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Cryogenic fatigue and stress-strain behaviour of fibre metal laminates.

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ICEC 25-ICMC 2014 8 July 2014

Introduction: Why alternative materials?

LNG infrastructure: search for optimal

- Cost effectiveness
- Safety
- Functionality

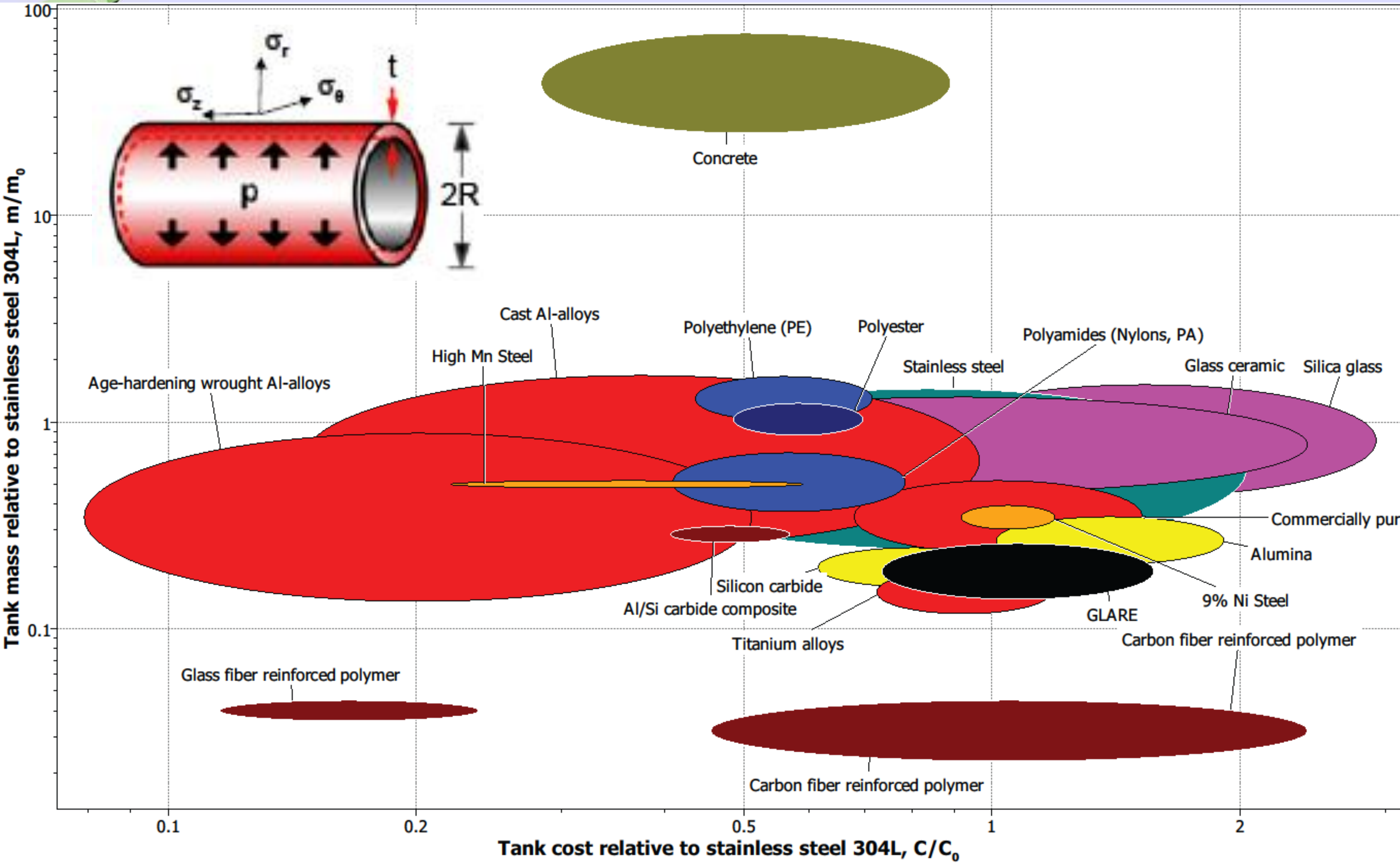
For small scale LNG applications

- <10.000 m^3

Type:	Application:
Stainless steel type AISI 304L	Piping Small vessels Sometimes for large storage tanks
9% Ni Steel	Storage Tank
Low expansion 36% Ni-Fe alloy	Sometimes for large storage tank construction. Piping in critical applications.
Aluminium alloy 5083 (Al - 4.5% Mg) Alloy 5154 (Al- 3.5% Mg) Alloy 6000 (Al - Si)	Spherical or prismatic storage tanks for ship transportation of LNG. Tubing for the main cryogenic heat exchanger. Forging such as flanges.

