METHOD FOR FORMING ZINC VIA DECOMPOSITION OF ZINC OXIDE

FIELD OF INVENTION

The invention relates to a method for forming zinc via decomposition of zinc oxide at high temperatures. In particular, the invention relates to a method for forming zinc via decomposition of zinc oxide in a cogeneration system.

BACKGROUND TO THE INVENTION

The following discussion of the background to the invention is intended to facilitate an understanding of the present invention. However, it should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was published, known or part of the common general knowledge in any jurisdiction as at the priority date of the application.

A fuel cell is an electrochemical conversion device. It produces electricity from the reaction between a fuel on the anode side and an oxidant on the cathode side in the presence of an electrolyte. The fuel and the oxidant flow into the fuel cell and the reaction products flow out of it. Fuel cells can operate virtually continuously as long as the necessary flows are maintained.

There are different types of fuel cells, each being classified based on the reactants and/or electrolytes employed in the fuel cells. One of them is a zinc-air fuel cell (ZAFC), which has a high energy density of about 200 Wh/kg thereby enabling smaller and lighter packaging. Briefly, zinc on the anode side is immersed in an electrolyte (e.g. concentrated potassium hydroxide); water and oxygen from the air react at the cathode forming hydroxyls which migrate into the zinc paste and form zincate ($Zn(OH)_4^{2-}$), at which point electrons are released and travel to the cathode side to produce electricity. The zincate decays into zinc oxide and water is released back to the system. Water and hydroxyls from the anode are recycled at the cathode. Electricity generation decreases when zinc in the anode becomes depleted. The anode is mechanically recharged by replacing the spent

anode with fresh anode containing high content of zinc so that continual electricity generation is maintained.

Thus, ZAFC manufacturers will have to provide for recovery means to recover zinc in the spent anodes in order to produce for fresh anodes. The reduction technique commonly employed by ZAFC manufacturers to reduce zinc oxide in the spent anodes to zinc is usually electrowinning. This technique is simple and is well accepted since the spent anodes contain mainly zinc oxide and residue zinc. However, the major operating cost for the electrowinning process is the amount of electrical power required to recover zinc from zinc oxide. One kilogram of zinc is equivalent to about 1.4 kWh of electrical power and it needs about 3 times the electrical power to regenerate the zinc from the zinc oxide. In recent attempts to demonstrate the feasibility of ZAFC to power motorized vehicles, it has been technically proven and successfully demonstrated by Powerzinc Electric (Shanghai), Inc. and separately by Electric Fuel Ltd to provide electrical power to city buses. Electrowinning was used to recover zinc from zinc oxide present in the spend anodes. Although the ZAFC-powered city buses were able to cover more than 200 km with a single charge of the ZAFC, the total replenishing cost of the fresh anodes via electrowinning was not justifiable for vehicles using electric propulsion compared to those using conventional internal combustion engines.

Zinc oxide is a useful raw material for industries such as the electronics, plastics, rubber and pharmaceutical industries. Zinc oxide present in the spent anode may then be sold as scrap to such industries. However, the selling price of scrap zinc oxide is relatively low compared to the buying price of zinc powder for fresh anodes.

Due to the high costs of recovering zinc from zinc oxide via the electrowinning process and the trading price difference between scrap zinc oxide and fresh zinc powder, ZAFC manufacturers are continuously searching for a more economical alternative to replenish the spent anodes. In the SolZinc project funded by the European Union, Paul Scherrer Institute (PSI) together with the Swiss Federal Institute of Technology Zurich (ETHZ) and other research institutes, a solar reactor that utilizes solar energy to decompose zinc oxide with coke at temperatures

around 1,200 °C has been developed. In this project, the extremely high temperature level was realized by using a solar power tower and a set of heliostats to collect the solar thermal energy. The collected solar energy of about 300 kW was able to generate about 45 kg of zinc per hour with carbon monoxide as a by-product off-gas. The freely available solar energy, coupled with the commercial values of by-product oxygen or carbon monoxide if coke is used as reducing agent, makes an attractive alternative to the costly electrowinning process. Nevertheless, the decomposition process is limited to the abundance of sunshine areas, the intensity of the sunshine and the duration of the sunshine.

Therefore, it is desirable to provide for a method for forming zinc via zinc oxide decomposition that overcomes, or at least alleviates, the above problems.

SUMMARY OF THE INVENTION

Throughout this document, unless otherwise indicated to the contrary, the terms “comprising”, “consisting of”, and the like, are to be construed as non-exhaustive, or in other words, as meaning “including, but not limited to”.

In a first aspect of the present invention, there is provided a method for forming zinc via decomposition of zinc oxide in a cogeneration system, the method comprising:

- Feeding combustible fuels into a combustion chamber generating heat and force capable of performing work; and
- Simultaneously feeding zinc oxide into the combustion chamber wherein the heat generated from the combustion of the combustible fuels in the combustion chamber provides the thermal energy required for the decomposition of zinc oxide to form zinc.

BRIEF DESCRIPTION OF THE DRAWINGS

In the figures, which illustrate, by way of example only, embodiments of the present invention,

FIG. 1 shows a portion of the longitudinal section of a combustion chamber in a gas turbine.

