



IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

“A COMPREHENSIVE REVIEW OF ADVANCED DUAL-STAGE TEMPERATURE REGULATION SYSTEMS FOR HEAVY-DUTY C.I. ENGINES”

Hemant Banke ¹, Prof. Anand Mahajan ²

¹ PG scholar, Department of Mechanical Engineering, SAGE University, Indore, Madhya Pradesh, India

² Professor, Department of Mechanical Engineering, SAGE University, Indore, Madhya Pradesh, India

ABSTRACT

Heavy-duty Compression Ignition (C.I.) engines are widely used in commercial vehicles, agricultural machinery, construction equipment, and industrial applications because of their high torque, durability, and reliability. However, maintaining an appropriate engine operating temperature under varying load and speed conditions remains a major challenge in achieving high thermal efficiency, lower fuel consumption, reduced emissions, and improved engine durability. Conventional single-stage thermostat systems generally provide limited control over coolant flow and may not respond effectively to rapid changes in engine operating conditions. Advanced dual-stage temperature regulation systems provide an improved approach by regulating coolant flow through multiple temperature-dependent stages and thereby maintaining the engine within a desirable operating temperature range. This review presents a comprehensive assessment of advanced dual-stage temperature regulation systems used for thermal management of heavy-duty C.I. engines. The review discusses the operating principles and limitations of conventional thermostat-based cooling systems and examines the development of dual-stage and electronically controlled temperature regulation systems. Particular attention is given to thermostat characteristics, coolant flow regulation, temperature sensing, electronic control, thermal response, pressure and flow behaviour, and integration with Engine Control Units (ECUs). The effects of improved temperature regulation on engine cooling performance, thermal efficiency, fuel consumption, combustion behaviour, component durability, and exhaust emissions are also discussed. The role of Computational Fluid Dynamics (CFD) and experimental investigations in evaluating coolant flow and temperature distribution is highlighted. Finally, current challenges, research gaps, and future opportunities for intelligent and adaptive thermal management systems are identified. The review indicates that advanced dual-stage temperature regulation can provide more responsive thermal control than conventional systems and has significant potential for improving the overall performance and reliability of heavy-duty C.I. engines.

Key Words: Heavy-Duty C.I. Engine, Thermal Management, Dual-Stage Temperature Regulation, Advanced Thermostat, Electronic Thermostat, Engine Cooling System, Coolant Flow, Temperature Control, And Thermal Efficiency.

I. INTRODUCTION

Compression Ignition (C.I.) engines are widely used in heavy-duty vehicles, agricultural machinery, construction equipment, generators, and industrial applications because of their high torque, durability, reliability, and good fuel economy. These engines generally operate under high loads for extended periods, resulting in considerable heat generation during the combustion process. Although only a portion of the chemical energy of fuel is converted into useful mechanical work, a significant amount of energy is released in the form of heat. Effective thermal management is therefore essential to maintain the engine components within their safe and desirable operating temperature range.

<https://www.ijrtsm.com> © International Journal of Recent Technology Science & Management

The operating temperature of an engine has a direct influence on combustion quality, lubrication, fuel consumption, component life, and exhaust emissions. If the engine operates at a temperature lower than the desired range, fuel evaporation and combustion may become less effective, frictional losses may increase, and condensation of moisture and unburned fuel can adversely affect engine lubrication. On the other hand, excessive temperature can cause overheating, thermal stresses, lubricant degradation, component deformation, and accelerated wear. Therefore, an effective cooling system must provide sufficient heat removal while avoiding unnecessary over-cooling.

Conventional engine cooling systems commonly use a thermostat to regulate the flow of coolant between the engine and radiator. The thermostat remains closed or partially closed during cold starting and low-temperature operation, allowing the engine to reach its normal operating temperature more quickly. As the coolant temperature increases, the thermostat opens progressively and permits greater coolant flow through the radiator. Although this arrangement is simple, reliable, and economical, a conventional single-stage thermostat has limited ability to respond to rapidly changing engine operating conditions. Heavy-duty engines frequently experience wide variations in speed, load, ambient temperature, and operating duty, making precise temperature regulation increasingly important.

