DISSIMILAR WELDED JOINTS FOR SHIP STRUCTURES

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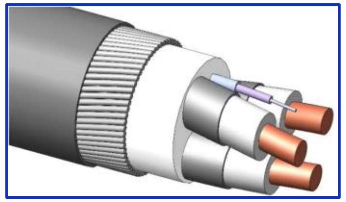
A.A 2025/2026

Research: underwater cables

FIRST STEP



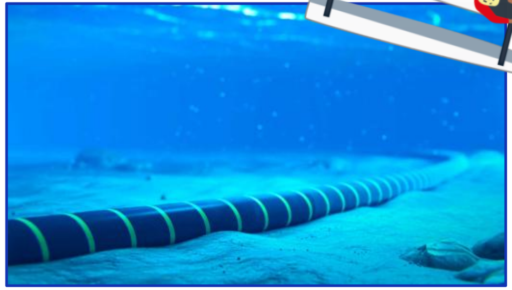
The study of the all applications for the cables and possible sensors to integrate.

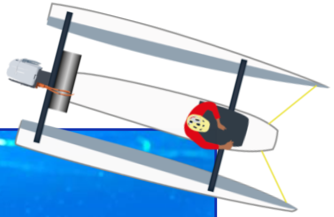
Integrated the study with experimental tests in the laboratory. Materials for marine applications.

Research development at underwater companies; Oceans & Cables

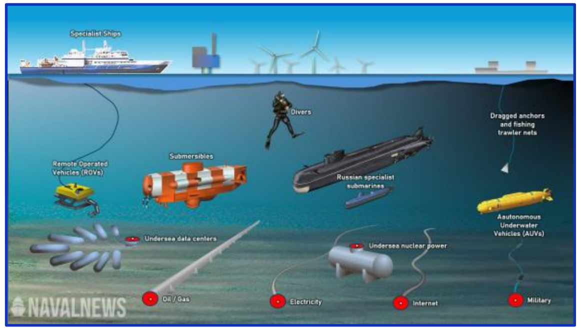
SECOND STEP

Research conducted at CENTEC for the development of a design procedure of the cables under in service loadings.





Combine the study with the water tests.



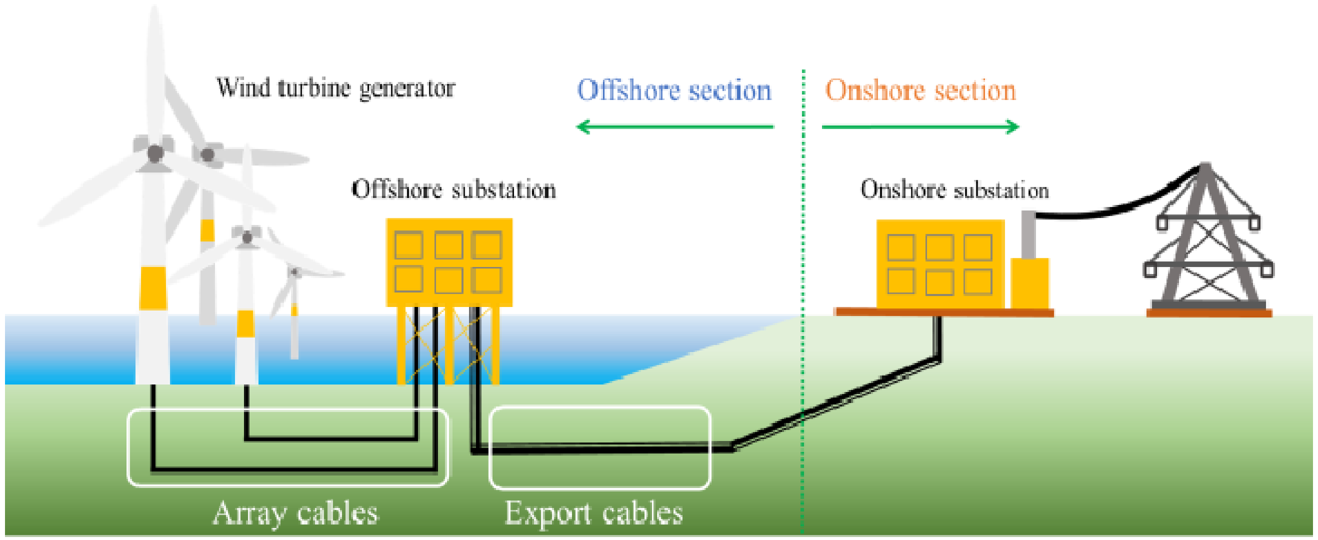
Expand the study with the other submarine infrastructure. Autonomous vehicles

Applications of bimetallic welded joints in the structural connections of supports for subsea cables in offshore structures

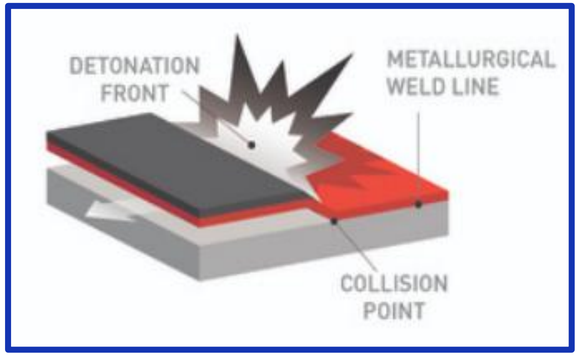
Shipbuilding and **offshore structures** (submarine cables) involve a variety of metallic materials, from standard steel to high-strength steels, and aluminium and titanium alloys.

