Alu-to-Energy conversion: Influence of microstructure and manufacturing process

on the kinetics of aluminium-water reactions

Student

Erik Schmidt

Introduction: A lot still needs to be done to enable the seasonal storage of renewable energy. There are many ideas on how to make seasonal energy storage possible. This article focuses on energy storage with aluminum and how the process could be improved. Aluminum is suitable as a renewable metallic fuel (ReMeF) because it is abundant, non-toxic and has a high energy density. The release of energy from metallic aluminum usually occurs through the reaction of metal powders (reaction surface) with water to produce H2 and heat. To avoid the risk of a dust explosion, a reaction with metal granules with a grain size of more than 0.5 mm appeared to be desirable. Based on previous results, it was hypothesized that, depending on the alloy and manufacturing process, a grain boundary morphology develops within the granules that strongly favors the reaction kinetics of the aluminum-water reaction. This hypothesis was to be tested.

Approach: The study examined aluminum granules from three main suppliers. Krampe Harex (KH) provided Al6060 cut-wire granules. Al6060 granules (KA) and Al5056 granules were provided by Kuhmichel. Ice Tech (IT) produced gas-atomized aluminum of high purity.
In order to destroy the original microstructure and form a new one, the granules were solution annealed at a temperature of 530°C. The granules were quenched in water. The reaction took place in a 2M-NaOH solution at 65°C. The generated pressure and temperature were measured, and the amount of hydrogen produced was calculated using the ideal gas equation. The surface properties of the granules were examined using images from a Scanning Electron Microscopy (SEM).

Result: The comparison of the reaction rate between annealed and not annealed granules shows that the temperature treatment results in changes in granule reactivity due to changes in the Al microstructure. While the not annealed granules show fast reaction rates and formation of pores during reactions, the annealing results in slow reaction rates and absence of pores (Fig.1 and Fig.2). Large differences can also be observed in the reaction behaviour of the various manufactured and alloyed granulates.Comparing results obtained from same grain size produced by different manufacturers (Fig. 3), the reaction time differs by a factor of 3 comparing KN & IT and SEM images show different granule depletion mechanism. While Al6056 cut wire shows no pore formation, Al6060 cut wires show formation of small pores in direction of extrusion. Pure Al granules prepared by atomisation exhibit random large pore formation. This evidences that both the Al alloy and manufacturing process affect the microstructure, porosity and reaction rates. These parameters can thus be used for rational design of efficient and safe ReMeF.

Fig.1 Comparison before and after annealing from Krampe Harex (KH).
Own presentment

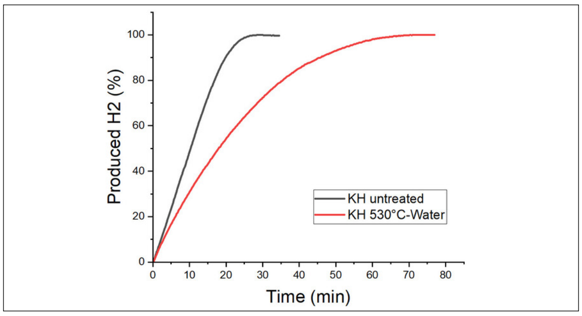


Fig.2 SEM-Images of A&D unreacted granules, B,C,E,F granules after 50% reaction time,
Own presentment

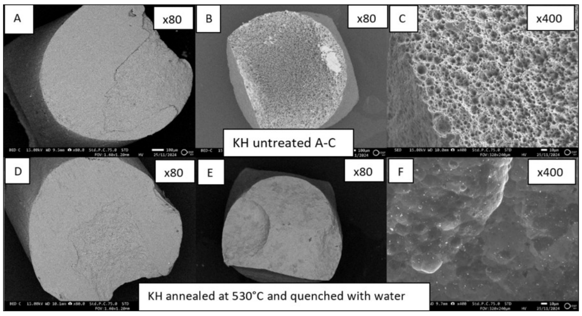
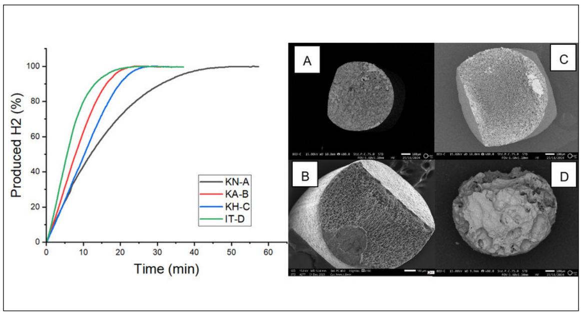


Fig.3 Comparison of granulates from different manufacturers with SEM images after 50% reaction time.
Own presentment



Advisor
Dr. Michel Haller

Co-Examiner
Dr. Miren Agote Arán, OST-UMTEC

Subject Area
General energy technology