An advanced dual-stage temperature regulation system can provide improved control of engine coolant flow over different operating temperature ranges. In such a system, temperature regulation may be performed through two successive stages using mechanical, electronic, or combined temperature-control mechanisms. The first stage can provide normal temperature regulation during moderate engine operation, while the second stage can provide additional coolant flow when the engine temperature increases beyond a specified threshold. Such a configuration can potentially provide faster thermal response and better temperature stability under high-load operating conditions. Recent developments in engine thermal management have also introduced electronic temperature regulation using temperature sensors, electronic control units (ECUs), electrically actuated thermostats, and electronically controlled coolant-flow devices. These systems allow coolant flow to be adjusted according to engine temperature and operating conditions rather than relying only on a fixed mechanical response. Integration of sensing and control technologies can improve the flexibility of the cooling system and provide opportunities for adaptive thermal management. The effectiveness of such systems can be investigated through both experimental testing and Computational Fluid Dynamics (CFD) analysis.

Thermal management is particularly important in heavy-duty C.I. engines because these engines operate for long durations under high thermal and mechanical loads. Improved temperature regulation can contribute to stable combustion, reduced thermal stress, better lubrication conditions, improved fuel utilization, and controlled exhaust emissions. At the same time, excessive coolant flow can increase pumping requirements and heat losses, whereas insufficient coolant flow can result in local overheating. Hence, the objective is not simply to maximize cooling but to regulate heat rejection according to the actual operating requirement of the engine.

The development of advanced dual-stage temperature regulation systems has therefore become an important area of research in modern engine thermal management. Researchers have investigated thermostat design, coolant-flow characteristics, temperature distribution, electronic control strategies, radiator performance, and CFD-based optimization to improve the thermal behaviour of engines. However, the available studies are distributed across different aspects of cooling and temperature control, and a comprehensive understanding of dual-stage temperature regulation for heavy-duty C.I. engines is required. This review paper presents a comprehensive assessment of advanced dual-stage temperature regulation systems for heavy-duty C.I. engines. It discusses the fundamentals of engine thermal management, conventional cooling systems, thermostat operation, limitations of single-stage temperature regulation, and the working principles of dual-stage systems. The review further examines electronic temperature control, sensor and ECU integration, coolant-flow regulation, CFD and experimental approaches, and the effects of improved temperature regulation on engine performance, fuel consumption, emissions, and component durability. Finally, the major research gaps, technical challenges, and future possibilities for intelligent and adaptive thermal management systems are discussed.

II. PROBLEM IDENTIFICATION

Heavy-duty Compression Ignition (C.I.) engines operate under continuously changing conditions such as engine speed, load, ambient temperature, and duty cycle. These variations directly affect the amount of heat generated inside the engine. Therefore, maintaining the engine within an appropriate operating temperature range is an important challenge in engine thermal management. An ineffective temperature regulation system may result in either excessive cooling or

