



PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 38th cycle

Research Area n. 1 - Advanced Materials and Smart Structures

PNRR_352 Research Field: DESIGN AND VERIFICATION OF ROLLING CUSHIONS FOR GT
AERO ENGINE MAIN SHAFT

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 proposed research focuses on mission M2C2 ENERGIA RINNOVABILE, IDROGENO, RETE E MOBILITÀ SOSTENIBILE of the PNRR. Starting from the 21th UN Climate Change Conference of Parties (COP21), hosted in Paris in 2015, world leaders committed to step up the efforts to contrast the impacts of climate change and to invest resources consistently with a pathway towards low greenhouse gas emissions and climate-resilient development. This implies also a more efficient way to product electrical power, both by using renewable energies and by improving the efficiency of the traditional plants. It is undeniable that energy transition will require the support of the last generation power units, like the GT aero engine, when, for example, other forms of energy (sun, wind) are not available. This requires very quick starts and stops for the machines of middle and large size, used in traditional power plants, and makes maintenance interventions more frequent. Moreover, the use of green fuels, like hydrogen, sets new challenges for the units installed in the already existing power plants. The need to carry out frequent starts and stops to be complementary to the supply of energy by other sources (solar and wind) not available continuously, involves significant thermal transients (which can become even more burdensome with the use of hydrogen as a fuel) and



	<p>a general stress of the components. In particular, the reliability of the GT aero engines depends a lot on the rolling bearings they use, and it is therefore essential to have on the one hand a prognostic system that evaluates the residual useful life in a precise way to allow the service not to be interrupted except for scheduled maintenance. On the other hand, it is necessary to improve the design and have a monitoring system possibly embedded in the bearing that allows to evaluate its condition continuously.</p>
<p>Methods and techniques that will be developed and used to carry out the research</p>	<p>To carry out this research the following methods and techniques will be developed: an accurate model of the roller-element bearings, of the different types, that are installed on the main shaft GT Aero Engine will be established; the model will be validated on the special full-scale test-rig available at the dept. of Mechanical Engineering of Politecnico di Milano, including the possibility to install bearings suitably modified with embedding sensors; the validated model will be used to develop diagnostics and prognostics tools for these components of GT Aero Engine in a hybrid model and data-driven approach exploiting a machine learning paradigm; the tools will be validated with the experimental evidences coming from the fleet of the GT Aero Engine installed in the worldwide plants.</p>
<p>Educational objectives</p>	<p>The educational objectives of the research are the acquisition of the advanced theoretical knowledge and empirical skills for the development of accurate modelling of roller-element bearings, implementing the most sophisticated numerical models and experimental techniques, exploiting the availability of high-end test-rigs. This would include newly developed data analytics, models and simulation tools for use in the design and operation of gas steam turbines, independently from the thermodynamic cycle and the fuel used. With the advent of new technologies and services, this program presents the latest developments that are better leveraged to improve system performance.</p>
<p>Job opportunities</p>	<p>Our last survey on MeccPhD Doctorates highlighted a</p>



	100% employment rate within the first year and a 35% higher salary, compared Master of Science holders in the same field.
Composition of the research group	1 Full Professors 2 Associated Professors 1 Assistant Professors 6 PhD Students
Name of the research directors	Prof. Paolo Pennacchi

Contacts	
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phd-dmec@polimi.it	

Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	Nuovo Pignone Tecnologie S.r.l.
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	University of Twente
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
<p>Financial aid is available for all PhD candidates (purchase of study books and materials, funding for participation in courses, summer schools, workshops and conferences) for a total amount of euro 5.707, 13.</p> <p>Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. 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.</p>



PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 38th cycle

Research Area n. 1 - Advanced Materials and Smart Structures

PNRR_352 Research Field: DYNAMIC BEHAVIOUR OF THE ROTATING MACHINERY FOR
POWER GENERATION IN STEADY STATE AND TRANSIENT CONDITIONS

