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Possibilities of Practical Usage of Dispersed Aluminim Oxidation by Liquid Water

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Abstract—The goal of this work is to show the possibility of practical usage of the environmentally pure oxidation process of preliminarily dispersed aluminum (aluminum powders of the ASD or PAD grade according to TU (Technical Specifications) 48-5-226-87, which are serially produced in industry) with liquid water in order to obtain gaseous hydrogen in volumes sufficient to provide the operation of energizers based on air–hydrogen fuel cells (AHFC) for portable and stationary devices (up to 3 kW). It is shown that the synthesis of aluminum oxides–hydroxides with the specified phase and chemical compositions as well as the particle shape and size can be provided simultaneously with producing commercial hydrogen.

The practical usage of hydrogen, which is formed in the oxidation reaction of metallic aluminum with liquid water at pressures close to atmospheric (particularly, to service AHFCs), requires reaction intensification to increase the oxidation rate of aluminum. In this work, we considered the aspects of practical implementation of thermal, ultrasonic, and chemical activation as well as their combinations for this purpose. As the chemical activator of oxidation, we used the additives of calcium oxide (<5% of the mass of oxidized aluminum). Application of each activation method affects the phase and chemical compositions as well as the structure of formed aluminum hydroxides, which provides the possibility of their reproducible production. Thus, simultaneously with the production of commercial hydrogen, solid oxidation products satisfying the needs of industry in aluminum oxides and having the specified composition, purity, and particle shape and size can be synthesized.

The acquired experimental results and elements of the design of specially developed industrial apparatuses, which were used when performing this work, can be applied when designing the model of the hydrogen generator—the prototype of the hydrogen generator for portable and stationary devices or devices of the corresponding productivity for manufacturing commercial aluminum oxides.

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1. INTRODUCTION

The necessity to develop technologies for accumulating the energy produced by renewable sources considerably distanced from the places of its consumption and the ways of transportation of energy from such sources to the localized places of power consumers is evident. For these purposes, metallic aluminum, which is a chemically active and power-consumable metal, as well as the third most abundant element of the earth's crust, is promising [1–3]. It is assumed that metal aluminum will be produced near the arrangement of renewable power sources with the use of electrical power elaborated by these sources, transported into the regions of power consumption, and used for the production of hydrogen and/or heat energy. As the oxidant, air (oxygen), water, and the mixture of water vapors with air (oxygen) can be used.

Energy parameters and unique characteristics of aluminum attract the attention of scientists and engineers [4–8]. This is also true for the heterogeneous oxidation reaction of solid aluminum with liquid water [4–8]. As the oxidation products, gaseous hydrogen and low-soluble solid compounds ($Al(OH)_3$, AlO(OH)) are formed. Simultaneously, a considerable amount of heat energy is evolved.

$$2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2 + 16.3\ \text{MJ/kg Al}. \quad (1)$$

This reaction is considered as a promising environmentally pure source of high-purity hydrogen for the needs of hydrogen power engineering, particularly as the source of "hot" hydrogen—working body for the magnetohydrodynamic (MHD) generators of a new generation [9]. The effective usage of solid products that form simultaneously with hydrogen such as aluminum oxides–hydroxides is also possible [10–13]. The mass of solid oxidation products (aluminum oxides and/or hydroxides) that form as a result of the energy usage of aluminum can be from 200 to 300% of the initial mass. These products can also be used as the secondary raw material for the reproduction of aluminum. They can be in demand by the building materials industry. However, solid aluminum oxides can be in demand as raw materials for other high-technology