A Study on the Improving Radiator Performance Prediction Accuracy to meet Cooling Target

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Automotive cooling systems primarily utilize water-based radiators, and radiator selection is accomplished through comparative analysis of three categories: existing production vehicles, radiators with frontal areas similar to benchmark vehicles, and radiators designed to meet new vehicle performance requirements. Existing production radiators demonstrate high prediction accuracy; however, newly developed products require performance validation through single-component testing due to insufficient performance data.

Evaluating multiple design concepts at the concept phase requires accurate performance data from component suppliers. Ideally, performance specifications should be provided through sample manufacturing and testing. However, due to constraints in development schedules and cost-effectiveness, component suppliers provide predictive data generated through analysis programs to original equipment manufacturers (OEMs). This underscores that the analytical accuracy of component suppliers' single-component analysis significantly influences the final completeness of vehicle cooling systems.

Component suppliers predict radiator performance data using commercial programs such as GT-Suite, Kuli, Amesim, and Flowmaster, or modified Inhousetoo. Since these programs cannot accommodate all radiator geometric information, correction factors are applied to improve prediction accuracy. However, the application of a single universal correction factor for coolant flow rate proved inadequate during hydrogen electric truck development.

Traditional radiators operate at 60–150 LPM, whereas hydrogen electric vehicles and electric vehicles operate at 150–450 LPM, representing a significant difference in coolant flow rates. This wide range spans multiple flow regimes, making it inappropriate to apply a single correction factor across the entire operating range. The fundamental issue is that laminar and turbulent flow characteristics differ substantially, and correlating different flow regimes with a single empirical correction factor introduces significant prediction errors..

As shown in Fig. 1, the transitional region can be identified through Reynolds Number variation with coolant flow rate. A comprehensive Nusselt number correlation equation was developed as follows:

$$Nu = a_{lam} Re^{b_{lam}} Pr^{1/3} \times | 1 - f_{turb} | + a_{turb} Re^{b_{turb}} Pr^{1/3} \times f_{turb}$$

Through experimental validation, this equation achieved the target error range of 0 to –10%. Empirical coefficients (a_{lam}, b_{lam}, a_{trub}, b_{turb}) according to radiator thickness were determined from radiators supplied by major suppliers in Hyundai Motor Company's commercial vehicle division. By sharing this program with component suppliers, Hyundai Motor Company can now ensure that radiators specified at the concept stage are manufactured according to design specifications with improved prediction accuracy.

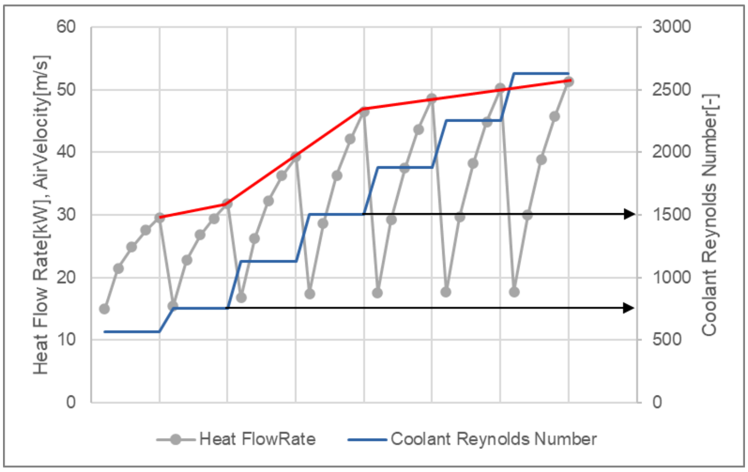

Fig. 1 Trend of Heat Flow Rate Change with Coolant Flow Rate Variation

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