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 proposed research focuses on mission M2C2 ENERGIA RINNOVABILE, IDROGENO, RETE E MOBILITÀ SOSTENIBILE of the PNRR. Starting from the 21th UN Climate Change Conference of Parties (COP21), hosted in Paris in 2015, world leaders committed to step up the efforts to contrast the impacts of climate change and to invest resources consistently with a pathway towards low greenhouse gas emissions and climate-resilient development. This implies also a more efficient way to product electrical power, both by using renewable energies and by improving the efficiency of the traditional plants. It is undeniable that energy transition will require the support of traditional power plants when, for example, other forms of energy (sun, wind) are not available. This requires very quick starts and stops for the machines used in traditional power plants and makes maintenance interventions more frequent. Moreover, the use of green fuels, like hydrogen, or renewable energies, like geothermal, sets new challenges for the units installed in the already existing power plants. The use of green fuels and the increase in the efficiency of the power units generally involves technical solutions that can determine the emergence of dynamic instabilities, both during the starting and stopping transients, which will become much more frequent, and during operation, fully operational.



	<p>From a technological point of view, the most immediate and least invasive intervention is on the support bearings which must guarantee large margins of stability. It is therefore essential to have reliable models to predict and guarantee smooth operation in the long term even in an energy transition scenario in which the power units are not used in their original design conditions.</p>
<p>Methods and techniques that will be developed and used to carry out the research</p>	<p>To carry out this research the following methods and techniques will be developed: an accurate model of the oil-film bearings, of the different types, that are installed on AEN turbine and generators will be established; the model will be validated on the test rigs available at the dept. of Mechanical Engineering of Politecnico di Milano, after suitable modifications; the developed model will be used to analyse the behaviour of turbines and generators in steady-state and in transient operations, especially to evaluate instability effects; the results obtained will be compared and the model tune-up, if necessary, with the experimental evidences coming from the fleet of the units installed by AEN worldwide.</p>
<p>Educational objectives</p>	<p>The educational objectives of the research are the acquisition of the advanced theoretical knowledge and empirical skills for the development of accurate modelling of oil-film bearings, implementing the most sophisticated numerical models and experimental techniques, exploiting the availability of high-end test-rigs. This would include newly developed data analytics, models and simulation tools for use in the design and operation of gas and steam turbines and generators, independently from the thermodynamic cycle and the fuel used. With the advent of new technologies and services, this program presents the latest developments that are better leveraged to improve system performance.</p>
<p>Job opportunities</p>	<p>Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared to Master of Science holders in the same field.</p>
<p>Composition of the research group</p>	<p>1 Full Professors</p>



	2 Associated Professors 1 Assistant Professors 6 PhD Students
Name of the research directors	Prof. Paolo Pennacchi

Contacts	
<i>Phone:</i> + 02 2399 8440, +39 338 936 8558 <i>Email:</i> paolo.pennacchi@polimi.it	
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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	Ansaldo Energia S.p.A.
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	Texas A&M University
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information	
<p>Financial aid is available for all PhD candidates (purchase of study books and materials, funding for participation in courses, summer schools, workshops and conferences) for a total amount of euro 5.707, 13.</p> <p>Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. 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.</p>	



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Research Area n. 1 - Advanced Materials and Smart Structures

PNRR_352 Research Field: FLOATING WIND FARM CONTROL

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	<p>Wind energy is a clean available renewable energy source, in 2019 wind energy saved 118 million tonnes of CO₂ in Europe and could save up to 270 million tonnes in 2030 - the equivalent of Spain's annual CO₂ emissions, moreover wind does not need to be mined or shipped and the more we use, the closer Europe gets to real energy independence and operating wind turbines do not emit greenhouse gases like carbon dioxide, considering both onshore and offshore, wind energy represents one of the cheapest renewable source on the market. It is estimated that 60-80% of the offshore wind resource of Europe is located in waters deeper than 50 m. Offshore wind turbines have been routinely installed on bottom- fixed foundations (i.e. the wind turbine is connected to the seabed), but this is no longer feasible in waters deeper than 50 m. The main limitation to the bottom-fixed technology is the increased hydrodynamic loads experienced by the support structure members that must be of larger diameters. The floating concepts can be generally implemented in areas where water depths are higher than 50-70 meters. These water depths are considered as a technical and economical limit for the conventional fixed bottom foundation types. Floating wind foundations are however a frontier technology since there are not yet operative large-scale commercial farms anywhere in the world nowadays. Their maturity though is</p>



