

## Lecture in HDM

# Comprehensive Computational Fluid Dynamics Multiphase Approach to Model Direct Oil Cooling in High-Performance Permanent Magnet Synchronous Motors for Automotive Applications

**Davide PAREDI, Phd.**  
**Thermal Engineer at Rimac Technology**

Development of high-performance electric vehicles requires continuous improvements of E-motor designs in terms of rated power, output torque and overall power density.

High-speed Permanent Magnet Synchronous Motors (PMSMs) represent the best architecture to satisfy these requirements, however they are characterized by complex topologies and by the necessity to implement direct oil cooling solutions to manage heat in critical internal components.

Within this context, Computational Fluid Dynamics (CFD) simulations can optimize the thermal design of PMSMs, allowing for a more efficient development phase.

However, given the complexity of thermal and fluid dynamics phenomena involved with direct oil cooling, employed CFD calculations cannot afford to partially model the motor domain or to simplify the physics of the system.

Instead, comprehensive numerical approaches are required to properly capture the internal fluid dynamics behavior in order to provide accurate feedback to motor design teams.

To achieve this goal, a reference CFD approach must take into account the realistic full motor topology by coupling rotational and static regions under a single numerical framework.

The entire fluid domain must also be modelled by means of suitable multiphase methods capable to properly track the complex air-oil mixture flow regimes which develop under high rotational speeds. Moreover, to ensure suitable applications within a fast-paced industrial environment driven by stringent deadlines, the model must also be computationally as efficient and robust as possible under a wide range of operating conditions.

In the proposed presentation, after a general introduction to E-motors and to a PMSM machine which is currently being developed by Rimac Technology, shortcomings of CFD models previously employed to simulate the direct oil cooling process of such motor will be highlighted. Expected impacts on numerical accuracy will then be highlighted as a basis to show how a comprehensive CFD full E-motor multiphase approach was subsequently built to overcome such limitations and it is now employed as a reference model within the company simulation R&D team.

Finally, an overview of latest achieved results will be provided along with a brief touch upon next steps required to further calibrate and optimize the proposed model.