



PhD in INGEGNERIA ELETTRICA / ELECTRICAL ENGINEERING - 37th cycle

**THEMATIC Research Field: DIRECTLY-COOLED WINDING CONFIGURATIONS FOR HIGH
TORQUE-DENSITY PERMANENT MAGNET MOTORS**

Monthly net income of PhDscholarship (max 36 months)

€ 1400.0

In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity

**Motivation and objectives of the research
in this field**

The torque density of electric motors is largely limited by the maximum temperature at the winding electric insulation, which dictates the electric loading (current density) levels. Developing improved motor cooling solutions is therefore of paramount importance in order to meet the performance specifications of the most demanding applications such as sport and racing cars, and aircraft propulsion. This project will look at winding configurations suitable for direct cooling of conductors for highly power-dense permanent-magnet electric motors, in order to increase the tolerable current density and ultimately boost both the motor rated torque-density and transient overload capability. Directly-cooled hollow conductors with channels (e.g. extruded or 3D printed) or stranded/braided around a core composite/polymer pipe (e.g. LCL or PTFE) will be investigated, for both concentrated-coil and distributed windings. Channelled-conductor windings will be benchmarked against more traditional options, and optimised for slot fill-factor maximisation, eddy-current loss minimisation - particularly in solid or 3D printed channelled conductors - temperature equalisation, and manufacturability. Criteria for optimal motor design will also be devised to fully exploit the benefits of direct cooling of conductors.

**Methods and techniques that will be
developed and used to carry out the
research**

The research programme will start with a thorough



	<p>literature review in the area of power-dense electric motor architectures, materials, and thermal management. This will be followed by multiphysics modelling studies on winding topologies using analytic and numeric (e.g. finite-element) techniques to predict losses and thermal behaviour. These studies will then feed into the design and optimisation of an electric motor prototype targeting typical application requirements for high-spec sport cars. The project will culminate with the build and test of critical components in order to validate the modelling methodology and the predicted performance.</p>
Educational objectives	<p>During the project, the PhD candidate will develop sound research and technical skills in the areas of electromagnetics, electric machine design, and thermal management. These will include advanced multiphysics modelling techniques and use of state-of-the art simulation software and lab instrumentation. During their work on the project, the candidate will also sharpen their soft-skills in technical writing, communication, and project planning.</p>
Job opportunities	<p>The strong technical background and research skills developed by the candidate during the project will facilitate taking on highly-paid jobs in industry both in engineering and R&D divisions, particularly within the automotive sector and related OEMs, motorsport and aerospace industry, which are currently transitioning towards electrification. The acquired expertise in electric motor design is also relevant to automation and appliance industry. According to a 2019 survey on PhD graduates in engineering at Politecnico di Milano, their employment rate after one year of graduation is 98%, with an average salary more than 30% above that of MSc graduates.</p>
Composition of the research group	<p>1 Full Professors 3 Associated Professors 0 Assistant Professors 3 PhD Students</p>
Name of the research directors	Matteo Iacchetti



Contacts

matteo.iacchetti@polimi.it

Additional support - Financial aid per PhD student per year (gross amount)	
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Housing - Foreign Students	--
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Housing - Out-of-town residents (more than 80Km out of Milano)	--
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Scholarship Increase for a period abroad	
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Amount monthly	566.36 €
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By number of months	6
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Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information

Educational activities:

Financial aid per PhD student is available for purchase of study books and material, funding for participation in courses, summer schools, workshops and conferences, instrumentations and computer, etc. The amount is about Euro 3.000,00.

Teaching assistantship:

Availability of funding in recognition of supporting teaching activities by the PhD student. There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.

Awards:

Awards will be recognized to the PhD candidate up to Euro 1.500,00 (gross amount, after completion of the 3rd year). More details about this program will be provided by PhD Program Steering Committee.

Computer availability: individual use.

Desk availability: individual use.