	<p>growing rapidly, with several concepts on various stages of development, with most of them at prototype level. A small number of floating concepts has already reached the pre-commercial demonstration level. Moving from the single turbine to the wind farm represents another big challenge of the research, in particular new and dedicated control strategies -at farm level- could represent a quantum leap in extracting power from the flow, reducing the costs of energy and making it more competitive on the market.</p>
<p>Methods and techniques that will be developed and used to carry out the research</p>	<p>Research objectives will be pursued combining numerical modelling and experimental tests and the state of the art of floating wind turbine control engineering. Reduced order models, multibody simulations and multi-fidelity models will be used for the design process. Considering the interdisciplinarity of the topic; the very complex aerodynamics and hydrodynamics problems the research must be studied with proper numerical and experimental methods.</p>
<p>Educational objectives</p>	<p>We provide doctoral candidates with high-level scientific training, fostering and refining research and problem-solving abilities by focusing on both theoretical and experimental skills. A PhD in Mechanical Engineering will be able to layout, draft and carry-on original research, by leading a research group or working in a team.</p>
<p>Job opportunities</p>	<p>Job opportunities can be found in the wind energy industry, floating wind energy industries, renewable energy. Among the companies and institutions that are cooperating in the research ENI, TUDelft and Peak Wind can be listed.</p> <p>Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared to Master of Science holders in the same field.</p>
<p>Composition of the research group</p>	<p>3 Full Professors 4 Associated Professors 4 Assistant Professors 5 PhD Students</p>



Name of the research directors	Prof. Marco Belloli
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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	ENI S.p.A.
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	Delft University of Technology
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
<p>Financial aid is available for all PhD candidates (purchase of study books and materials, funding for participation in courses, summer schools, workshops and conferences) for a total amount of euro 5.707, 13.</p> <p>Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. 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</p>



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Research Area n. 1 - Advanced Materials and Smart Structures

**PNRR_352 Research Field: METHODS FOR NI AND CO-BASED SUPERALLOYS DAMAGE
ANALYSIS AND SERVICE LIFE ASSESSMENT: STATE OF THE ART SURVEY AND
DEVELOPMENT/TESTING OF NEW METHODOLOGIES**

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	<p>In the field of high-temperature materials one way to increase the material efficiency is extending their service life, limited by microstructural modifications referred as material damage. Proper methodologies can well predict service exhaustion by material damage on the basis of multiple analyses of parts. The objective of the thesis is the development of a methodology for damage evaluation and service life prediction to be easily implemented at industrial level by the project partner to Ni or Co-based superalloys. The PhD project is coherent with Mission 4C2 of PNRR (since it favours the applied research in synergy between Universities and Companies) and M1C1 (digitalization, innovation and competitiveness of the production system).</p>
Methods and techniques that will be developed and used to carry out the research	<p>The PhD student will carry out a detailed survey on damage forms, damage development and methodologies to predict damage development and service life exhaustion of Ni and Co- based superalloys. In a second stage of the PhD will focus on the development of a methodology based on multi-level approach, including material and material damage characterization, material-processing-properties correlations and their analyses. The initial focus will be on a reference alloy for which</p>



	experimental data are available for project partner, possibly adding up new specific innovative material tests. The proposed methodology will be validated on another material.
Educational objectives	At the end of the PhD cycle the candidate will be able to define, design and carry out original research programs by working in a team or leading a research group in the field of high-performance materials. Educational activities during PhD will include research management, exploitation of research results and intellectual property.
Job opportunities	Job opportunities are foreseen at national and international academic institutions, high-tech companies and SMEs involved in innovation and technical development, specifically where high-performance materials are applied. Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared to Master of Science holders in the same field. The PhD student will cooperate with institutions such as CNR, TU Graz, OVG Magdeburg as well as other Institutions and Companies related to the project partner.
Composition of the research group	2 Full Professors 2 Associated Professors 2 Assistant Professors 4 PhD Students
Name of the research directors	Prof. Elisabetta Gariboldi

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Additional support - Financial aid per PhD student per year (gross amount)

Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad



Amount monthly	700.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	Nuovo Pignone Tecnologie S.r.l.
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	Graz University of Technology
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
<p>Financial aid is available for all PhD candidates (purchase of study books and materials, funding for participation in courses, summer schools, workshops and conferences) for a total amount of euro 5.707,13.</p> <p>Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. 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.</p>