insufficient cooling, both of which can negatively influence engine performance, efficiency, emissions, and component life. Conventional cooling systems generally use a single-stage mechanical thermostat to regulate coolant flow according to engine temperature. Although such systems are simple, economical, and reliable, their response is mainly dependent on a predetermined temperature range. They have limited capability to respond rapidly to changes in engine operating conditions. During low-load operation, excessive cooling may delay engine warm-up and keep the engine below its desired operating temperature. In contrast, during high-load operation, the heat generation rate increases significantly and insufficient coolant-flow regulation may increase the possibility of overheating. Another important problem is the variation in temperature throughout different regions of the engine. Improper coolant distribution can result in non-uniform temperature fields and localized hot spots. Excessive temperature gradients may increase thermal stresses in components such as the cylinder head, cylinder liner, piston, valves, and other critical engine parts. Repeated heating and cooling cycles can further contribute to thermal fatigue, material degradation, and reduced component durability. Engine operating temperature also has a significant effect on combustion, lubrication, fuel consumption, and exhaust emissions. If the engine operates below its optimum temperature, combustion efficiency and lubrication conditions may be adversely affected. On the other hand, excessive operating temperature can cause lubricant degradation and thermal deterioration of engine components. Temperature regulation is therefore required not only to prevent overheating but also to maintain the engine within a suitable thermal operating range. The thermal behaviour of heavy-duty engines becomes more challenging during transient operating conditions. Rapid changes in engine load and speed can cause sudden variations in heat generation and coolant temperature. A conventional mechanical thermostat may not respond sufficiently quickly to these changes. This limitation creates a need for a temperature regulation system capable of providing different levels of coolant-flow control according to the actual thermal requirement of the engine. The development of electronic temperature regulation provides an opportunity to overcome some of these limitations. Temperature sensors can continuously monitor coolant temperature, while an electronic control unit (ECU) can process the temperature information and control an actuator or electronically operated thermostat. Such a system can provide more flexible coolant-flow regulation. However, the integration of electronic control with a dual-stage temperature regulation arrangement requires appropriate design, control strategy, and performance evaluation. A major problem is therefore the lack of precise and adaptive coolant-flow control over a wide range of engine operating conditions. A single-stage thermostat may not provide adequate control during both low-temperature and high-temperature conditions. An advanced dual-stage system can address this issue by providing temperature regulation through two distinct stages. The first stage can support faster engine warm-up and normal temperature control, while the second stage can provide increased coolant flow when the engine experiences higher thermal loads. There is also a need to evaluate the influence of dual-stage temperature regulation on overall engine performance. Parameters such as coolant temperature, coolant velocity, pressure drop, heat-transfer rate, temperature distribution, fuel consumption, thermal efficiency, and exhaust emissions should be considered. Computational Fluid Dynamics (CFD) can be used to investigate coolant-flow behaviour and temperature distribution, while experimental testing can provide validation of the numerical results. Thus, the primary problem identified in this review is the limitation of conventional single-stage temperature regulation systems in maintaining optimum thermal conditions for heavy-duty C.I. engines under varying operating conditions. The development and evaluation of an advanced dual-stage temperature regulation system can provide a potential solution by improving temperature control, coolant-flow management, thermal stability, and engine cooling response. A comprehensive review of existing research is therefore required to identify the current developments, limitations, research gaps, and future opportunities in advanced dual-stage thermal management of heavy-duty C.I. engines.

III. RESEARCH OBJECTIVE

The main objective of this review is to study and evaluate advanced dual-stage temperature regulation systems for improving the thermal management of heavy-duty Compression Ignition (C.I.) engines. The specific objectives of the research are as follows.

The major objectives of this review paper are:

1. To study the fundamentals of thermal management and cooling requirements of heavy-duty C.I. engines under different operating conditions.
2. To review the working principles, construction, and limitations of conventional single-stage thermostat-based cooling systems.

3. To investigate the working principle and potential applications of advanced dual-stage temperature regulation systems for heavy-duty C.I. engines.
4. To examine the effect of dual-stage temperature regulation on coolant flow, engine temperature, heat transfer, and overall thermal stability.
5. To review the application of electronic thermostats, temperature sensors, actuators, and ECU-based control systems for improved engine temperature regulation.
6. To study the influence of improved temperature regulation on engine performance, thermal efficiency, fuel consumption, and component durability.
7. To examine the relationship between engine thermal management and exhaust emissions, particularly NO_x, CO, and unburned hydrocarbons.
8. To review the use of Computational Fluid Dynamics (CFD) and experimental methods for analyzing coolant flow, pressure distribution, velocity distribution, and temperature distribution.
9. To identify the major limitations, challenges, and research gaps associated with advanced dual-stage temperature regulation systems.
10. To discuss future research possibilities for developing efficient, responsive, adaptive, and reliable thermal management systems for heavy-duty C.I. engines.

IV. LITERATURE REVIEW

The thermal management of internal combustion engines has been an important research area because engine temperature directly affects combustion, fuel consumption, emissions, lubrication, and component durability. Conventional cooling systems generally use mechanically driven coolant pumps, fans, and wax-type thermostats. These systems are simple and reliable, but their ability to regulate coolant flow according to changing engine operating conditions is limited. Research has therefore increasingly focused on electronically controlled pumps, variable-position thermostats, intelligent control systems, and advanced thermal management strategies.

Amit Gupta et al (2026) investigated thermal management and optimization of a six-cylinder heavy-duty diesel engine using coupled CFD, combustion, and conjugate heat-transfer analysis. The study developed a detailed numerical methodology for simultaneously evaluating combustion, coolant flow, and heat transfer. Critical hot spots in the cylinder block and cylinder head were identified through the coupled analysis. Different coolant-flow-path modifications were then evaluated to improve heat transfer in critical regions. The optimized cooling-jacket design improved heat-transfer efficiency by approximately 18% and reduced critical component temperatures. The study demonstrates the importance of detailed CFD and thermal analysis in optimizing cooling systems for heavy-duty diesel engines.

