



# PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 39th cycle

**THEMATIC Research Field: EFFICIENT AND VERSATILE MODELLING FOR COMPONENT  
DESIGN**

<b>Monthly net income of PhDscholarship (max 36 months)</b>
<b>€ 1400.0</b>
In case of a change of the welfare rates during the three-year period, the amount could be modified.

<b>Context of the research activity</b>	
<p><b>Motivation and objectives of the research in this field</b></p>	<p>Design of composite parts requires the prediction of the failure modes occurring in the different components. Such endeavour requires to develop experimental and computational methods for the assessment of the structural integrity and advanced design of mechanical components, vehicles and structure. Of all the failure modes of composites, delamination is one of the most common and dangerous. Several Finite Element (FE) software currently implement different techniques to analyse the onset and growth of such defects and are thus an important tool for the design of lightweight composite parts. However, models dedicated to delamination predictions under fatigue are still a trade-off between accuracy and computational efficiency. Moreover, these models are mainly developed and adopted for specimens or simple parts: their adoption to large parts and arbitrarily shaped delamination fronts is still limited. As a result, composite parts are overdesigned with very high safety coefficients. One of the objectives of the present research is to develop and validate a numerical design approach for laminated composite parts. This requires the development of a modelling strategy to efficiently predict the propagation rate under fatigue loadings of arbitrarily shaped delaminations.</p>
<p><b>Methods and techniques that will be developed and used to carry out the research</b></p>	<p>First of all, the PhD student will be required to study in-depth the literature available on the topics related to the research. These include finite element modelling, fracture</p>



	<p>research. These include finite element modelling, fracture mechanics, fatigue tests on specimens and on parts, non-destructive techniques, tests on components. Regarding composite failure, several models have been developed so far for the fatigue predictions of delamination propagation under fatigue using Cohesive Zone Modelling (CZM) or the Virtual Crack Closure Technique (VCCT). However, both techniques are based on the description of the strain energy release rate as a combination of three basic fracture modes: mode I (opening, <math>\perp</math>) and modes II and III (shearing modes, <math>\parallel</math> and <math>\text{III}</math>). However, when dealing with curved non-planar cracks, the decomposition of the shearing modes <math>\parallel</math> and <math>\text{III}</math> is accurate only when the FE mesh is orthogonal to the crack front. The PhD student will thus benchmark all the available approaches, both CZM-based or VCCT-based, and evaluate the different performance in terms of accuracy, computational efficiency and application to curved crack fronts or large composite parts.</p> <p>After the benchmarking of the state-of-the-art models, the PhD student will develop an improved approach for the calculation of <math>\perp</math>, <math>\parallel</math> and <math>\text{III}</math>. The student will exploit the enhanced potentialities of combining Abaqus with Python or with Fortran via User Subroutines. In particular, the student will ensure an automatic remeshing is performed during the simulations, so that the shearing direction are always correctly and constantly defined during the advancing delamination front. Once this approach is developed, existing CZM or VCCT models will be applied using the improved calculation of <math>\perp</math>. The models will then be evaluated and compared with the prior benchmarking activity, to assess the achieved improvements. It will then be possible to implement the developed approach and improved model into a holistic design tool for laminated composites. This will then be validated against experimental data on large laminated parts.</p>
<p><b>Educational objectives</b></p>	<p>The Doctor in Mechanical Engineering will be able to define, start and carry out original research by working in a team or leading a research group. Both theoretical and experimental skills will be mastered.</p>



<p><b>Job opportunities</b></p>	<p>The holder of a PhD in Mechanical Engineering will have job opportunities in structures/organizations aimed at innovation and/or research and technical development, high-tech SMEs, and government departments ruling on public needs. Specifically, the proposed research topic can offer job opportunities in the field of advanced manufacturing of composite structures.</p> <p>List of Universities, Companies, Agencies and/or National or International Institutions that are cooperating in the research include:</p> <ul style="list-style-type: none"> <li>•AMADE (Analysis and Advanced Materials for Structural Design) research group of the University of Girona</li> <li>•KU Leuven</li> <li>•University of Bristol</li> <li>•University of Leeds</li> </ul> <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><b>Composition of the research group</b></p>	<p>1 Full Professors 1 Associated Professors 1 Assistant Professors 4 PhD Students</p>
<p><b>Name of the research directors</b></p>	<p>Prof. Andrea Bernasconi, Dr. Luca Martulli</p>

<b>Contacts</b>
<p><i>Phone:</i> +39 02 2399 8222 <i>Email:</i> andrea.bernasconi@polimi.it</p> <p>For questions about scholarship/support please contact phd-dmec@polimi.it</p>

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

<b>Scholarship Increase for a period abroad</b>	
<p><b>Amount monthly</b></p>	700.0 €
<p><b>By number of months</b></p>	6



**Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information**

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.

Our candidates are strongly encouraged to spend a research period abroad, joining high-level research groups in the specific PhD research topic, selected in agreement with the Supervisor. An increase in the scholarship will be applied for periods up to 6 months (approx. 700 euro/month- net amount).

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.