Infinitum

Blog | By Paulo-Guedes-Pinto

We Tested Oil Cooling on Our Electric Motor. Here's What Happened.

In an effort to move the world into a new era of sustainability, Infinitum has broken ground with a smarter air-core motor design that dramatically improves efficiency, reliability, and ease-of-use. Replacing the traditional steel core and copper windings with a PCB stator eliminates loss, noise, and unnecessary weight in a smaller footprint. Our technology helps OEMs across the HVAC and industrial landscapes, and as electric vehicle (EV) manufacturers quicken their pace, we see even more opportunities to improve energy efficiency in the transportation industry.

Air-core electric motors have the advantage of simplified prototyping and production, and integrating an oil-cooling system can increase the power density of the motor by three to five times – meaning the same motor form factor could accommodate 30-50 horsepower versus 10.

With all eyes on EV development, Infinitum is currently partnering with a top-tier automotive supplier to prototype one of our motors with oil cooling in situ. EVs make use of cooling systems to regulate the temperature of the car's battery pack and a variety of other electronic systems. Manufacturers are interested in the possibility of increasing the power density of the electric motor used in, for example, the drive train.

To prove this concept, we converted an air-cooled 10 HP Infinitum motor to oil-cooled (see Figure 1). In this system, the cooling oil is pumped into the motor through a rotary connector, coupled to a hollow shaft, that sprays the oil between rotor disks and the PCB stator. Then, the cooling oil is collected at the bottom of the housing and pumped back to the oil reservoir/heat exchanger.

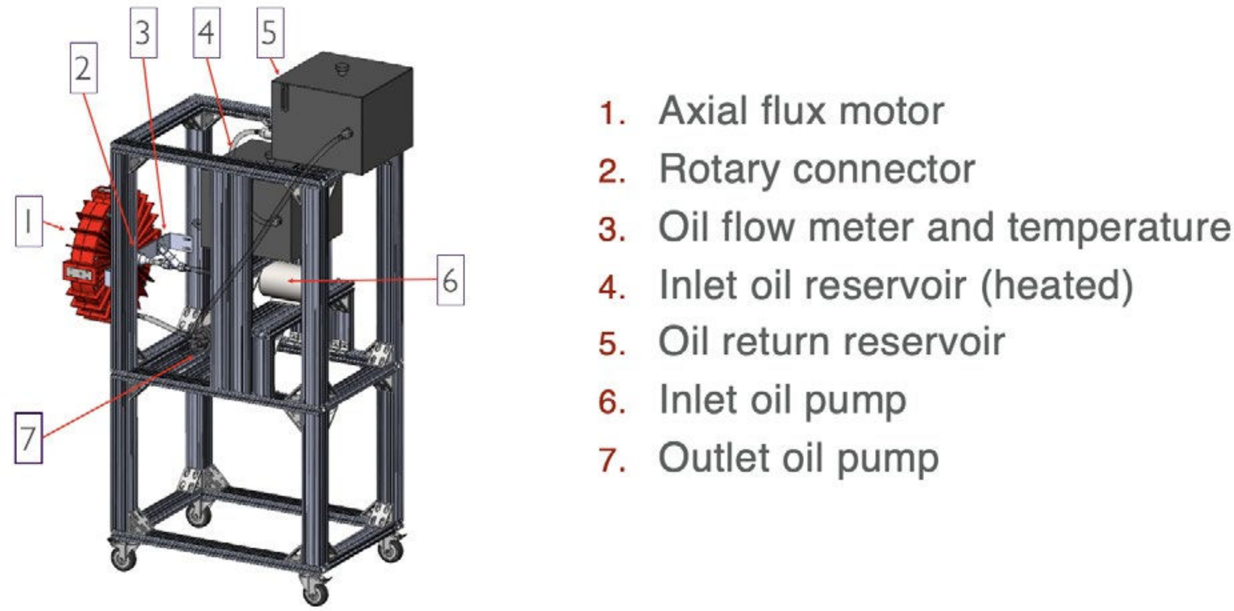

Figure 1: Main components of experimental testing set up, featuring Infinitum's air-core, axial-flux, permanent magnet (PM) motor

Preliminary results show that, with oil flowing at 6 L/min, the cooling system could remove nine times more losses than the air-cooling system, allowing us to increase the motor power by a factor of three. At 6 L/min flow, as a function of losses, the temperature rise rate in the motor is only 0.0081°C/W. Compared to air cooling, where we see a temperature rise rate of 0.0729°C/W, the temperature rise of the 10 HP motor running a full load dropped from 41°C to only 5°C. If we allow the temperature rise in the oil-cooled motor to match the 41°C of the air-cooled version, the oil-cooled system could remove up to 5,000 W of losses – corresponding to the three-fold increase in motor power mentioned above.

The maximum temperature of the materials inside the motor, especially the stator, determine the maximum power rating. The more effective the cooling system, the higher the possible power density. In a radial-flux motor, like those used in EVs from Tesla and Volkswagen, the air gap between the stator and the rotor surfaces is usually too narrow for coolant to flow through, so designers need to apply coolant outside of the air gap. Further, with traditional copper windings, a large amount of the copper surface area isn't exposed to the coolant. With Infinitum's axial-flux motor, fluid is sprayed directly over the surface of the stator which maximizes heat transfer away from the current-carrying copper. Since the stator generates the most heat, direct coolant application has a significant advantage. While we have more work to do, initial modeling and testing of oil-cooled Infinitum motors show great promise for the electrification of vehicles because of their smaller relative size, light weight, and high power density.

To hear more from Infinitum, check out our recent conference presentation on PCB stator technology for EV motors.