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$KNO_3/NaNO_3$ – Graphite materials for thermal energy storage at high temperature: Part I. – Elaboration methods and thermal properties

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ABSTRACT

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 cold-compression 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 has been devoted to the analysis of the thermal properties of these new graphite/salt composites. It is proven that cold-compression is a simple and efficient technique for improving the salt thermal conductivity. For instance, graphite amounts between 15 and 20%wt lead to apparent thermal conductivities close to 20 W/m/K (20 times greater than the thermal conductivity of the salt). Furthermore, some advantages in terms of cost and safety are expected because materials elaboration is carried out at room temperature. The second part of the paper is focused on the analyses of the phase transition properties of these graphite/salt composites materials.

1. Introduction

Thermal energy storage at high temperature (>120 °C) is an efficient way for energy saving in industrial processes. A survey carried out in the U.S.A into the use of thermal energy storage as a means of recovering waste heat has indicated an energy saving potential of 10^8 GJ/year for five main industrial sectors. Similar saving has been recently identified within the UK industry [1]. Temperatures above 500/600 °C and the temperature range of 100–300 °C have been recognized as the main areas of interest. Dominating heat transfer fluids are flue gas and air, in the first case (500/600 °C), and steam at low or intermediate pressures in the second one (100–300 °C). High temperature energy storage is also a key element for electricity generation based on new conversion techniques and renewable energy resources [2]. For solar thermal power plants, the integration of thermal energy storage avoids interconnection and grid stability problems by stabilizing solar power generation within the fence of the plant. For stand alone solar thermal plants, energy storage allows maximization of the capacity factor and assures availability. In both cases, the most important benefits result from reduction of the internal costs due to the increased efficiency and extended utilization of the power block.

In spite of the interest, no or very few examples of commercial high temperature thermal energy storage are realized. Main reasons are the still too high investment cost of the existing technologies which lead to non economic systems. In order to achieve the required reduction cost the realization of long-term stable, low cost materials with improved thermo physical properties are required. In the same way, high efficient and economic heat exchangers configurations, as well as optimized integration and operation strategies, are essential.

This paper addresses to low cost materials with improved thermo physical properties for energy storage about 200 °C. Important applications using steam as working fluid can be found at this temperature in the industry (food, textile, manufacturing, etc.) and in solar power generation sector (cf. [3]). 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

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