Abstract

In view of the growing energy demands and dwindling fossil fuels, there is a need to develop alternate energy sources. The alternate energy sources must be environment friendly and renewable. Many scientists believe that in future energy scenario, hydrogen will play a major role. However, safe and compact storage of hydrogen is one of the issues to be tackled before the so called *hydrogen economy* is put in place. In this context, the reversible metal hydrides become important as they can be used for safe, compact and efficient storage of hydrogen. The fact that these materials can be tailored to suit any requirement adds to their value. In addition to hydrogen storage, metal hydrides also find applications in a wide variety of energy systems starting with water pumping to rechargeable batteries.

However, it is well known that poor heat and mass transfer aspects of metal hydride beds is one of the major drawbacks of all metal hydride based energy conversion devices. Design of efficient hydride based systems calls for detailed energetic and exergetic analysis of these systems. However, there is a lack of literature in this area.

Hence, in the present thesis, accurate mathematical models are formulated to study the heat and mass transfer and entropy generation aspects of metal hydride reactors. These models are then used to study the performance aspects of: a) A low temperature metal hydride based hydrogen storage system, b) A high temperature metal hydride based hydrogen storage system for large capacity storage, and c) Small and large systems suitable for storage of bio hydrogen. Using the analysis it is shown how one can minimize the heating and cooling requirements by minimizing entropy generation. For example, it is seen that the heating fluid temperature can be reduced by as much as 100 K by suitable design changes through the application of entropy generation minimization. Using the mathematical models, large scale reactors which have charging times less than 5 minutes are designed and analyzed. It is expected that these models and the results obtained will be useful in the optimal design and operation of hydrogen storage systems suitable for a variety of applications.

Literature shows that use of metal hydrides for pumping water using low grade thermal energy sources such as solar or waste heat is a promising application that requires a detailed analysis. Hence in this thesis different models of metal hydride based water pumps are proposed and analyzed to suit a variety of applications. Thermodynamic analyses of metal hydride based water pumps shows that water up to 100 m heads can be lifted with a double stage pump using a heat source temperature of about 70^{o}C with an overall efficiency of 4.1%, and for the same head a single stage water pump requires a heat source temperature of about 110^{o}C with an overall efficiency of 7.8%. A detailed heat transfer analyses of a simple single acting metal hydride based water pump shows that it is possible to achieve an overall thermal efficiency that is higher than other types of thermal energy driven water pumps. To evaluate the economic viability of these systems, a methodology is developed considering various factors such as future price escalation of conventional fuels (diesel), financial incentives, subsidies, design improvements etc. From the techno economic analysis it is seen that, without any subsidies and incentives, a double acting, biomass based water pump can be economically attractive and can compete with the conventional diesel engine driven pumps if the number of cycles could be increased by improving the heat and mass transfer aspects of the hydride reactor. With improvements, hydride based pumps are shown to compete favourably with solar photo voltaic water pumps.

It is expected that the comprehensive thermodynamic, heat and mass transfer and economic analyses of the metal hydride based systems presented in this thesis will be useful in the design and development of these systems in the near future.