Zhou et al. (2026) investigated the thermal management of diesel engines using advanced cooling-system concepts and numerical modelling. Their work considered the limitations of conventional mechanically driven cooling components and examined the advantages of electrically controlled pumps, fans, and valves. The study emphasized that conventional cooling systems are generally designed for maximum heat-load conditions and may provide excessive coolant flow during many operating conditions. Advanced thermal management allows coolant flow and cooling capacity to be adjusted according to actual engine requirements. The research demonstrated the importance of control strategies in maintaining suitable engine operating temperatures. Such approaches provide an important foundation for developing advanced temperature-regulation systems for heavy-duty applications.

Savaripour et al. (2025) investigated engine thermal management using a map-controlled thermostat. The study considered an advanced cooling system consisting of an electrical water pump, electrical fan, and heated thermostat. The thermostat was controlled according to engine operating conditions instead of relying only on a fixed opening temperature. The results showed improvements in engine performance over different operating conditions, including engine warm-up and low- and high-load operation. The study reported a reduction in fuel consumption along with reductions in HC and CO emissions. The work demonstrates the potential of variable thermostat control for improving engine thermal management.

Liu et al. (2025) reviewed advanced thermal management systems and control strategies for internal combustion engines. The study discussed the limitations of conventional mechanical cooling components and the development of electrically controlled pumps, fans, valves, and thermostats. The researchers emphasized that controllable cooling components can provide greater flexibility in regulating engine temperature. Electronic control allows the cooling system to respond to changes in engine operating conditions more effectively than fixed mechanical systems. The study also highlighted the importance of selecting suitable control strategies for achieving optimum thermal conditions. These findings are directly relevant to the development of advanced temperature-regulation systems for heavy-duty C.I. engines.

Praveen et al. (2024) reviewed advanced thermal-management techniques for internal combustion engines and discussed the importance of improved cooling control. The study examined the limitations of conventional cooling arrangements under varying engine operating conditions. Electrically controlled coolant pumps and temperature-regulation devices were identified as important technologies for improving thermal control. The authors emphasized that coolant flow should be matched with the actual thermal requirement of the engine rather than being continuously supplied at a fixed rate. Improved control can reduce unnecessary cooling losses and support better engine efficiency. The study provides useful background for the development of advanced dual-stage temperature regulation systems.

Bakatwar et al. (2024) investigated the performance and optimization of an engine cooling system using an electronically controlled thermostat. The study recognized that a fixed thermostat temperature may not be suitable for different combinations of engine speed and load. An electronic thermostat was therefore considered to provide improved control of coolant temperature over different operating conditions. The research discussed the relationship between coolant temperature, fuel consumption, power, emissions, and mechanical loading of engine components. The results indicated the potential of electronically controlled thermostats for improving thermal efficiency and engine operating conditions. This work supports the development of temperature-regulation systems that can respond more effectively to changing engine requirements.

Haghighat et al. (2023) investigated an intelligent cooling system and its control model for improved engine thermal management. The system incorporated an electrical fan, electrical thermostat, and electrical water pump instead of relying completely on conventional mechanically controlled components. A control strategy was developed to regulate the cooling components according to engine operating conditions. The study compared the intelligent system with a conventional cooling system consisting of a conventional thermostat, fixed-speed water pump, and conventional fan operation. The work demonstrated the importance of integrating electronically controlled cooling components for improved thermal response and energy management. The study provides a significant basis for further development of intelligent and multi-stage engine temperature-regulation systems.

Mu et al. (2022) investigated methods for improving the thermal efficiency of an engine using an advanced cooling system incorporating an electronic water pump and dual thermostats. Their study considered different engine operating conditions, including low-speed, medium-load, and high-load operation. The main electronic thermostat was used to regulate coolant temperature according to the engine operating condition. Under high-load conditions, the electronic water pump and dual thermostats could open fully to provide increased coolant flow through the engine. The study demonstrated the importance of variable coolant flow and dual-stage temperature regulation in controlling engine thermal loads.

