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Focus on Motor Cooling;
Using CFD to Understand the 3D Heat Transfer Effects

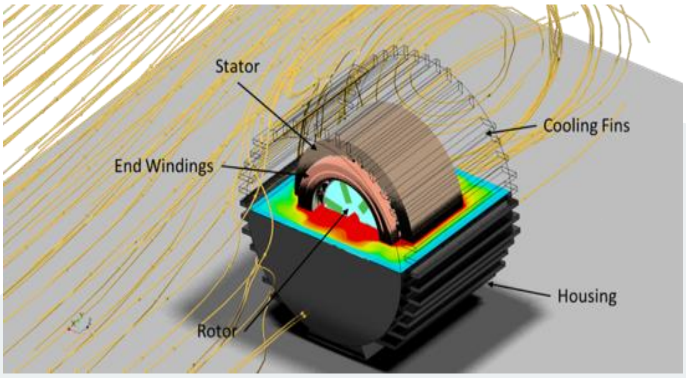
FTS Engineering Answers is regularly asked to provide insight into the effectiveness of the cooling of electric motors particularly for the overall packaging of the motor within the electric machine, and to optimize the cooling design of electric motors. This article provides a brief overview of the engineering challenges of cooling electric motors and then highlights the CFD approaches developed by FTS Engineering Answers to answer these.

Design of motors is typically carried out in 2D motor design software. These capture the temperature dependent physics but are limited in the 3D effects around the stator end windings.

FTS Engineering Answers has developed CFD modelling approaches for three methods of cooling:

- Air cooling
- Water cooling
- Oil Cooling

For all of these methods the underlying temperature dependent physics are incorporated from the motor design software, and then the cooling is carried out in 3D CFD software, which captures the 3D effects around the stator end windings.



Air Cooling

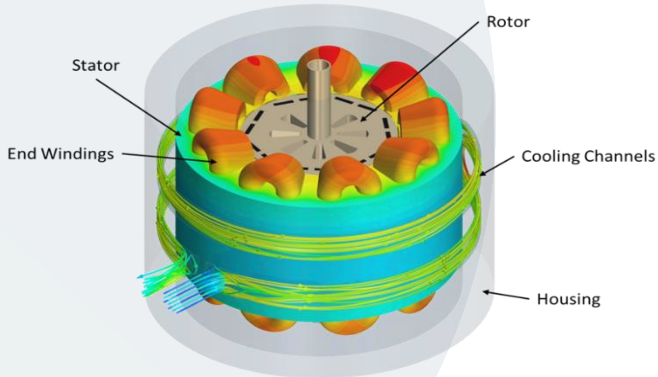
Air cooling is the simplest form of cooling. In the example, there is forced convection over the motor; the heat that's generated within the motor is transferred to the housing and convected away from the device via the cooling fins or conducted away via a heat sink.

Key engineering challenges are the effectiveness of the cooling within the overall packaging and the optimization of the cooling fin arrangements.

Oil Cooling of the Stator Windings Directly

In contrast to the indirect water cooling, here jets of oil are aimed directly on to the stator windings. The oil is injected via a series of high-pressure nozzles, and after the oil is injected it must be drained and cooled and can then be recycled. The challenges of this approach are the arrangements for the high-pressure nozzles; ensuring that the oil coverage of the windings is as uniform as possible to give even cooling; and the incorporation of oil outlets to drain the oil effectively. The major benefit of the approach is achieving very high convective heat transfer coefficients.

Key engineering challenges are the effectiveness and optimization of the oil cooling jets in ensuring uniform coverage of the windings and the drainage of the oil from the motor.



Water Cooling

Typically, a water/glycol mix is pumped through a series of channels in the motor's housing. This approach is typical of larger automotive motors, because the approach is simple and robust, and the motor can be easily sealed. However, it leads to an increase in packaging of the motor. The cooling is indirect; the thermal inertia associated with the heat transfer from the hot stator windings to the cold-water jacket can lead to reduced performance. Additionally, the cooling of the rotor is not as effective as the cooling of the stator.

Key engineering challenges are the effectiveness and optimization of the cooling channels within the motor housing.