume than in its liquid and in its gas form. Each one of these techniques has its own advantages and disadvantages [9]. Therefore, metal and complex hydrides have attracted attention as hydrogen storage materials. Among these metals, the $LaNi_5$ intermetallic alloys are commonly chosen as the hydrogen storage medium because of their attractive characteristic features. Such as their high storage capacity, their favorable operating temperatures and pressures, their low hysteresis, their easy activation, their low density, their high volumetric density, their highest safety level compared to other metals and fast reaction rates [10,11]. These metals can be used in reversible hydrogen storage. The kinetic reaction of hydrogen sorption by the metal depends on the heat and the mass transfer within the reactor. This explicates that the hydride reactor designs are extremely important for the heat removing from reactor [12,13]. The effects of operating conditions for performance of metal hydrogen storage tanks are complicated and they need detailed investigations for further optimization [14,15]. The geometry and the design of the metal-hydrogen reactors, which have evolved over years of study, are important factors in the heat and the mass transfer in the hydride bed. Several numerical and experimental research works have been devoted to optimize the design parameters of metal-hydrogen tanks [16–41].

In parallel, the rate at which hydrogen can be absorbed and desorbed by a particular metal or alloy is an important factor for the hydrogen storage. This reaction rate depends on

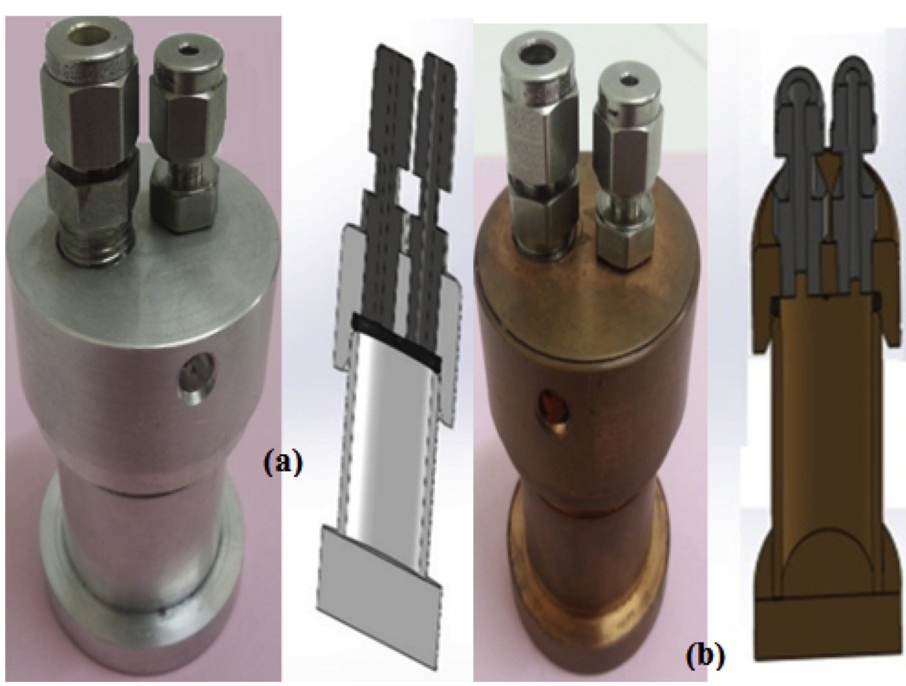

Fig. 1 – (a, b): Photograph of the reactor Aluminum and Copper.

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