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$KNO_3/NaNO_3$ – Graphite materials for thermal energy storage at high temperature: Part II. – Phase transition properties

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A B S T R A C T

Composites graphite/salt for thermal energy storage at high temperature (~200 °C) have been developed and tested. As at low temperature in the past, graphite has been used to enhance the thermal conductivity of the eutectic system $KNO_3/NaNO_3$. A new elaboration method has been proposed as an alternative to graphite-foams infiltration. It consists of compression at room temperature of a physical mixing of expanded natural graphite particles and salt powder. Two different compression routes have been investigated: uni-axial compression and isostatic compression. The first part of the paper shows that both uni-axial and isostatic cold-compression are simple and equally efficient techniques for improving the salt thermal conductivity. The second part of the paper is focused on the analysis of their phase transition properties. It is shown that graphite does not degrade the salt within the composites; that is, no changes are observed neither in the salts transition temperatures nor in its latent heat. On the contrary, some negative effects as pores over pressurization and salt leakage can appear if no void space enough is available within the composite for salt volume expansion when melting. Such negative effects are only observed in the composites obtained by isostatic cold-compression.

1. Introduction

This paper addresses the development and the analysis of new low cost materials with improved thermophysical properties for thermal energy storage at high temperature (~200 °C). Important applications using steam as working fluid can be found at temperature close to 200 °C in the industry (food, textile, manufacturing, etc.) [1–4] and in solar power generation sector [5,6]. Efficient storage systems for such applications usually demand transfer of energy during the charging/discharging process at constant temperature. This is the reason why our attention has been focused on phase change materials (PCM) as storage media. Taking into account cost constraints, salts have been preferred to metals. However, salts are characterized by low thermal conductivities (~1 W/m/K) that reduce heat exchanges rates during melting/crystallization. Thus, graphite has been used to enhance their thermal conductivity.

The eutectic system $KNO_3/NaNO_3$ ($NaNO_3$ 50 mol%) has been selected as PCM. It has been successfully used in the past for high temperature energy storage purposes, mainly in applications concerning electricity generation by solar concentration technologies [7]. The melting temperature and the latent heat of this eutectic system are 223 °C and 106 J/g respectively. Moreover, $KNO_3/NaNO_3$ has other desirable characteristics such as negligible undercooling, chemical stability, no phase segregation, low corrosion and hygroscopicity, as well as commercial availability at low cost.

As said before, graphite has been used to enhance the thermal conductivity of the $KNO_3/NaNO_3$ binary system. It is well-known that graphite has strong resistance to corrosion and chemical attack, which make it compatible with most PCM. Moreover, thermal conductivity of graphite particles is considerably high and their density is lower than the metals one. As shown in ref. [8], using graphite additives (dispersion of graphite particles in molten salt) leads to insignificant thermal conductivity improvement in the overall application. From another hand, graphite-foams infiltration with molten salt leads to highly conductive materials but with very low energy density because low saturation degree of salt is achieved [6]. Hence, a new elaboration method has been proposed as an alternative to foams infiltration. It consists of cold-compression (at room temperature) of a physical mixing of expanded natural graphite particles and salt powder. Two different compression routes have been investigated: uni-axial compression and isostatic compression. The first part of the paper [9] has been devoted to the detailed description of the resulting composites as well as to the analysis of their thermal properties. It has been shown that both uni-axial and isostatic cold-compression are

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