POLITECNICO DI MILANO

PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 38th cycle

Research Area n. 3 - Engineering Design and Manufacturing for the Industry of the Future

PNRR_352 Research Field: CIRCULAR DESIGN ENHANCING CLOSED-LOOP WIND BLADE RECYCLING

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	Fibre-reinforced polymers has gained increasing significance in the past few decades in several important manufacturing sectors. In particular, glass fiber and carbon fiber reinforced polymer composites (GFRP and CFRP respectively) have been successfully employed in different manufacturing areas that include transportation (automotive, aerospace, recreational boating, naval), construction (building and infrastructures, wind turbines), electrical/electronic components and consumer/sporting goods, as a result of their lighter weight, excellent mechanical properties and intrinsically better chemical resistance with respect to metals. In particular wind turbine (WT) blades widely use GFRP and CFRP. Recent wind turbine models use on average 10t of GFRP per MW. The growing demand of WT blades is increasing constantly at a faster rate. On the other hand, taking into consideration that WT has a standard design service lifetime of about 20-25 years, a significant proportion of installed WT (about 200 ktons of composite waste) will complete its standard lifetime from 2020 to 2034. The complex material compositions and the cross-linked nature of fiber-reinforced plastics, especially thermoset, make recyclability complex. Most of the composites used today are disposed in landfills. Unlocking the potential of a closed loop business model for blades from wind energy

	would therefore significantly contribute to a shift towards a more carbon-neutral economy and industry, avoiding landfilling and re-introducing in the manufacturing cycle a large amount of recycled fibers. The objective of the Phd will be to increase the closed-loop recycling and re-use capabilities of wind blade materials through smart high-voltage fragmentation and thermo-chemical technologies enhanced by novel thermo-responsive composite resins embedded within a sustainable re-design of wind blades. This objective is coherent with the green and digital development path of the Italian industry, as reported in the Mission of the PNRR.
Methods and techniques that will be developed and used to carry out the research	The work will be carried out following the different phases reported below: critical review of the current design of wind blades in view of easier disassembly, cutting, sorting of composite fractions and transport; analysis of commercial thermo-responsive resins and their potential for a massive penetration in the wind blade market; design of experimental activities for testing the technical efficiency of novel high-voltage fragmentation and thermo-chemical recycling technologies to treat the analyzed composite fractions; development of validation tests and characterization of the dependency of the output performance on the characteristic process parameters, exploiting physics-based and AI-based digital twins of the recycling processes; investigating the re-usable potential of the obtained fiber and resin fractions; validation of reuse options within reprocessed composite samples in view of future closed-loop applications in the wind energy systems. The output of the activity will include detailed blade re-design criteria to support a sustainable-by-design approach to future wind blades.
Educational objectives	This work will increase the competences of the candidate in the area of sustainable composite materials, novel design of complex technical structures, advanced and digitally-enhanced recycling processes and circular economy business cases.
Job opportunities	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.
Composition of the research group	0 Full Professors 1 Associated Professors 5 Assistant Professors 7 PhD Students
Name of the research directors	Prof. Marcello Colledani

Contacts
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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)	to be defined
By number of months abroad	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. 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.