Journal of Thermal Analysis and Calorimetry (2022) 147:5117–5132
https://doi.org/10.1007/s10973-021-10863-7

Experimental performance of a mobile air conditioning unit with small thermal energy storage for idle stop/start vehicles

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Received: 24 October 2020 / Accepted: 21 April 2021 / Published online: 20 June 2021

Abstract

In this study, an attempt was made to extend the comfort of a passenger car cabin during the compressor off cycle using thermal energy storage (TES) in an HFO-1234yf mobile air conditioning (MAC) unit for idle stop/start vehicles. Fatty acid (OM08), as a phase change material (PCM), with 0.1–0.5 vol% of graphene nanoplatelets (GnPs) was used in this study. It was found that the inclusion of GnPs increases the thermal conductivity and dynamic viscosity of the liquid PCM nanocomposites by ~46% and ~53%, respectively, with 0.5 vol% of GnPs. During the pull-down cycle, the enhanced thermal conductivity outweighs the increased dynamic viscosity, resulting in a quicker decrease in PCM temperature. The test results revealed that the cabin temperature increases through the addition of TES, with a marginal decrease in the coefficient of performance. The addition of TES with the use of pure PCM increases the compressor power consumption of the MAC system by less than 1%. However, with the inclusion of graphene the power consumption increases with respect to the volume fraction. Without TES, the cabin comfort is extended by 78 s, 60 s, and 43 s for heating loads of 500, 1000, and 1500 W, respectively, and with the inclusion of TES, using pure PCM, the cabin comfort increased by up to 106 s, 87 s, and 63 s, respectively. The inclusion of 0.5 vol% GnPs extends the cabin comfort further by up to 189 s, 147 s, and 105 s for heating loads of 500, 1000, and 1500 W, respectively. Further, the CO_2 equivalent emissions of the MAC system with TES using a pure PCM and a PCM nanocomposite are 10.54% and 5.64% lower than that of the system without TES, respectively.

Keywords Mobile air conditioning system · Thermal energy storage · Graphene nanoplatelets · COP · Total equivalent warming impact

Abbreviations

GHG	Greenhouse gas
GnP	Graphene nanoplatelets
GWP	Global warming potential
HFO	Hydrofluoroolefin
HVAC	Heating, ventilation, and air conditioning
IRD	Integrated receiver dryer
MAC	Mobile air conditioning
NEPCM	Nano-enhanced phase change material
RPM	Revolution per minute
RPS	Regulated power supply
SEM	Scanning electron microscope
SLHX	Suction line heat exchanger
TES	Thermal energy storage
TEWI	Total equivalent warming impact
TXV	Thermostatic expansion valve
VFD	Variable frequency drive

Symbols

COP	Coefficient of performance
cp	Specific heat of the air (kJ kg^{-1} K^{-1})
DBT	Dry bulb temperature (°C)
h	Enthalpy (kJ kg^{-1})
h	Mass flow rate (kg s^{-1})
N	Lifetime of the system
L	Average refrigerant leakage (%)

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