[Friedrich et al]

Introduction: Relative Mass and Cost of a LNG tank



Introduction: cryogenic FML

Conceptual example: tank wall

- Stainless Steel (impact strength, chemical compatibility)
- Polyimide (transverse thermal insulation)
- Aluminium (strength, in-plane thermal conductivity)
- Titanium alloy (strength, vacuum insulation)
- Filled epoxy resin (bonding, shear strength)

Central question:

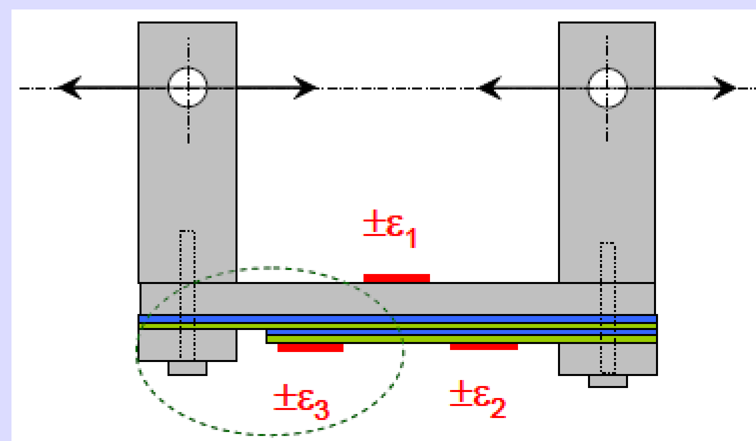
"*Why do some laminates weaken upon cool-down, while others strengthen?*"

Experimental Details

Fatigue:

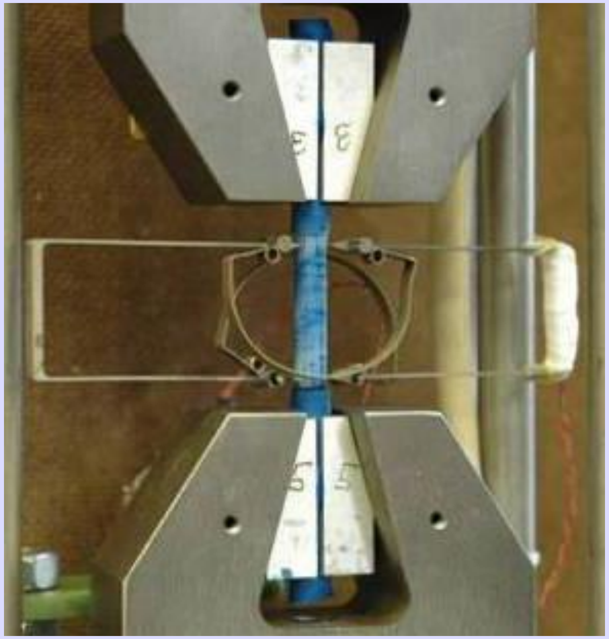
Crack Nucleation and Crack Propagation under cyclic strain at room temperature and 77 K.

