POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 38th cycle

PARTENARIATO PNRR Research Field: PNRR MOST-URBAN MOBILITY: NEW MATERIALS AND STRATEGIES FOR PASSIVE SAFETY OF VEHICLES WITH ADVANCED DRIVING SYSTEMS

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 diffusion of advanced assisted driving systems and the expected introduction of autonomously driven vehicles in mass transportation pose new challenges and opportunities for the passive safety of cars. Several studies report that autonomous (or assisted-driving) vehicles (AV) are capable to avoid pedestrian collisions by active actions, but are significantly more prone to rear-end crashes with conventional vehicles (CV) at relatively low speeds. Such studies indicate the effectiveness of on-board sensors to detect potential collisions with Vulnerable Road Users (VRU), such as pedestrians, cyclists, and motorized 2-wheelers, but also suggest that the number of crashes in transportation systems where AV and CV coexist could actually increase. This scenario may amplify the current conflict of requirements for bumpers and vehicle front-ends that arises considering collisions with VRU and car damageability in vehicle-to-vehicle collisions. At the same time, new materials, meta-materials, and smart structures emerged in the last decades, with the potential of increasing and tuning the absorbing capabilities of the energy absorbers, of providing functionally graded systems for modulating the stiffness according to the severity of impacts, and even of adapting their characteristics according to external stimuli, such as those provided by collision detection systems. Such possibilities are offered by cellular meta-materials with

	variable, an even negative, Poisson’s ratios, multi-materials absorbers, and passive or active structural systems, with variable stiffness configurations and capability to undergo progressive shape changes without mechanisms, as in the case of morphing structures studied in aerospace applications. A proper selection of material and manufacturing choice, application of recycled materials, and diffusion of additive manufacturing techniques could lead to innovative, but cost-affordable and environmentally sustainable solutions for new generations of absorbers to be integrated into modern vehicles. The scope of the research program, activated within the activity of the MOST centre for sustainable mobility funded by PNNR, is the investigation of innovative energy absorbing systems and their application to vehicles with assisted driving systems, developing potential solutions assessed by virtual testing methods, possibly including the adoption of biomechanical models of the VRU and the application of machine learning regression techniques to evaluate optimal configurations (CUP D43C22001180001 D.D. 1033 del 17/06/2022).
Methods and techniques that will be developed and used to carry out the research	The research program will involve numerical activities for the exploration and evaluation of crash scenarios involving vehicle-to-vehicle and VUR-vehicle collisions and for the definition of structural solutions to be integrated into the vehicles, including active or semi-active configurations. Some experimental activities will be carried out on representative samples of the solutions conceived and explored for the innovative absorbing systems. An initial phase will be dedicated to the set-up of crash scenarios and the choice of the most appropriate numerical tools. In particular, a commercial explicit code for crash simulations will be selected among the different options (Abaqus Explicit, LS-Dyna, Open Radioss) available at Dept. of Aerospace Science and Technology (DAER), also considering the commercially available virtual models of cars and of Anthropomorphic Test Devices. Moreover, collaborations will be activated with other research labs to explore the possibility of applying

	biomechanical models of the human body parts exposed to injuries in VUR-vehicles collisions. The current solutions for bumpers and front-end cars will be reviewed and critically analysed to formalize the requirements for optimal systems in various types of collisions. In the central phase of the program, solutions based on cellular geometries, also including foam-filled and multi-materials solutions will be modelled including the possibility of functionally graded absorbers and the introduction of actuation to achieve stiffness or geometry modifications on the basis of the information acquired by collision detection systems. In this phase, the program will take advantage of the experience gained at DAER on cellular meta-materials and smart structures. Material selection will be carried out considering mechanical performances, the cost, the difficulties involved in manufacturing, and the potential application of recycled materials. A limited set of configurations will be produced, by using 3D printing techniques, and tested to assess the performance and validates the numerical models. In the third phase of the project, the materials selected with be applied to bumpers and front-end geometries to evaluate the performances of the systems. The finite element models will be developed from the ones adopted in the first phase of the study, modifying the vehicle front-ends according to the solution developed in the second phase, and comparing the results with more conventional solutions.
Educational objectives	The candidate will acquire significant competencies in the numerical approaches for high-velocity transients, including the development of meshes, modelling of contacts in complex scenarios, analysis management, and post-processing. The development of codes for automatic model generation and the application of regression methods for data analysis and selection of solutions will be part of the activity and will represent the opportunity to attain general skills in numerical and data analysis. The development of realistic models will involve the practical application of material constitutive laws for non-linear responses, including elastic-plastic, visco-elastic-

	plastic cases, and the representation of fractures. Moreover, the researcher will also capitalize on the studies carried out at DAER on cellular meta-materials and morphing structures, applying existing knowledge to specific problems with well-defined requirements. From the engineering point of view, the activity will lead to the acquisition of a broad set of competencies for the design of crashworthy structures and energy-absorbing systems, which will be valuable not only in the automotive considered in the program but also in other technical fields related to transportation vehicles and safety. Such competencies will be integrated by the technological activity for the production of representative samples with innovative production methods, such as additive manufacturing. The experimental activity performed to assess the solutions will complete the formation of the researcher with fundamental skills and insight related to the development and qualifications of new products.
Job opportunities	The research program will provide a set of competencies related to crashworthiness, which are fundamental in the design of ground transportation systems, thus opening job opportunities for all the companies involved in the design of structures for automotive and railway vehicles. Important possibilities are offered in the areas of motorsport applications, where regulations impose more and more severe requirements on occupant protection in case of crashes. Such opportunities will arise both at the level of manufacturing companies and of original equipment manufacturers, which require professional figures capable of managing crashworthy design. Possibilities are amplified considering the transformation that is currently undergoing in the field of mass transportation, which includes not only the diffusion of vehicles with autonomous or assisted drive but also applications of new energy storage concepts, with new hazards and new architectures for structural integration. The competencies regarding crash design are also very important for companies in the aeronautical field, particularly for the design of impact-tolerant structures and crashworthy structures for helicopters and innovative vehicles, such as tilt rotorcraft and electrical take-off and

	landing vehicles. The specific numerical skills acquired in the activity and the more general competencies regarding finite element analysis and data analysis will be valuable for a large number of companies acting in the field of engineering consultancy. The more innovative aspects of the program, such as the identification of absorber configurations with new cellular materials, variable stiffness, and adaptive characteristics, will make possible the continuation of the research activities in universities and research centres, at the national and international levels.
Composition of the research group	0 Full Professors 2 Associated Professors 1 Assistant Professors 2 PhD Students
Name of the research directors	Prof. Alessandro Airoldi

Contacts
Dipartimento di Scienze e Tecnologie Aerospaziali - Politecnico di Milano Via La Masa 34, 20156 Milano - Italy +390223998323 - email: phd-daer@polimi.it web: https://www.aero.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	2100.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
The Ph.D. candidate will receive a desk and a personal computer. Apart from the compulsory ones, the Ph.D. candidate will have the opportunity to follow additional courses, receive economic support to attend summer schools, and participate in conferences. There will be the possibility of paid teaching assistantship.