CHARACTERISTICS OF THERMAL MANAGEMENT AND COOLING SYSTEMS IN ELECTRIC AND VEHICLES

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Introduction

Nowadays, global environmental challenges and the need for efficient use of energy resources require the introduction of advanced technologies in the automotive industry. For this reason, electric vehicles (EVs) are rapidly developing as an alternative to conventional internal combustion engine (ICE) vehicles. EVs are distinguished by their lower environmental impact, higher energy efficiency, and the integration of modern, innovative technologies.

However, the efficient operation of these vehicles largely depends on their thermal management system. In particular, maintaining optimal temperatures for batteries and electronic components is crucial for ensuring their performance, safety, and long service life. The aim of this work is to study the thermal management system in electric vehicles and compare it with that of internal combustion engine vehicles.

Cooling System in Internal Combustion Engines In internal combustion engine vehicles, thermal energy is generated as a result of fuel combustion. This process produces extremely high temperatures, and if not properly controlled, it can lead to engine failure. The main components of the cooling system include the radiator, thermostat, water pump, and cooling fan. This system removes heat from the engine using a coolant (antifreeze). The operating principle is based on the circulation of heated coolant from the engine to the radiator, where it is cooled before being recirculated back into the engine. However, this system can lead to energy losses and, in some cases, there is still a risk of engine overheating. Thermal Management in Electric Vehicles Unlike internal combustion engines, electric vehicles do not involve a combustion process, but heat generation still occurs. The primary sources of heat in EVs are the battery, electric motor, and inverter. The optimal operating temperature for electric vehicles is typically within the range of 20–40°C. An increase in temperature reduces battery efficiency, shortens its lifespan, and negatively affects safety. Therefore, thermal management systems in EVs perform not only cooling but also heating functions. These systems are automatically controlled through advanced sensors and electronic control units, ensuring precise temperature regulation under various operating conditions.

Battery Cooling Systems the battery is the most critical and sensitive component of an electric vehicle. Overheating can reduce its capacity and may lead to a dangerous condition known as *thermal runaway*. If this process becomes uncontrolled, it can result in fire or even explosion.

There are several methods of battery cooling. Air cooling is simple and cost-effective, but its efficiency is relatively low. Liquid cooling is the most widely

used and effective method, as it quickly dissipates heat. Phase-change cooling absorbs heat through evaporation, providing high efficiency, but it is more complex and expensive to implement. In modern electric vehicles, liquid-based cooling systems are predominantly used due to their high efficiency and reliability.

Table 1. Comparison of Thermal Management Systems in ICE and EV Vehicles

Feature	Internal Combustion Engine (ICE)	Electric Vehicle (EV)
Heat Source	Combustion process	Battery and electronics
Temperature Range	High (90–120°C)	Low (20–40°C)
System Function	Prevent overheating	Maintain optimal temperature
Complexity	Relatively simple	Complex and intelligent
Safety Requirement	Moderate	High

Modern Technologies today, thermal management systems in electric vehicles are rapidly advancing. Intelligent control systems monitor temperature in real time using sensors and automatically adjust cooling or heating processes. For example, in Tesla electric vehicles, advanced liquid cooling systems and battery thermal management technologies are implemented to achieve maximum performance and efficiency. In the future, systems based on artificial intelligence are expected to further improve thermal management by optimizing temperature control, reducing energy consumption, and enhancing overall system reliability.

In conclusion, the thermal management system in electric vehicles is more complex and critical compared to that of conventional vehicles. Maintaining optimal battery temperature directly affects the efficiency, safety, and lifespan of the vehicle. Therefore, the development of advanced cooling technologies is considered one of the key directions in the evolution of the electric vehicle industry. In the future, these systems will continue to improve, contributing to the creation of more efficient, reliable, and safer transportation solutions.

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