Welding is the most common joining technique, but connecting dissimilar materials remains a major challenge. **Explosion welding (EW)** technique has been increasingly applied for joining dissimilar metallic materials.

The **implementation** of explosion welding in shipbuilding has been supported by an extensive experimental research program, which has now led to widely adopted commercial solutions utilizing various base materials and interlayers.



Applications of bimetallic welded joints in the structural connections of supports for subsea cables in offshore structures



The explosion welding process is a solid-state welding technique that uses high energy of explosives to join two dissimilar metals through cold welding.

The bonding occurs as a results of the intense plastic deformation at the collision front of the metal surface, driven by a controlled chemical explosive charge.

Applications of bimetallic EW joints:

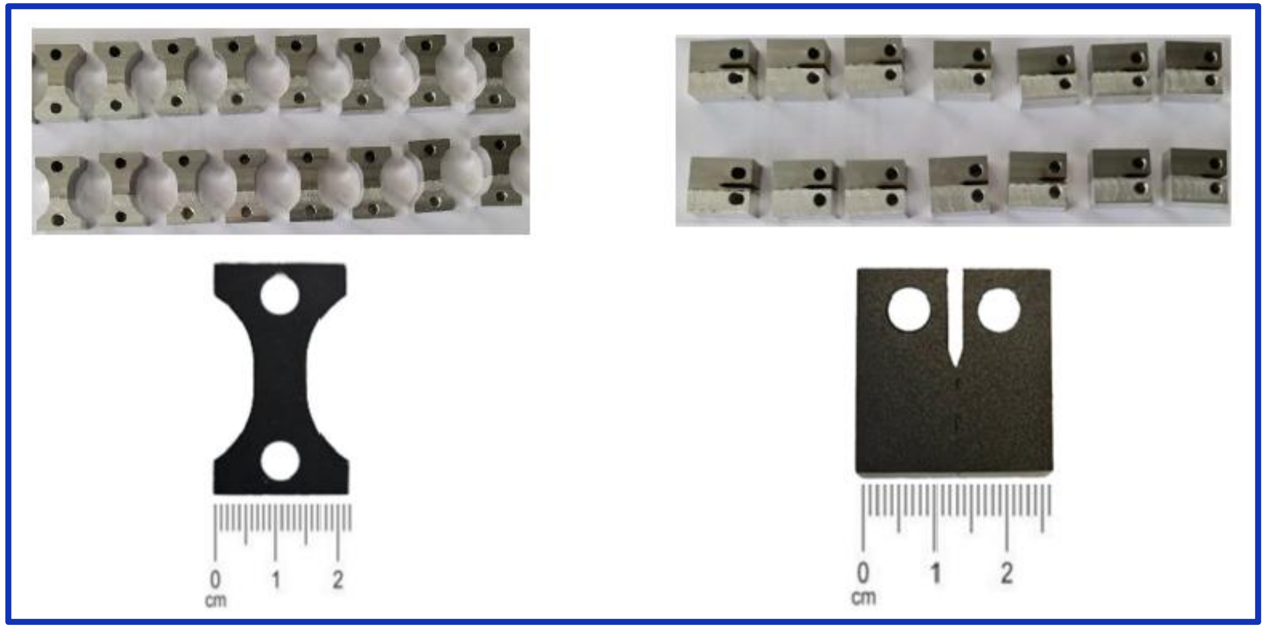
- *Shipbuilding connection* of Al superstructure to steel deck (a).
- *Offshore structures* connection to the deck and the supporting structure (b).

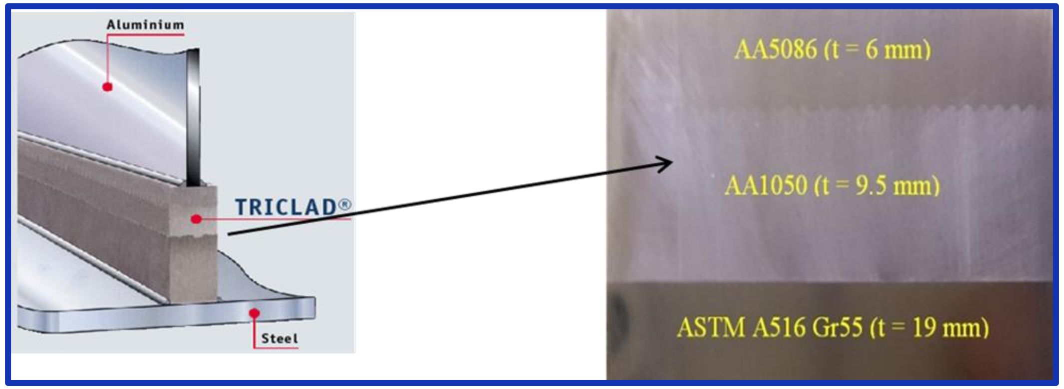
a

b

Materials and methods

Evaluation of the mechanical behaviour of aluminium/steel explosion welded joints for ship structures. Investigated EW joints:
ASTM A516 Gr55 structural steel, clad by explosion welding with AA5086 aluminium alloy with an intermediate layer of AA1050 commercial pure aluminium.