Zhang et al. (2022) investigated an advanced control strategy for engine thermal management systems having significant time delays. The system consisted of an electric thermostat, electric coolant pump, mechanical pump, radiator, and electric fan. A control strategy was developed to improve engine temperature tracking while minimizing the energy consumption of the thermal-management system. The study used a state predictor and disturbance estimator to improve temperature-control accuracy. Experimental testing demonstrated accurate engine-temperature regulation and energy consumption close to the theoretical optimum. The work highlights the importance of advanced control algorithms for modern electronically controlled cooling systems.

Wang et al. (2021) investigated the temperature-control characteristics of an intelligent cooling system for a high-speed marine diesel engine. The developed system used controllable cooling components, including an electronic thermostat and electrically driven coolant pump. A variable-universe fuzzy-control algorithm was applied to regulate the electronic thermostat, while a combined fuzzy and BP-PID strategy was used for pump control. Experimental results showed reduced warm-up time and improved cooling accuracy under different operating conditions. The intelligent system also reduced cooling-system power consumption and several measured emissions.

Assessment study (2021) investigated the application of an electrical coolant pump in a heavy-duty diesel engine. The study examined different coolant-flow circuits and evaluated the behaviour of the system under different thermal conditions. At coolant temperatures below the thermostat opening temperature, the short coolant circuit allowed coolant to recirculate through the engine without passing through the main heat exchanger. When the thermostat opened, the long coolant circuit directed coolant through the cooling module to reject heat to the surroundings. The study demonstrated the importance of controllable coolant flow for heavy-duty engine thermal management. The findings support the use of electrically controlled cooling components in advanced temperature-regulation systems.

Adsul et al. (2020) conducted a simulation study of the cooling system of a heavy-duty six-cylinder diesel engine. A one-dimensional GT-Suite/GT-ISE model was developed to investigate coolant mass-flow and thermal distribution at different steady-state operating conditions. The cooling system incorporated two interdependent thermostat valves, identified as master and slave thermostats. The master thermostat controlled the radiator circuit, while the slave thermostat provided a bypass flow path to the coolant pump. The simulation methodology was validated using experimental engine-test data, and reasonable agreement was obtained between analytical and experimental results. The study is particularly relevant to dual-stage temperature regulation because it demonstrates the application of multiple thermostat valves in a heavy-duty diesel cooling system.

V. CONCLUSION

The literature reviewed in this paper demonstrates that effective thermal management is essential for achieving reliable and efficient operation of heavy-duty Compression Ignition (C.I.) engines. Engine temperature has a direct influence on combustion behaviour, fuel consumption, lubrication, component durability, and exhaust emissions. Conventional cooling systems based on fixed-response mechanical thermostats are simple and reliable, but their ability to respond to rapidly changing engine operating conditions is limited. The reviewed studies indicate that advanced temperature regulation systems can provide improved control of coolant flow and engine operating temperature. Electrically controlled thermostats, variable-speed coolant pumps, electronic fans, temperature sensors, and ECU-based control strategies provide greater flexibility than conventional cooling arrangements. These technologies can regulate the cooling capacity according to actual engine requirements and can reduce unnecessary coolant circulation and associated energy losses. Dual-stage temperature regulation provides an additional opportunity to improve engine thermal management. By regulating coolant flow through different stages according to temperature and engine load, the system can support faster warm-up during low-temperature operation and provide increased cooling capacity during high-temperature and high-load conditions. Such an approach is particularly suitable for heavy-duty C.I. engines, which experience significant variations in thermal load during practical operation. The literature also shows that improved temperature regulation can contribute to better thermal stability, reduced thermal stress, improved lubrication conditions, and potentially lower fuel consumption and exhaust emissions. However, the effect on individual emission parameters may vary depending on engine operating conditions and control strategy. Therefore, temperature regulation should be optimized as an integrated engine-management problem rather than simply maximizing coolant flow. Computational Fluid Dynamics (CFD), one-dimensional engine-system modelling, and experimental investigation are important tools for evaluating advanced cooling systems. These methods can be used to study coolant velocity, pressure drop, temperature distribution, heat-transfer characteristics, and thermal response. Combining numerical analysis with experimental validation can provide a better understanding of the performance and limitations of advanced dual-stage temperature regulation systems. Overall, the literature indicates a clear transition from conventional fixed-temperature cooling systems toward adaptive, electronically controlled, and intelligent thermal-management systems. Although significant research has been conducted on electronic thermostats, electric coolant pumps, intelligent cooling systems,

and dual-thermostat arrangements, comparatively limited work has comprehensively evaluated an advanced dual-stage temperature regulation system specifically for heavy-duty C.I. engines.