Al 2024 / Stycast 2850 FT Specimen



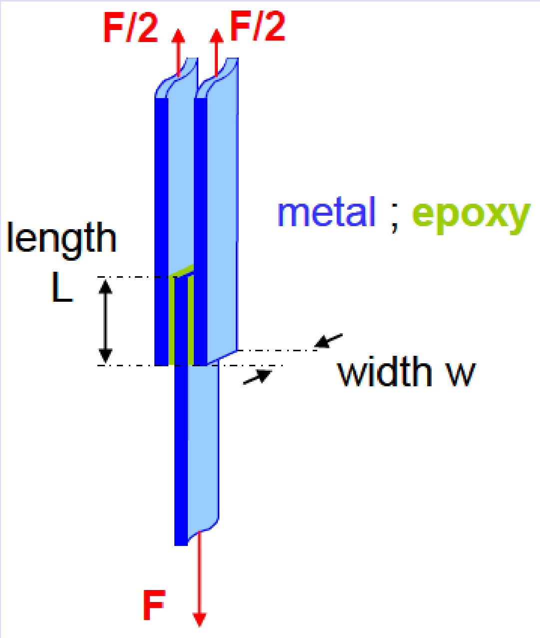
Experimental Details

Stress-Strain



- Young’s modulus
- yield strength
- ultimate strength

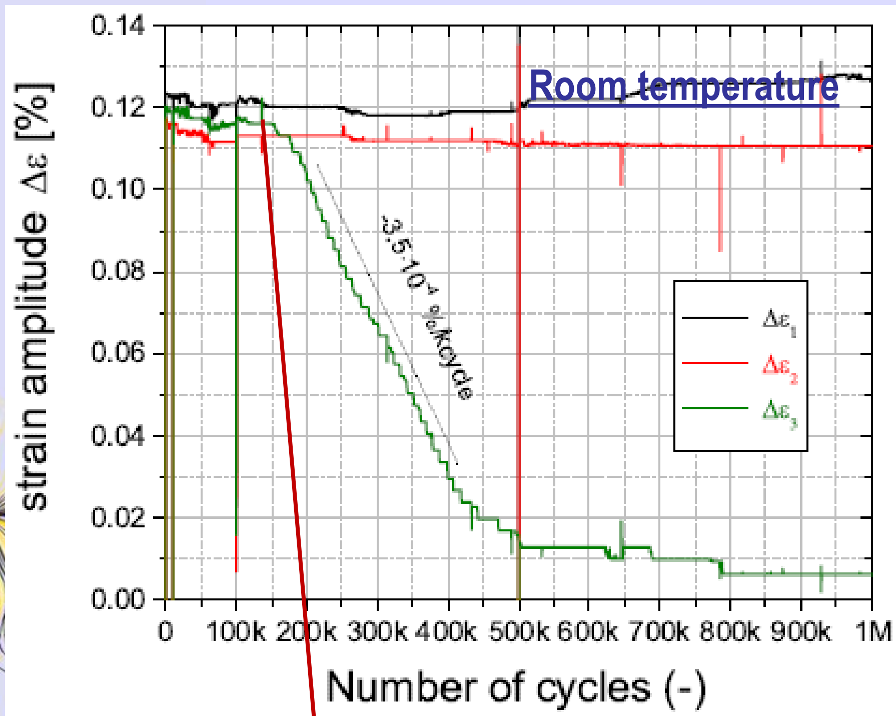
Shear Strength

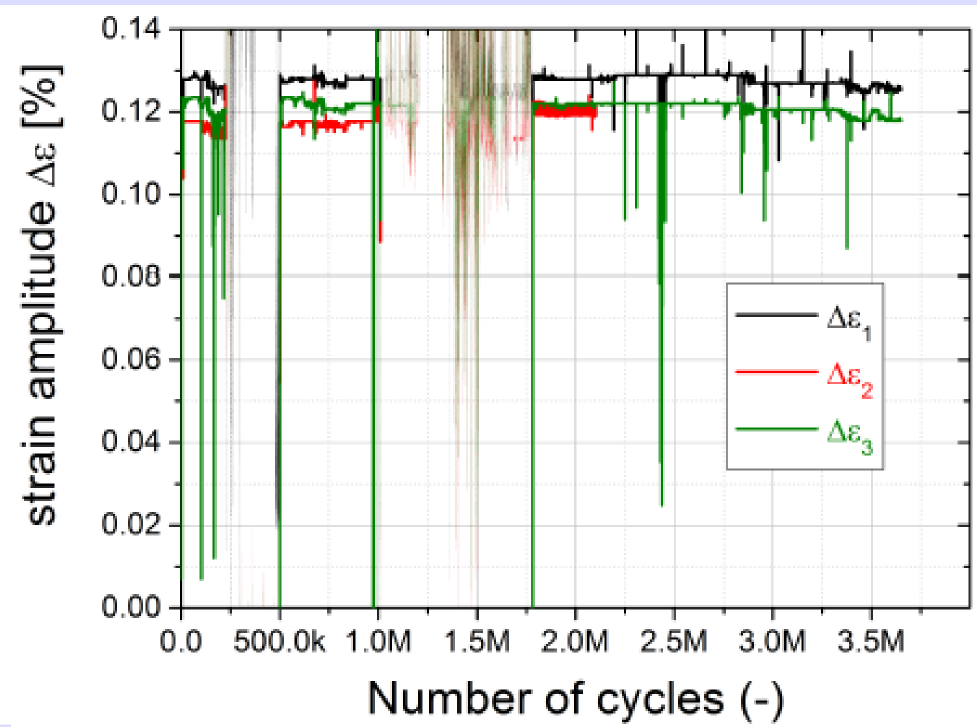


- Shear Strength at failure
- Type of failure

Results: Fatigue

Certain material combinations show
> 20X fatigue life at 77 K vs. 300 K