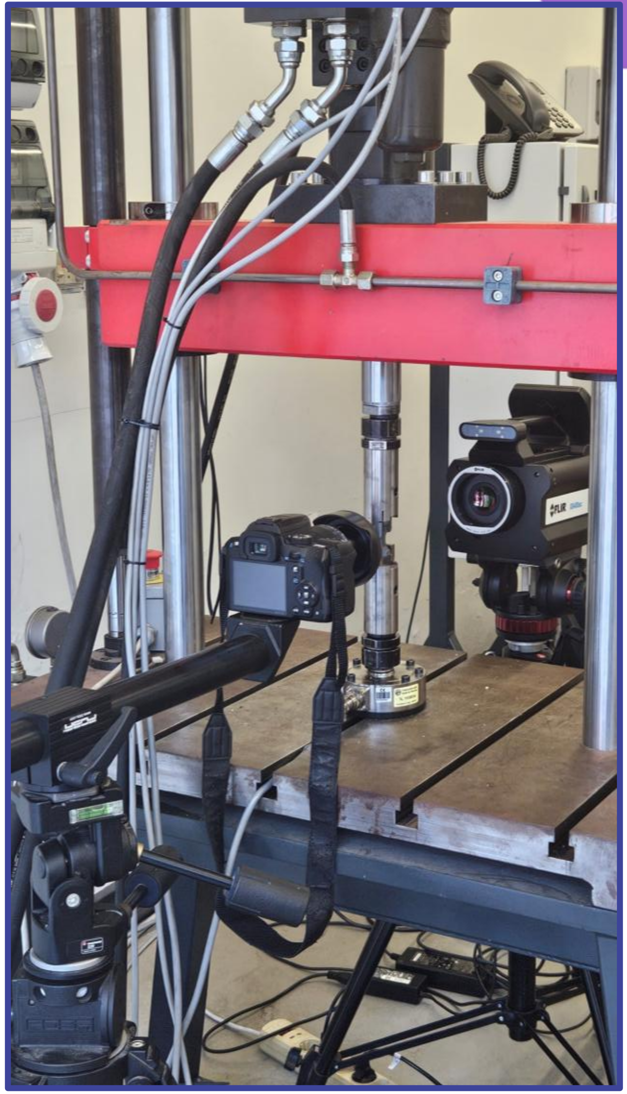


- ✓ Tensile tests carried out on dog bone specimens
- ✓ Mechanical tests carried out on compact tension (CT) specimens
- ✓ Non-destructive evaluation of failure modes and damage mechanisms.

Materials and methods

The material selected for the welded joints is TriClad® aluminium/steel transition joints produced by explosion welding.

- The specimens were first subjected to visual analysis by optical microscopy for defects detection.
- The mechanical tests were performed by an Italsigma servo-hydraulic testing machine equipped with a 25 kN load cell.
- Tests speed was equal to 5 mm/min in displacement control.

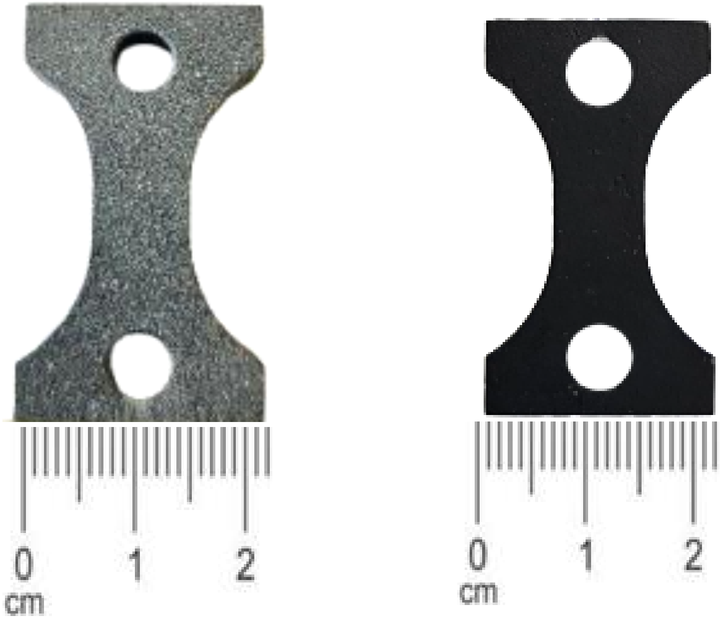


Materials and methods

The set-up included the following non-destructive techniques:

- **Digital Image Correlation (DIC)**, used to calculate the field of displacements and strain during the tensile tests with open source 2D DIC software Ncorr v1.2;

