Oil Spray Cooling System in Electrical Machine

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TOPIC

Choosing the appropriate cooling method significantly affects the amount of heat extraction from the electrical machine. This improvement in heat extraction directly impacts the power rating of the electric machine and the reliability of temperature-sensitive components such as insulation materials and magnets. As the electric motors used in electric vehicle (EV) traction drive applications have compact structures, the conventional cooling methods cannot provide sufficient heat transfer. Accordingly, this paper presents a survey on the oil spray cooling approach as the new cooling methodologies implemented in these motors. This study aims to introduce the cooling system and describes the method's capability to cool the electrical machine. Furthermore, it tries to get a broader view of the reader about implementing this cooling method on the EV electrical motors.

DESCRIPTION

The oil spray cooling method counts as a phase change method. Accordingly, this method benefits from two-phase heat transfer regimes. It means some portions of oil is converted to vapor and increase the heat transfer rate. In this approach, the nozzle is a mechanical device responsible for transforming the liquid into droplets. Accordingly, the liquid (oil) force to pass through the tiny orifice to change fluid into small droplets spread on the hot surface to remove the enormous amount of heat energy and reduce its temperature. In this cooling system. The process of transforming the liquid into drops is called atomization. Fig. 1 shows the atomization procedure in nozzles.

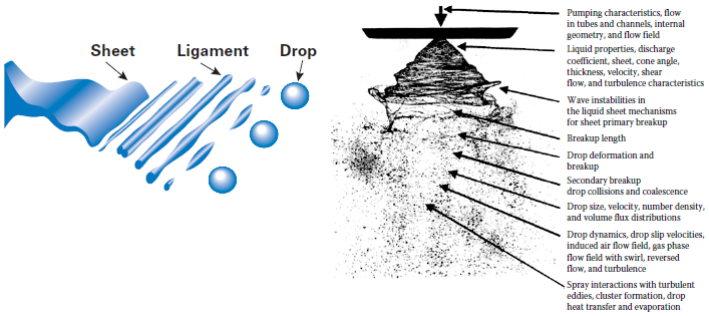

Fig. 1. Example of Atomization procedure [1], [2].

The spray cooling approach itself is not a novel method, and there are numerous research studies in this field [3], [4]. Moreover, this cooling method has a complex heat transfer mechanism that most of the findings are based on the experimental way. However, these findings are mostly concentrated on thermal engineering devices such as computers, hybrid vehicle power electronics, fusion reactor, and satellite and spacecraft electronics, laser, and advanced radars, instead of the motors windings; consequently, they are less applicable to electrical machines.

Oil spray cooling approach in electrical motor

One early study on utilizing a spray cooling approach for the electrical machine is presented by Li Zhenguo et al. in [5], [6], [7]. They performed a series of experiments on implementing the spray cooling on a large electrical machine to investigate the effect of nozzle inlet pressure, spray coverage parameters such as the distance of nozzle orifice from the cooling surface (D), spray angle (A), oil coolant inlet temperature. However, most of their experiments were about evaporative cooling on an electrical

machine, and they utilized the fluorocarbon coolant in these experimental studies that need a complex hydraulic circulating system.

One of the early studies considering implementing oil spray cooling on the EV traction motor was presented by Davin et al. in [8], [9]. They implemented the motor's cooling system and considered rotor rotation on power dissipation and oil flow distribution. Finally, they proposed the inverse approach to determine the value of interior heat transfer coefficients. However, they used one nozzle with a fixed location on the top of the housing. As a result, the oil film was not distributed uniformly on all end winding surfaces, which led to uneven temperature distribution on end windings.

The latest and comprehensive study on the oil spray cooling approach was presented by Liu et al. [10]. They implemented this method on the electrical motor with hairpin winding to consider different spray cooling setups and investigate the effect of different parameters such as flow rate, outlet velocity, and the number of nozzles on the system's cooling capability.

CONCLUSIONS

This paper summarized the oil spray cooling approach's application and thermal performance on the electrical motors for EV traction application drives. It was mainly considered the phase change principle. Besides, It was tried to provide a review study on this mechanical device's spray nozzles.

Finally, the paper provides a suitable survey on the previous research studies of this cooling method for this purpose; it was considered research studies and provided the advantages, challenging, and drawbacks of each research work in this filed.

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