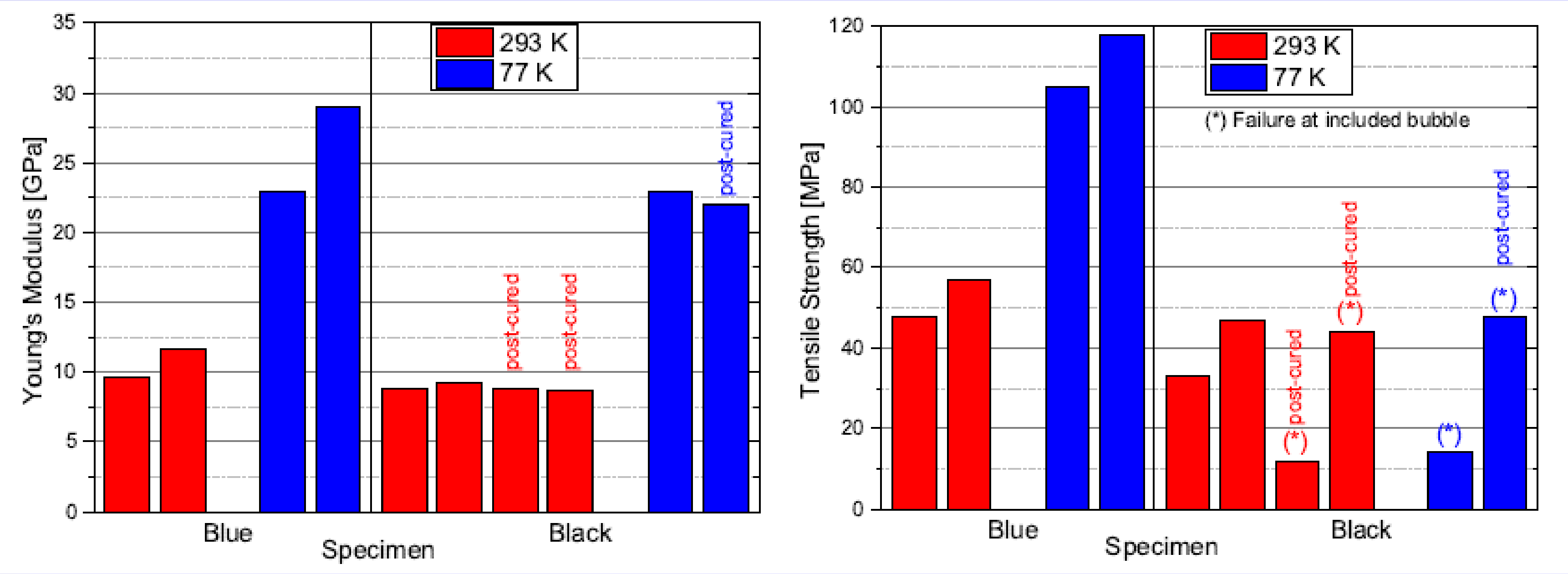
150k cycles

> 3.5M cycles

Results: Young's Modulus and Tensile Strength

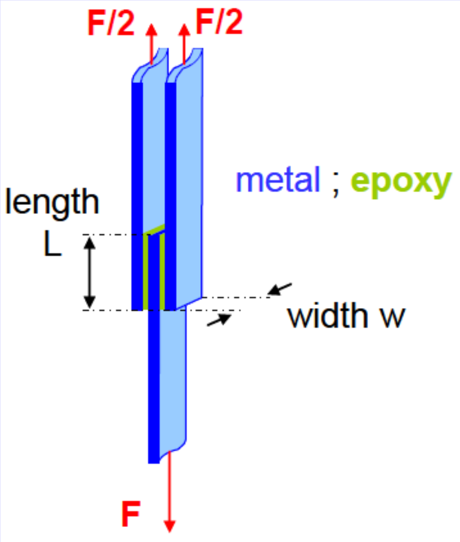
Stycast 2850 FT black and blue at 77 K

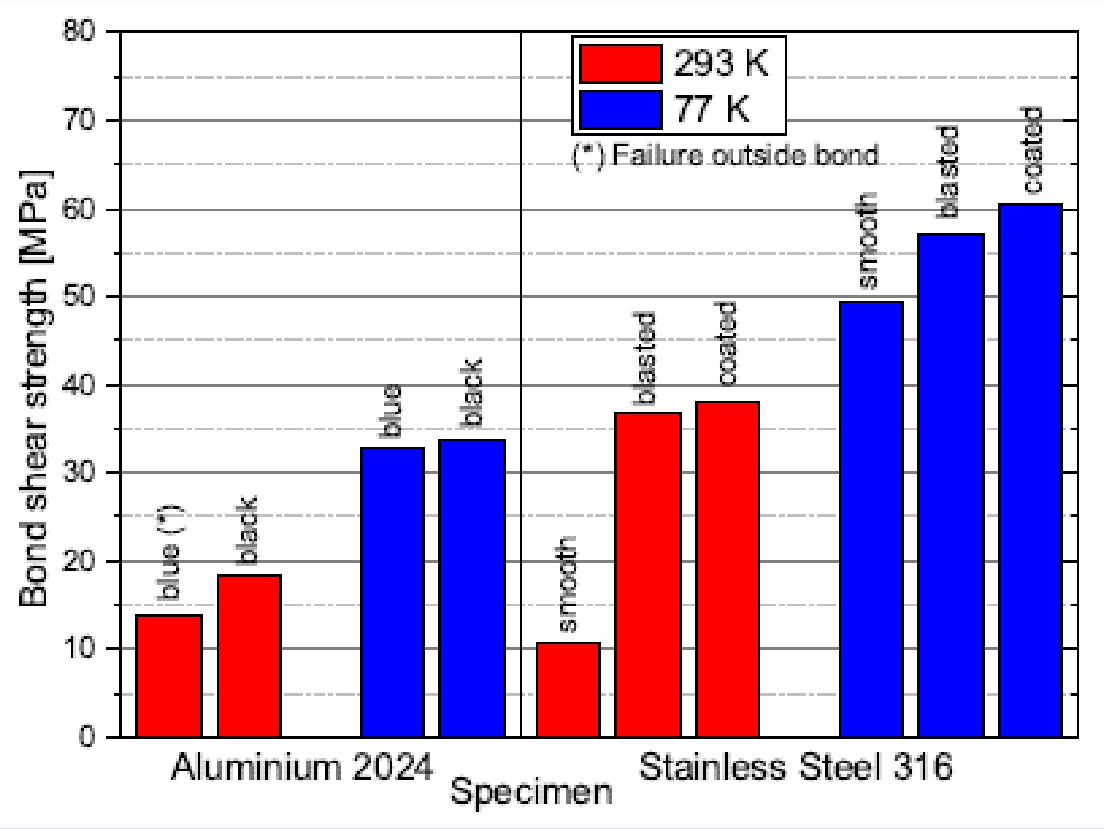
- Increase of E_y by factor 2
- Increase of σ_u by factor 2 for blue variant
- σ_u of black variant inconclusive.



Results: Bond Shear Strength

Stycast 2850 FT blue and black at 77 K
Increase of τ_u by a factor 1.5





Discussion

Some material combination show at 77 K

- Withstand repeated cool-down
- >20x increase fatigue life
- Its constituents show
  - 2x Young's Modulus
  - 2x Tensile Strength
  - 1.5x Shear Bond Strength

Cryogenic FML based on the tested materials should be feasible.

Prospects:

- Micro-scopic investigation in the interfacial behaviour of cryogenic FML