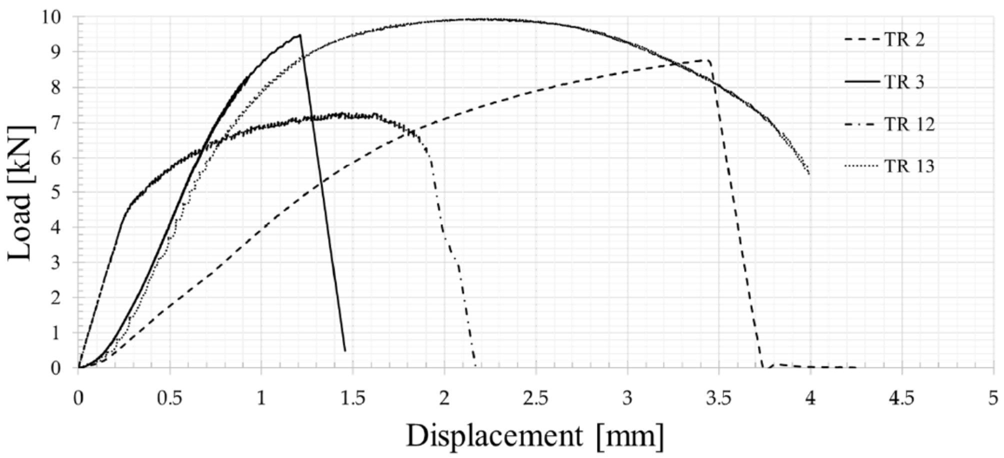
- **Infrared thermography (IRT)** by using a cooled FLIR X8400sc infrared camera. The thermal image were acquired at 150 Hz. The surface of the specimens was painted black. The tests were recorded with a resolution of 1920 x 1080 pixels and an acquisition rate of 25 fps. The images were calibrated, considering the dimensions of the specimens, with a resolution of 0.04 mm/pixel for tensile specimens and 0.03 mm/pixel for fracture mechanics tests.



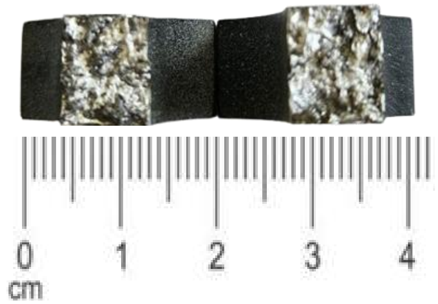
Speckle pattern

Results and discussion

Analyzing the results of the tensile tests, the strength and the plastic behaviour seem to be affected by defects detected on the fracture surface.

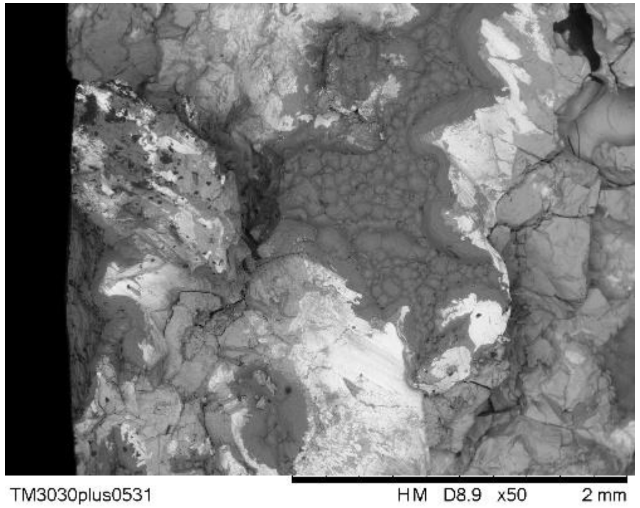


TR2

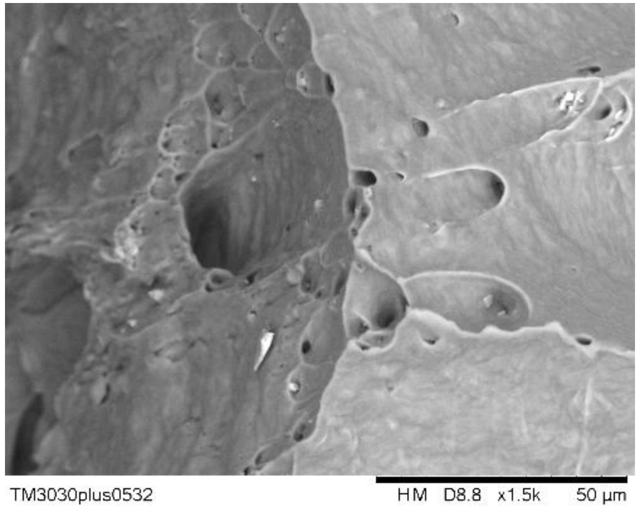


Scanning Electron Microscope (SEM) images

a (TR2)

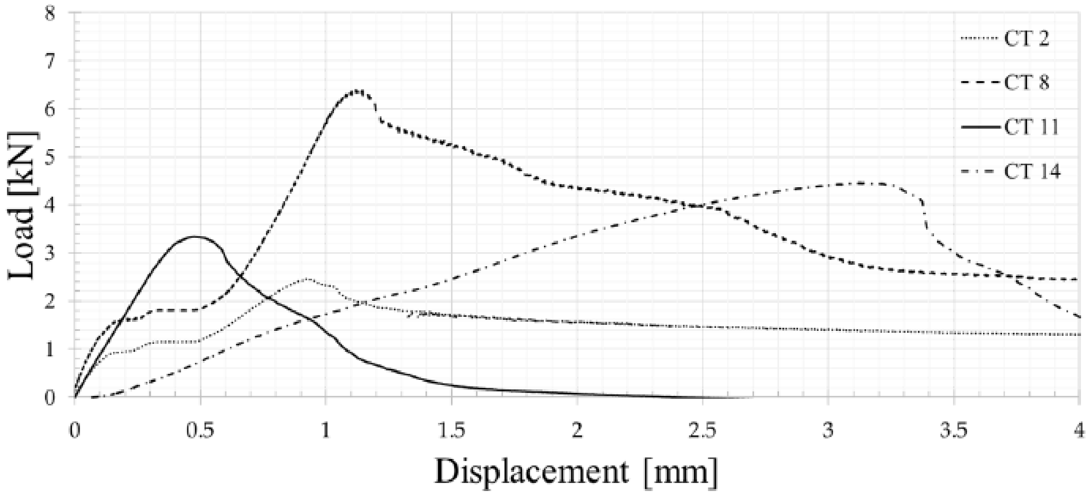


b (TR2)

