Reliability Modeling of Microballoon Hydrogen Storage in Transportation Systems

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Hydrogen is presumably the transportation fuel of the future for insuring energy security and affordability while averting the emissions of greenhouse gases and the resultant adverse environmental effects. High efficiency and versatility of use are argued to be the two main advantages that make hydrogen more attractive than other fuels. Implementation of the "hydrogen economy" (hydrogen as the fuel for transportation and other applications) is dependent upon developing solutions to overcome the technological and economic barriers to hydrogen production, storage, transmission and utilization technologies. Storage of hydrogen in quartz, glass or polymer microballoons can attain gravimetric densities as high as 0.5 while requiring significantly lower energy expenditures for filling and extraction than practically all other modes of storage. The on-board microballoon based hydrogen storage system will involve one or more canisters filled with microballoons from which hydrogen will be released by heating.

The reliability of this system is dependent upon maintaining the integrity of the microballoons. Reliability is the key of any mission critical, real-time systems. Faults, errors, and failures, whether benign or malicious will result in degradation of some or all functionalities. However, when it comes to critical infrastructure systems such as the one considered in this paper, it is of outmost importance for the system to be designed so that those deteriorations will be gradual. This way, damage to human lives and greater material damage can be either prevented, or at least minimized, so the catastrophic consequences will be avoided.

There are several important steps in designing a reliable, gracefully degrading system. Those include system requirement specifications, choice of appropriate subsystems with respect to reliability, estimation of whole system reliability, and optimization with respect to cost/benefit criteria. For already existing systems, first step would be estimation of whole system reliability, followed by decomposition of that system.

In this paper, several modeling techniques will be investigated, starting from Markov models and Petri nets. Experimental results will include a design of storage and transportation infrastructure and estimation of parameters of such system. For the purpose of this paper, authors will concentrate on several typical transportation subsystems that can be used as building blocks of an infrastructure system of general nature.

Directions for improvement and optimization of reliability of existing system will be given. Finally, future directions for modification of system with respect to cost/benefit analysis will be given.