MATERIALS SCIENCE AND TECHNOLOGY

Ateneo - Localized heating joining technologies

Funded By	Politecnico di TORINO [P.iva/CF:00518460019]
Supervisor	FERRARIS MONICA - monica.ferraris@polito.it
Contact	DE MADDIS MANUELA - manuela.demaddis@polito.it
Context of the research activity	Localized heating joining technologies such as laser joining are high-precision joining technologies essential for industries like automotive, aerospace, and nuclear sectors. Localized heating is aimed to generate intense, focused heat with minimal material impact, to ensure efficiency and versatility.This research aims to exploit localized heating technologies for extreme environments, focusing on advanced materials, process optimization to improve joint quality and durability.
	Among localized heating joining technologies, laser assisted joining is a widely used method for obtaining high-quality welded joints using a high-density laser as the heat source. Its versatility and efficiency make laser joining an indispensable solution in various industries, such as automotive, aerospace and nuclear applications. By adjusting process parameters such as wavelength, power, focal position, and speed, the desired heat source needed for specific applications can be generated. The process provides intense, focused heat with minimal impact on surrounding materials, excellent accuracy and high speeds. This advanced technique demonstrates the adaptability and precision of laser welding, which can meet the stringent requirements of modern industries. More innovative applications of laser joining may require advances in the process, such as the use of filler materials or continuous oscillation of the laser beam at a relatively high frequency (wobbling technique to increase the width of the joint interface and induce a stirring action within the molten weld pool) or the shaping of the laser beam to optimize the energy distribution of the laser spot.(con la nostra testa laser non abbiamo il wobbling o il beam shaping ma lo hanno altre università con le quali si potrebbe collaborare) Among the most significant challenges for laser joining is the application of laser brazing to join traditional stainless steel with advanced materials such as carbon fiber-reinforced ceramic matrix composites (exceptional performance in extreme environments) or laser-assisted joining, which employs fillers such as silica-alumina-yttria-based glass for bonding high-performance ceramic components such as silicon carbide (SiC, is known for

Objectives	its strength, thermal stability, and corrosion resistance, which are essential for nuclear applications). The main objectives of this research activity involve the development and implementation of advanced welding and joining techniques in the aerospace and nuclear fields, with a particular focus on the use of ceramic materials, advanced composites, and metal alloys. The primary research objectives include: -Literature review : Review of current localized-heating joining technologies and materials used in aerospace and nuclear applications to identify gaps and areas for improvement, directing future research efforts. -Study of new materials : Study of materials that can be welded effectively for various applications, including nuclear use, by improving their resistance to extreme conditions such as high temperatures, vacuum and radiation. -Welding process optimization: Identification and optimization of welding techniques for various combinations of materials. This includes defining optimal environmental and configuration conditions to improve joint quality and energy efficiency. -Experimental validation: Conducting joining experiments on advanced materials to evaluate the mechanical properties, durability, and overall performance of the joint, with a focus on the possibility of joining materials previously considered difficult or impossible to join -Advanced NDT methods: Use of nondestructive testing techniques to detect and characterize defects without damaging components, ensuring the integrity and safety of structures in aerospace and nuclear applications. Integration of sensors for monitoring: Implementation of advanced sensors to monitor joining processes in real time, enabling precise control, early detection of anomalies, and comprehensive data collection to improve process understanding and related results.

Skills and competencies for the development of the activity	This research requires expertise in materials science, joining technology, including knowledge of alloys, ceramics, and composites. Proficiency in process optimization, parameter control, and mechanical test of joined components is essential. Experience with advanced nondestructive testing (CT-scan) methods and data analysis is critical. Familiarity with aerospace and nuclear industry standards, as well as collaboration in multidisciplinary research environments, is highly valuable.