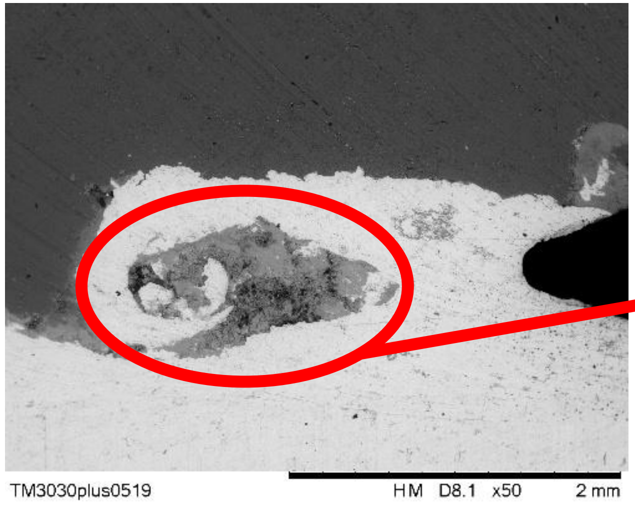


Fracture surface of the TR2 tensile specimen:
(a) crack initiation site;
(b) a details of pore clusters.

Results and discussion

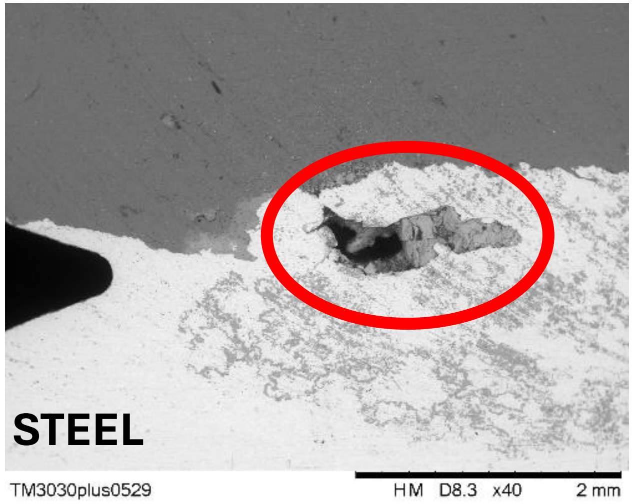


a (CT14)



b (CT14)

c (CT14)



