Corrosion effect of phase change materials in solar thermal energy storage application


ABSTRACT

The thermal energy storage (TES) system using phase change materials (PCMs) has been studied since past three decades. PCMs are widely used in heat storage applications due to their high storage density, as well as the wide range of melting and solidifying temperatures. Nevertheless, the main disadvantage of PCMs, especially salt hydrates, is their corrosive behavior with container materials. PCMs are normally encapsulated in containers, hence the compatibility of the container materials with PCM plays an important role. As such, this paper summaries the investigations made on the corrosion behavior of PCM in various applications, besides suggesting ways to reduce (or rectify) the effect for long term successful energy storage. Moreover, PCM-storage material interaction in the latent heat TES system is important as the issue of corrosion affects the life of the container, as well as the performance of TES. The compatibility of the most commonly used PCMs with several major container materials was reviewed and it was revealed that stainless steel has emerged as the most compatible storage container material among others. On the other hand, aluminum was found to be corrosive when it is used with salt hydrates. Nonetheless, some contradictory articles are reported that several salt hydrates demonstrated compatibility with container materials. Corrosion causes thinning of cross sectional area of materials, making it brittle thus leading to an easy collapse. This situation is even more critical mainly in large scale concentrating solar thermal power plants. Hence, with the fact that there are currently large scale power plants employing TES under operation and under construction; issues pertaining to PCM-storage material compatibility should be properly and accurately addressed. Therefore, more research work is recommended in the area of finding new eutectics and less corrosive container material(s).

1. Introduction

Energy is becoming more and more important at this present age for survival of mankind, making energy a basic need [1–3]. Since the time wheel rolled from the Stone Age, humans needed more energy to overcome their survival problems, such as cooking, heating, lighting, hunting, transportation, and so on. With evolution, fellow humans began using other forms of energies like wind and water [4,5]. Obviously, the primitive humans either directly or indirectly, used only renewable energy sources. After the industrial revolution (1700 AD), people began making use of fossil fuels (coal, natural gas, and petroleum) to satisfy their energy needs in domestic, agriculture, and transportation fields. In fact, the two broad categories of available energy resources are non-renewable energy sources (fossil fuels) and renewable energy sources (nuclear fission and fusion, hydro power, wind power, solar energy, biogas, tidal, geothermal energy, and ocean thermal energy) [2,5–7]. Non-renewable energy sources approximately satisfy 81% of energy requirement of the world, while renewable energy sources contribute only 19% [8–10]. Thus, it is obvious that non-renewable energy sources are further depleting at an alarming rate and such usages badly pollute the atmosphere by emitting CO2 and NO2, leading to greenhouse effect. So, the world is in dire need of finding alternate sources of energy for further use and to slow down the depletion rate of fossil fuels.

As portrayed in Table 1, there is vast potential for utilization of renewable energy as the current total utilization at 19% can further increase. This notion can definitely decrease the percentage of non-renewable energy utilization, and thereby, diminishing their associated challenges. Solar energy is a type of vast, clean, and renewable energy source. Besides, estimated to be 1.8×1011 MW, it is many thousand times larger compared to the total energy consumption on earth from all other energy sources. This estimation confirms that solar energy...