Development of Control Logic for Preventing Cooling Fan Motor Damage

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In South Asia, especially India, concentrated heavy rainfall during the monsoon season frequently causes road flooding and severe waterlogging. In many urban areas, insufficient drainage infrastructure makes vehicles highly vulnerable to temporary submerged driving conditions. Under these conditions, the cooling fan motor is exposed to a sudden increase in rotational resistance caused by water intrusion and road debris. As a result, the motor experiences excessive load, increased armature current, thermal stress in the winding, and eventually internal damage such as insulation failure, carbon trace formation, or disconnection. Such damage leads not only to cooling fan failure, but also to engine overheating and degradation of air-conditioning performance, resulting in a large number of field claims in monsoon regions.

Fig.1 Flooded conditions and motor damage (disconnection)

Various hardware-based countermeasures were previously considered, such as increasing motor torque capacity and improving water drainage structure. However, those measures had clear limitations in cost, packaging, and fundamental protection capability under severe flooded conditions. For this reason, this study focused on a software-based protection strategy that could be implemented with the existing vehicle system and without additional hardware cost. The objective of this work was to develop a control logic capable of detecting flooded conditions and temporarily restricting cooling fan operation before motor damage occurs.

The proposed method uses the refrigerant pressure behavior of the air-conditioning system as an indicator of flooding. During normal air-cooled operation, refrigerant pressure changes relatively gradually. In contrast, when the condenser and cooling module are exposed to water, heat exchange is intensified by water cooling, and the refrigerant pressure decreases much more rapidly. Based on this physical difference, flooded conditions can be identified using the rate of pressure change. Through feasibility testing, refrigerant pressure variation was monitored during forced submerged driving, and a distinct pressure drop pattern was confirmed under flooded conditions. Flood entry and flood release were therefore determined using pressure change rate thresholds with hysteresis, enabling stable discrimination between submerged and normal states.

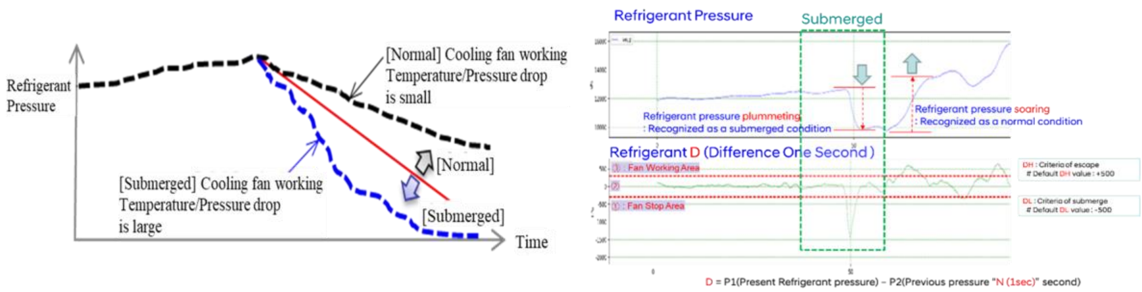

Fig.2 Refrigerant Pressure Determination of Flood Conditions

Based on this detection principle, flood control logic was configured with entry conditions and protection actions. The logic checks vehicle operating conditions such as vehicle speed, air-conditioning switch status, compressor relay status, refrigerant pressure range, coolant temperature, and fan operating status before activating flood detection. A moving average method was applied to reduce noise sensitivity in pressure signals, and the pressure change rate was calculated over a specified time window. When flooded operation is detected, the cooling fan is stopped to prevent continuous overload, and Idle Stop and Go (ISG) operation is also limited in order to avoid engine restart issues under submerged conditions. Normal fan control is restored after the flood release condition is satisfied.

The developed logic was validated in collaboration with the ECU supplier and applied to gasoline and diesel vehicles for vehicle-level verification. Test results confirmed that flooded conditions were detected properly and that prolonged overloaded motor operation could be prevented effectively. After final calibration, the logic was sequentially applied to production vehicles in India from January 2024. Field claim analysis for two vehicle models showed that the cooling fan motor failure rate decreased by approximately 73%, from 0.03571% to 0.00954%, while claim cost was also reduced significantly. These results demonstrate that the proposed logic is an effective and low-cost solution for improving cooling fan motor durability and reducing flood-related market claims in monsoon regions.