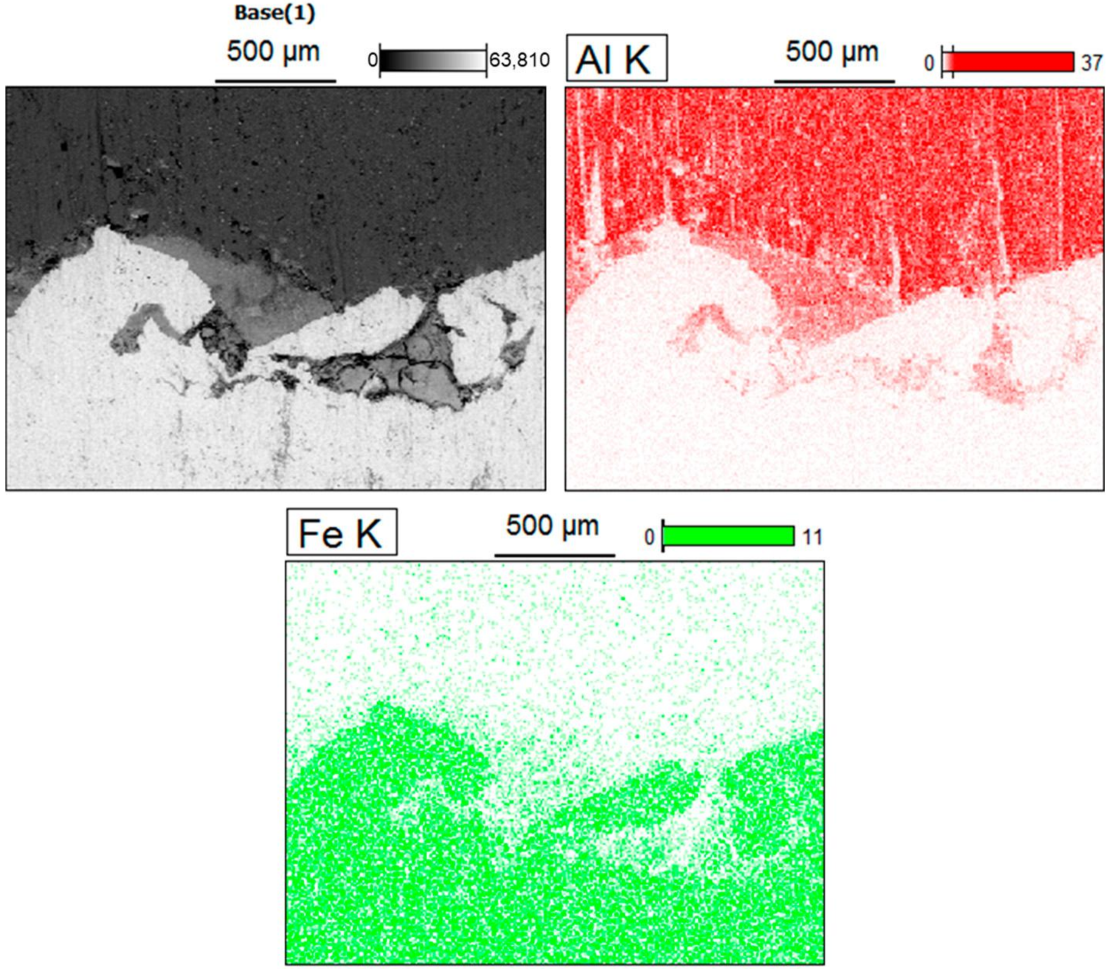
CT14

Analyzing the results for the CT specimens, the strength and the plastic behaviour appear to be affected by the morphology of the welding interface:

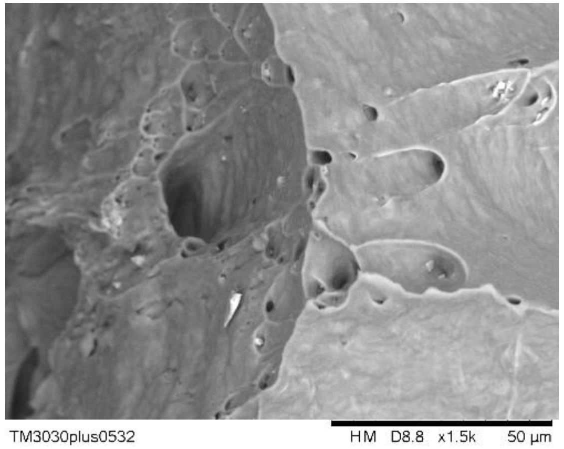
(a - b) intermetallics in the crack path and (c) defects in the external surface.

Results and discussion

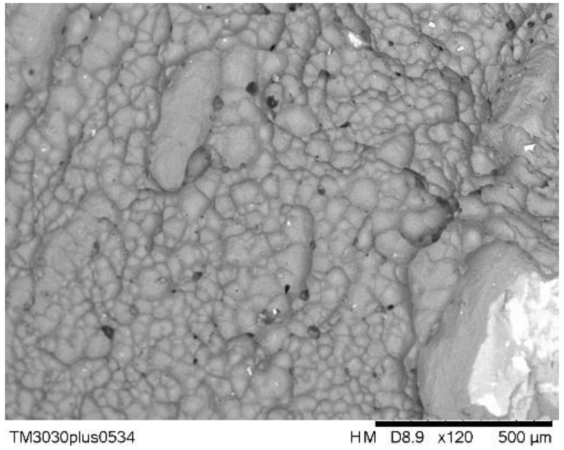
The presence of intermetallics was detected by energy - dispersive X-ray spectroscopy (EDS) analyses, which highlighted phases containing both Al and Fe.



a (TR2)

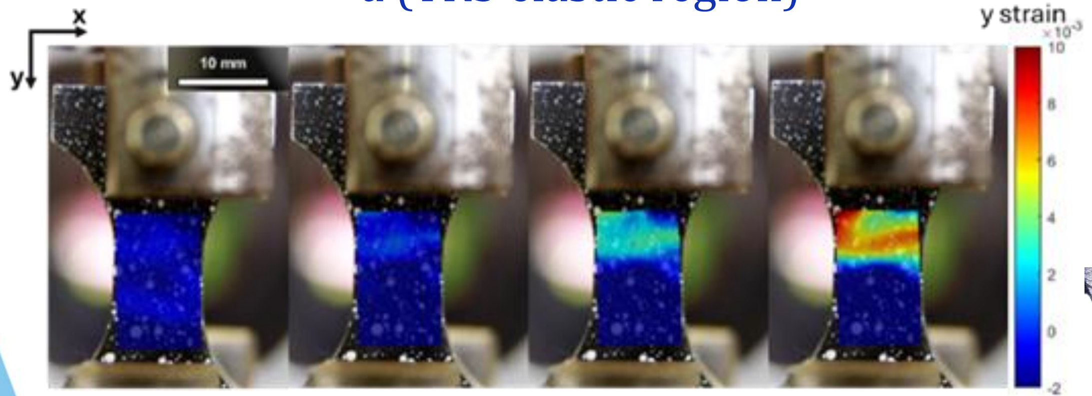


b (CT14)