DETAILED DESCRIPTION

The invention relates to a method for forming zinc via decomposition of zinc oxide at high temperatures.

In accordance with a first embodiment of the invention, there is provided a method for forming zinc via decomposition of zinc oxide in a cogeneration system. Combustible gases are being fed into a gas turbine to generate electrical power and heat. Zinc oxide and optionally include carbon like coke as reducing agent, is simultaneously being fed into the gas turbine wherein the heat generated from the combustion of the combustible gases in the gas turbine provides the thermal energy required for the decomposition of zinc oxide to form zinc.

Thermal dissociation or decomposition of zinc oxide requires heating temperatures of above 1,975 °C. A gas turbine is a rotary engine that extracts energy from a flow of combustible gases. It has an upstream compressor coupled to a downstream turbine, and a combustion chamber in-between. Energy is added to the gas stream in the combustion chamber, whereby air or oxygen is mixed with a fuel (e.g. hydrogen) and is ignited. The combustion increases the temperature, velocity and volume of the gas flow. This is directed through a nozzle over the turbine's blades, spinning the turbine and powering the compressor.

The exhaust gas exiting the turbine after spinning and powering the compressor is typically about 500 °C and heat from the exhaust gas is recovered by means of a steam turbine generator or for other heating purposes in a combined cycle design. The combustion of gases generally converts 30 % to 50 % of its energy to electrical energy with the remainder as heat energy. The heat generated in the combustion chamber may go up to more than 2,000 °C and may end up as wasted heat unless a cooling system is being employed in the gas turbine. By providing a means for feeding zinc oxide into the gas turbine to thereby decompose zinc oxide into zinc, the heat released by the combustion is recovered, thereby increasing the overall energy efficiency of the gas turbine.

Figure 1 shows a portion of the longitudinal section of the combustion chamber **8** in the gas turbine **10**. The combustion chamber **8** comprises an inner chamber **8A** and an outer chamber **8B**. The gas turbine **10** is insulated by means of an insulator **3** surrounding the combustion chamber **8** to contain the heat released by the combustion of combustible gases within the gas turbine **10**. Fuel and air enter the inner chamber **8A** via inlets **1**. Combustion takes place in the inner chamber **8A**. The combusted gases flow downstream and exit the inner chamber **8A** as exhaust gas at outlet **7** to drive the turbine or other loads. Inert gas enters the outer chamber **8B** via inlets **2** located at the beginning of the combustion chamber **8**. Zinc oxide and optionally, carbon source such as charcoal, enters the outer chamber **8B** via inlets **4** located further downstream away from the inert gas inlets **2**. Heat released by the combustion is transferred from the combusted gases near the wall of the inner chamber **8A** to the wall, which in turn is transferred from the wall of the inner chamber **8A** to the inert gas near the wall. This way, by the time the inert gas reaches zinc oxide fed into the outer chamber **8B** at inlets **4**, the inert gas would have reached approximately the same temperature as the wall of the inner chamber **8A** and the combusted gases. At such high temperature, zinc oxide quickly decomposes to zinc vapour and oxygen (or carbon monoxide if carbon source is also present). The inert gas helps to prevent the zinc vapour from recombining with oxygen to form zinc oxide. The zinc vapour, together with the inert gas and oxygen (or carbon monoxide), exits the outer chamber **8B** via outlet **5** where zinc vapour is collected and quenched to obtain zinc powder (not shown).

The inert gas and oxygen (or carbon monoxide) are also quenched. The heat released by the quenching may be absorbed by a heat transfer system to create water steam to power a separate steam generator and/or for use in a redox reaction with zinc to produce hydrogen gas, which may serve as a fuel for the combustion chamber.

The afore-described method provides a simple, economic and reliable method of decomposing zinc oxide to form zinc using existing gas turbine technology. The zinc oxide source may come from spent anodes in ZAFC. In a cogeneration power

plant consisting of ZAFC and gas turbines, the overall electrical power output is much increased.

For ZAFC to be widely accepted by consumers, the replenishing cost of zinc has to be low. The present method provides a way of regenerating zinc at very low cost using the waste heat from the gas fired turbine that generates electricity. The sales of electricity generated and the by-product from zinc oxide provide financial subsidy to the replenishing cost of the zinc. In addition, with the present method, it is possible to establish many replenishing centres to generate electricity for sales and regenerate zinc for stock as well as the by-products. The replenishing centre can generate revenues even without ZAFC demand yet, thus making the mass replenishing facility ready for mass market of this alternative energy.

Although the foregoing invention has been described in some detail by way of illustration and example, and with regard to one or more embodiments, for the purposes of clarity of understanding, it is readily apparent to those of ordinary skill in the art in light of the teachings of this invention that certain changes, variations and modifications may be made thereto without departing from the spirit or scope of the invention as described in the appended claims.

I CLAIM:

1. A method for forming zinc via decomposition of zinc oxide in a cogeneration system, the method comprising:

   – Feeding combustible fuels into a combustion chamber generating heat and force capable of performing work; and

   – Simultaneously feeding zinc oxide into the combustion chamber wherein the heat generated from the combustion of the combustible fuels in the combustion chamber provides the thermal energy required for the decomposition of zinc oxide to form zinc.