Institute for Sustainable Energy, University of Malta

SUSTAINABLE ENERGY 2016:
THE ISE ANNUAL CONFERENCE

Tuesday 4th October 2016, The Auditorium, University of Malta, Valletta Campus, Malta

ISBN 978-99957-853-1-4a

ANALYSIS OF A COLD STORE WITH PHASE CHANGE MATERIAL

Gülenay Alevay Kılıç[1], Enver Yalçın[1], Ahmet Alper Aydın[2]*

[1]Department of Mechanical Engineering, Engineering Faculty, Balıkesir University, Balıkesir-TR

[2]Department of Chemical Engineering, Faculty of Chemical and Metallurgical Engineering, Istanbul Technical University, İstanbul-TR

Tel: (+90) 2122853362

Corresponding Author E-mail: aydinal@itu.edu.tr

ABSTRACT: Thermal energy storage systems provide the potential to attain energy savings and reduce the environmental impact related to energy use. In this respect, phase change materials (PCMs) work as ‘‘latent heat storage units’’ which store or release large amounts of thermal energy. The aim of the presented study is to investigate the function of PCM on on/off periods of the compressor and the required time to reach operation temperature from start. The indoor temperature, relative humidity, air flow speed, PCM temperature in the macrocapsules and ambient temperature are recorded. are the continuously monitored parameters in this research. The results indicate that PCM load covering 71% of the total heat transfer surface area provides significant decrease in on/off periods of the compressor. Although the time required to reach operating temperature is longer in the starup, the energy consumption of the store is lower as a result of 20.73% shorter compressor on time during continous operation.

Keywords: Phase Change Material, Thermal Energy Storage, Cold Store, Energy Efficiency

1 INTRODUCTION

In the refrigeration and heating systems, the latent heat storage is frequently used due to its high energy saving potential and high system efficiency. Latent heat storage systems have attracted the interest of many researchers as a result of its smaller volume per unit of stored energy and its narrow temperature range for heat transfer via phase change, latent heat storage systems have attracted the interest of many researchers. Today, latent heat storage is utilized in cold storage as part of thermal energy storage applications. In these applications, phase change materials (PCMs) play an important role to enhance thermal maintenance with high energy storage capacity per unit mass and volume [1-7].

2 MATERIALS AND METHOD

In this study, an industrial cold store operating at -18^{o}C with dimensions of 212x113x218 cm in length, width and height is used. The conducted experiments include cases with and without PCM load in the store. The required time to reach operation temperature from start and compressor on/off periods are observed and compared in each case. In the first case, the cold store is cooled down to -18oC from 25oC without PCM on the side walls and the compressor on/off periods are monitored for 36 h. In the second case, 71% of the total heat transfer area of the cold store walls is covered with PCM in high-density polyethylene macrocapsules and the experiment runs are repeated. The thermophysical properties of the PCM are given in Table 1.

Table 1. Thermophysical properties of the PCM used in the study

Melting onset and peak temperatures, °C	-14.7/-10.7
Viscosity, kg/m.s (25^{o}C)	0.0055
Density, g/cm^3 (25^{o}C)	1.04
Latent heat, kJ/kg	274.3

The industrial PCM used in this study is a commercial eutectic mixture and it has melting and freezing temperatures of -7.9^{o}C and -14.7^{o}C, respectively. The indoor temperature, relative humidity, air flow speed, PCM temperature in the macrocapsules and ambient temperature are recorded with 10-second intervals by the sensors mounted in the cold store. The differential temperature range of the compressor is -18^{o}C/-15^{o}C and mechanical refrigeration system is not defrosted. The cold store cabin is shown in Fig. 1.

Figure 1: The cold store cabin: (a) inner view, (b) position of the sensors and (c) outer view

3 RESULTS AND DISCUSSION

With respect to the time required to reach -18^{o}C from 25^{o}C, the cold store containing PCM macrocapsules requires 6.62 times longer time than the case without PCM load. It can be stated that the PCM causes an auxiliary thermal load to the mechanical refrigeration system in the startup. However, advantageous changes are observed for on/off periods of the compressor in the presence of PCM.

Stable compressor on/off periods of 36 h are recorded in the absence of PCM during the operation time of the cold store. However, significant improvements are delivered with mounted PCM macrocapsules. Therefore, latent heat storage effect of the PCM is monitored in detail for each run.

In the beginning, the PCM temperature is initially recorded as -11.80^{o}C after temperature equilibrium is reached in the store and it changes between -14.60^{o}C and -14.80^{o}C after 18h. Besides, the mean compressor on time is 9.24 min for the first 6h of the run and decreases to 4.70 min after 18h. The decrease in compressor on time is ensured by the thermal maintenance in the cold store provided by the latent heat effect of the PCM. The compressor on time of the cold store with PCM is 20.73% shorter than the case without PCM. In this way, the store consumes less electricity for 2h per day and the PCM provides also energy efficiency in addition to thermal maintenance.

4 CONCLUSION

In practice, industrial cold stores operate continually if there is no operational failure, electricity shortage or required mechanical maintenance. Therefore, the additional time and energy required to reach operation temperature are negligible compared to the later energy savings with less compressor on time in the presence of PCM.

The results of this research are in good agreement with the data of Marquez et al. [8]. However, a compressor with higher capacity is not actually needed to decrease the time required to reach set temperatures as suggested by Marquez et al. [8], which would also increase the investment costs. The important point is to choose PCM with appropriate phase change temperature interval with respect to the operation temperature of the cold store.

5 REFERENCFES

[1] Abhat, A. Solar Energy. Vol 30, (1983) 313-332.

[2] Zalba, B, Marin, J M, Cabeza L F, et al. Applied Thermal Engineering. Vol 23, (2003) 251–283.

[3] Farid, M, Khudhair, A M, Razack, S A K, et al. Energy Conversion and Management, Vol 45, pp (2004) 1597–1615.

[4] Dutil, Y, Rousse, D R, Salah, N B, et al. Renewable and Sustainable Energy Reviews. Vol. 15 (1), (2011) 112-130.

[5] Marques, C, Davies, G, Maidment, G, et al. The Institute of Refrigeration at London Chamber of Commerce and Industry. London, EC4R 1AP (2013).

[6] Aydın, A.A. Solar Energy Materials and Solar Cells Vol. 113, (2013) 44-51.

[7] Aydın, A.A., Aydın, A. Solar Energy Materials and Solar Cells Vol. 96, (2012) 93-100.

[8] Marques, C, Davies, G, Maidment, G, et al. Application of phase change materials to domestic refrigerators. In: Proceedings of IIR 9th International Conference on Phase-Change Materials and Slurries for Refrigeration and Air Conditioning, Sofia, Bulgaria (2010).