REFERENCES

- [1] N. V. Duong, P. T. Pham, et al., "Developing a Computational Fluid Dynamics-Finite Element Method Model to Analyze Thermal-Mechanical Stresses in a Heavy-Duty Medium-Speed Diesel Engine Piston During Warm-Up," *Journal of Heat Transfer*, vol. 146, no. 2, Art. no. 021301, 2026, doi: 10.1115/1.4063901.
- [2] Z. Xu, Q. Xia, C. Peng, and Y. Wang, "Thermal Management Development for a Dedicated Hybrid Engine," *SAE Technical Paper 2025-01-2416*, 2025, doi: 10.4271/2024-01-2416.
- [3] A. Ravikumar, S. Wright, L. Redmond, E. Gingrich, et al., "Numerical Evaluation of Injection Parameters on Transient Heat Flux and Temperature Distribution of a Heavy-Duty Diesel Engine Piston," *SAE Technical Paper 2025-01-2688*, 2025, doi: 10.4271/2024-01-2688.
- [4] M. Di Bartolomeo, D. Di Battista, R. Cipollone, F. Fremondi, and U. Camagni, "A New Design Rule of Engine Coolant Pump in ICEs Focused to Energy Consumption Reduction," *SAE Technical Paper 2024-37-0015*, 2024.
- [5] "Numerical and Experimental Analysis of Thermal Boundary Conditions of Heavy Duty Diesel Engine Cylinder Head for Different Combustion and Fuel," 2024.
- [6] H. Savaripour, S. A. Hosseini, S. Nasrollahnezhad, A. Jahangiri, and M. A. Rosen, "Investigation of Engine's Thermal Management Based on the Characteristics of a Map-Controlled Thermostat," *International Communications in Heat and Mass Transfer*, vol. 137, Art. no. 106156, 2023, doi: 10.1016/j.icheatmasstransfer.2023.106156.
- [7] H. Mu, Y. Wang, C. Yang, H. Teng, X. Zhao, H. Lu, D. Wang, S. Hao, X. Zhang, Y. Jin, and others, "Technical Research on Improving Engine Thermal Efficiency," *Advances in Mechanical Engineering*, 2022, doi: 10.1177/16878132221125032.
- [8] "Smart Cooling Design Using Dual Loop Cooling to Increase Engine Efficiency and Decrease Fuel Emissions with Artificial Intelligence," *Case Studies in Thermal Engineering*, vol. 40, Art. no. 102351, 2022, doi: 10.1016/j.csite.2022.102351.
- [9] H. Liu, M. Wen, H. Yang, Z. Yue, and M. Yao, "A Review of Thermal Management System and Control Strategy for Automotive Engines," *Journal of Energy Engineering*, vol. 147, no. 2, 2022, doi: 10.1061/(ASCE)EY.1943-7897.0000743.
- [10] A. Kaleli and H. İ. Akolaş, "The Design and Development of a Diesel Engine Electromechanical EGR Cooling System Based on Machine Learning-Genetic Algorithm Prediction Models to Reduce Emission and Fuel Consumption," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 236, no. 3, 2022, doi: 10.1177/09544062211020045.
- [11] S. M. Praveen, B. Saravanan, B. Siddharthan, and S. B. Kumaragurubaran, "Thermal Management in Conventional Diesel Engines," *Materials Today: Proceedings*, vol. 45, pp. 1161–1165, 2021, doi: 10.1016/j.matpr.2020.03.531.
- [12] H. Ghasemi Zavaragh, A. Kaleli, İ. Solmuş, and F. Afshari, "Experimental Analysis and Evaluation of Thermostat Effects on Engine Cooling System," *Journal of Thermal Science*, vol. 30, no. 2, pp. 540–550, 2021, doi: 10.1007/s11630-020-1264-8.
- [13] S. Wilson, H. Yoon, Y. Sun, J. Lee, et al., "A Comparative Study on Engine Thermal Management System," *SAE Technical Paper 2020-01-0946*, 2020, doi: 10.4271/2020-01-0946.
- [14] A. Kaleli, "Development of the Predictive Based Control of an Autonomous Engine Cooling System for Variable Engine Operating Conditions in SI Engines: Design, Modeling and Real-Time Application," *Control Engineering Practice*, 2020.