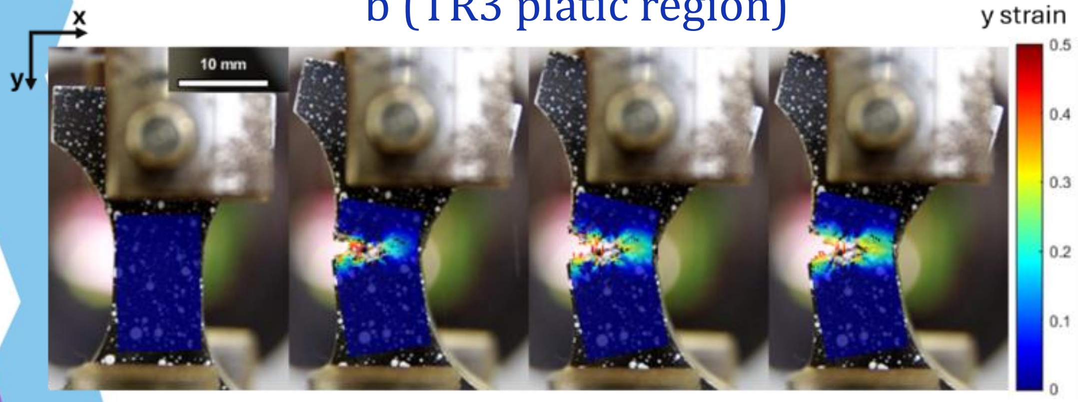


Results and discussion

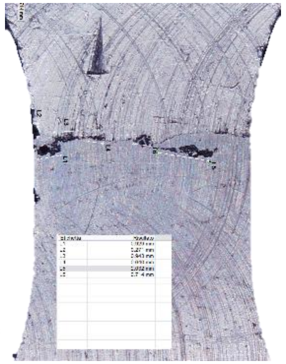
a (TR3 elastic region)



b (TR3 platic region)



c (TR3)



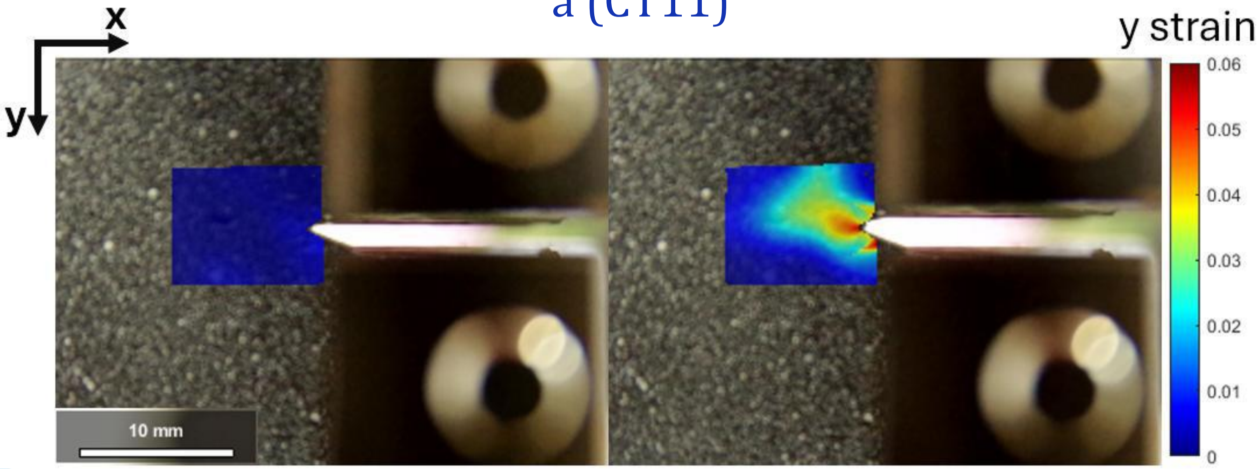
DIC images of dog-bone specimens highlighted that the strain field in the elastic region is strongly affected by the mismatch between the elastic moduli of the steel and the aluminium.

Not only the elastic strain is higher in pure Al, but also it is concentrated along the interface, where great quantities of intermetallics and discontinuities were detected by *digital microscopy inspection*.

The final failure of the specimen was placed in correspondence of the weld.

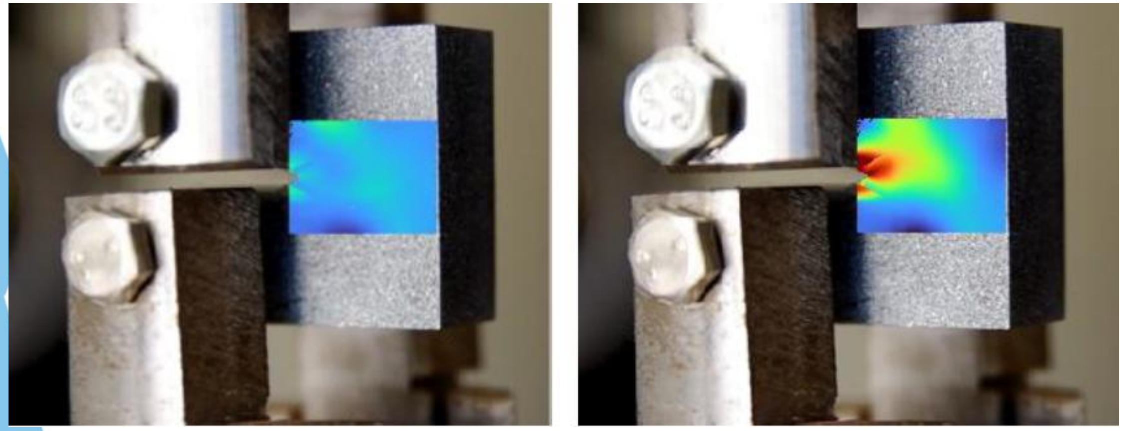
Results and discussion

a (CT11)



DIC results for the CT11 specimen: when the crack started propagating, the strain concentration appears at the notch, but the values are higher in the aluminium part of the specimen.

b (CT14)



DIC results for the CT14 specimen - *only for a qualitative evaluation* – which considers a wider range of interest (ROI): when crack initiation occurred, the strain values increase mainly towards aluminium interface.

