Energy Conversion and Management 236 (2021) 114083

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

# Performance analysis of an electric vehicle heat pump system with a desiccant dehumidifier

Sun-Ik Na, Yoong Chung, Min Soo Kim *

*Department of Mechanical Engineering, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 08826, Republic of Korea*

ARTICLE INFO

*Keywords:*
Desiccant coated heat exchanger (DCHE)
Dehumidification
Heat pump
Electric vehicle (EV)
Thermal management system (TMS)

ABSTRACT

A battery-electric-vehicle (BEV) relies on the state of charge (SoC) of the built-in battery system because it exclusively uses electric energy stored in rechargeable battery packs. The EV's mileage would be reduced due to the electricity consumption when the mobile heat pump system (MHP) is operated. In the case of the the winter season, the heat pump system operates not only for heating the cabin to achieve thermal comfort but also for defogging to maintain driving safety. To ensure the EV's driving range, the energy consumption of MHP should be minimized as much as possible by recovering waste heat and applying a dehumidifier. For these purposes, the desiccant coated heat exchanger (DCHE) is introduced into the system, which is able to simultaneously transfer heat and mass (water vapor). In this study, the MHP and cabin thermal load models were made, and the DCHE model was validated by experiments using the unit DCHE. Based on the models, the energy consumption of the EV MHP with the DCHE was conducted, and compared to the conventional system, the proposed system required less energy.

## 1. Introduction

In order to restrain global warming, many countries have enacted strict environmental regulations for conventional internal combustion vehicles that emit greenhouse gases. Moreover, more than 14 countries have decided that they will ban the sale of petrol and diesel cars by the 2040s. In these circumstances, automobile manufacturers are presenting their visions of phasing out internal combustion engines (ICE) to avoid regulation and protect the environment. Instead, electric vehicles (EV) manufacturing capacity is being expanded, and sales have been increasing rapidly in global markets [1,2]. The battery-electric-vehicle (BEV), the main portion of EVs, operates strongly depending on the state of charge in the installed battery packs. The stored energy must be consumed not only for driving but also for operating equipment to handle the heating and cooling loads. In particular, when an automotive heat pump system (MHP) consumes a lot of energy to deal with the heating loads in winter seasons, this causes a drastic decrease in the driving distance of the electric vehicle [3,4]. This is one of the barriers to purchasing an EV instead of a conventional internal combustion vehicle, due to anxiety [5]. To solve the problem, installing more battery packs in the EV seems to be an inappropriate solution. Because it would cause price rise and vehicle weight increase, which leads to a reduction in the range and efficiency. Therefore, it is necessary to reduce energy consumption for not only air heating but also defogging.

In a traditional system, the outdoor heat exchanger (ODHX) plays the role of an evaporator during heating mode as shown in Fig. 1(a). When the windshield temperature is lower than the dew point, tiny droplets will be formed on the glass surface of the windshield. The condensed droplets might be disturbed the visibility of a driver by scattering the light rays. For driving safety, a dehumidification process should operate to defogging. A traditional method for removing moisture in the air, especially in a vehicle, is to make air temperature drop below the dew point. Thereby, water vapor in the air will be condensed at the indoor evaporator (IDEVA), as shown in Fig. 1(b). But the dehumidified air needs heating again to supply the cabin since the air temperature is too low to directly interface with the skin of passengers; thereby inevitably a lot of energy is required to dehumidification using the condensing method, as shown in Fig. 2. In contrast with the condensing method, dehumidification using a solid desiccant has merit because it almost follows the isenthalpic line without unnecessary cooling and heating processes when uptaking water vapor [6,7].

In the automotive heat pump system (MHP), the compressor is the most energy-consuming device. A compressor tends to require less energy by decreasing the pressure ratio as the evaporating temperature rises. It is able to increase by utilized an additional heat exchanger to

* Corresponding author.
*E-mail address:* minskim@snu.ac.kr (M.S. Kim).

https://doi.org/10.1016/j.enconman.2021.114083
Received 30 December 2020; Accepted 18 March 2021
Available online 1 April 2021