Results and discussion

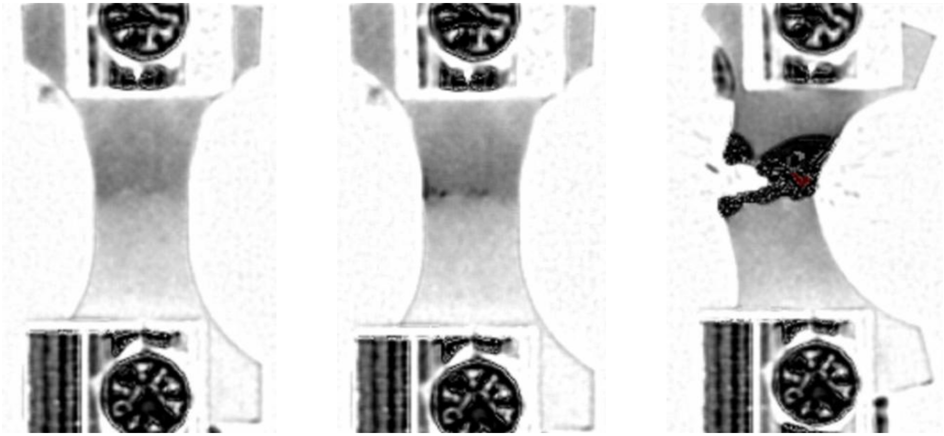
POST-PROCESSING:

- Manual Thermal Focus;
- Filter Windows avarage kernel 3 x 3;
- Digital Detail Enhancement (DDE): an advanced non linear image processing algorithm that preserves details in high dynamic range imagery;

The **thermal images** recorded during the mechanical tests allowed the detection of crack initiation and the thermal field due to its propagation.

Considering the different thermal behaviour of steel and aluminium, in both dog-bone and CT specimens, the apparent temperature distribution is not symmetric and is mostly shifted to the Al side.

a (TR2)



b (CT14)

Conclusion

- ✓ In this research activity, the mechanical behaviour of explosion welded specimens has been evaluated by static mechanical tests and non-destructive testing;
- ✓ The results highlighted that the mechanical behaviour is strongly affected by the mismatch of the elastic moduli at the interface Al-Fe.
- ✓ These aspects require additional experimental tests to explore deeply the mechanical characteristics of the Al-Fe interface.

Acknowledgment

This study shows the results of the research activities of the Research Project **PRIN PNRR 2022 "LODE"** (circuLar economy-Oriented DEsign using hybrid-dissimilar joints and sustainable materials for lightweight structures), project funded by the Italian Ministry of Scientific and Technological Research.

PNRR - Missione 4, Componente 2, Investimento 1.1, "Fondo per il Programma Nazionale di Ricerca e Progetti di Rilevante Interesse Nazionale (PRIN)" - Bando Prin 2022 PNRR - Decreto Direttoriale n. 1409 del 14-09-2022

Progetto *circuLar economy-Oriented DEsign using hybrid-dissimilar joints and sustainable materials for lightweight structures - LODE*

CUP J53D23015810001 - codice identificativo PRIN_2022PNRR_P2022SXTA4_002

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Università degli Studi di Messina

Università degli Studi di Messina

Politecnico di Bari

Research: publications

INTERNATIONAL JOURNALS

G. Brando, F Distefano, F Di Carolo, V Crupi, G Epasto, U Galietti. **“Dissimilar Welded Joints and Sustainable Materials for Ship Structures”.** Journal of Marine Science and Engineering, Vol. 13(12), 2296, 2025. ISSN: 2077-1312, DOI: 10.3390/jmse13122296

INTERNATIONAL CONFERENCES

G. Briguglio, G. Brando, V. Crupi. **“Green and Lightweight Boat: A Case Study of Samothrace Project”.** CNM 2024, Proceedings of the 4th lnternational Conference on Nautical and Maritime Culture, from the Past to the Future, pp. 138 – 151, Venice, ltaly, 28-29 November 2024. DOI: 10.3233/PMST240014. Scopus code: 2-s2.0-85216805791.

V. Crupi, G. Epasto, F. Distefano, G. Brando, F. Di Carolo, E. D’Accardi, U. Galietti. **“Dissimilar Welded Joints for Ship Structures”.** NAV 2025, 21st International Conference on Ships and Maritime Research, pp. 1066 - 1074, Vol. 10, Messina, Italy, 18-20 June 2025. DOI: 10.3233/PMST250125, ISBN 978-164368610-3. Scopus code: 2-s2.0-105016224688

S. Bertagna, N. Taucher Marchesi, V. Bucci, G. Brando, F. Distefano, V. Crupi, A. Marinò. **“Investigation on the Tensile Properties of Virgin and Recycled HDPE for Boatbuilding Applications Through Experimental Tests”.** NAV 2025, 21st International Conference on Ships and Maritime Research, pp. 999 - 1008, Vol. 10, Messina, Italy, 18-20 June 2025. DOI: 10.3233/PMST250118, ISBN 978-164368610-3. Scopus code: 2-s2.0-105016238537

G. Brando, S. Bertagna, V. Crupi, F. Distefano, G. Epasto, A. Marinò. “**Experimental Techniques for the Assessment of the Mechanical Behaviour of HDPE Used in Boat Building”.** NAV 2025, 21st International Conference on Ships and Maritime Research, pp. 1009 - 1017, Vol. 10, Messina, Italy, 18-20 June 2025. DOI: 10.3233/PMST250119, ISBN 978-164368610-3. Scopus code: 2-s2.0-10501617624

THANK YOU FOR YOUR ATTENTION!

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