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Investigating the applicability of existing mechanical test standards for fibre-reinforced polymer matrix composites at cryogenic temperatures

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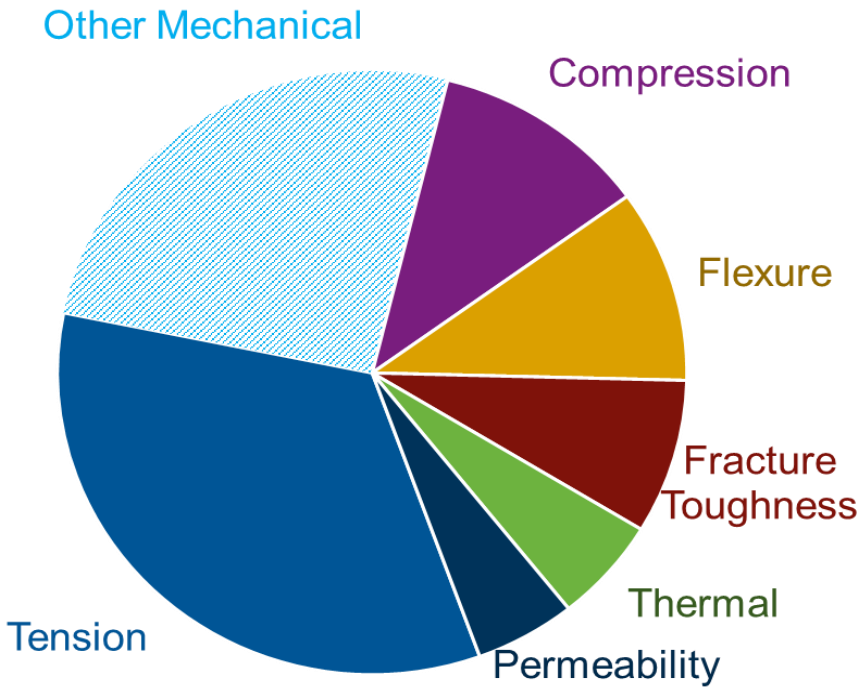
Agenda

- Introduction
  - The current state of Cryogenic Mechanical Testing
  - Test standards
  - Main limitations
- Testing at 110K
- Towards testing at 4K

Introduction

The current state of cryogenic mechanical testing

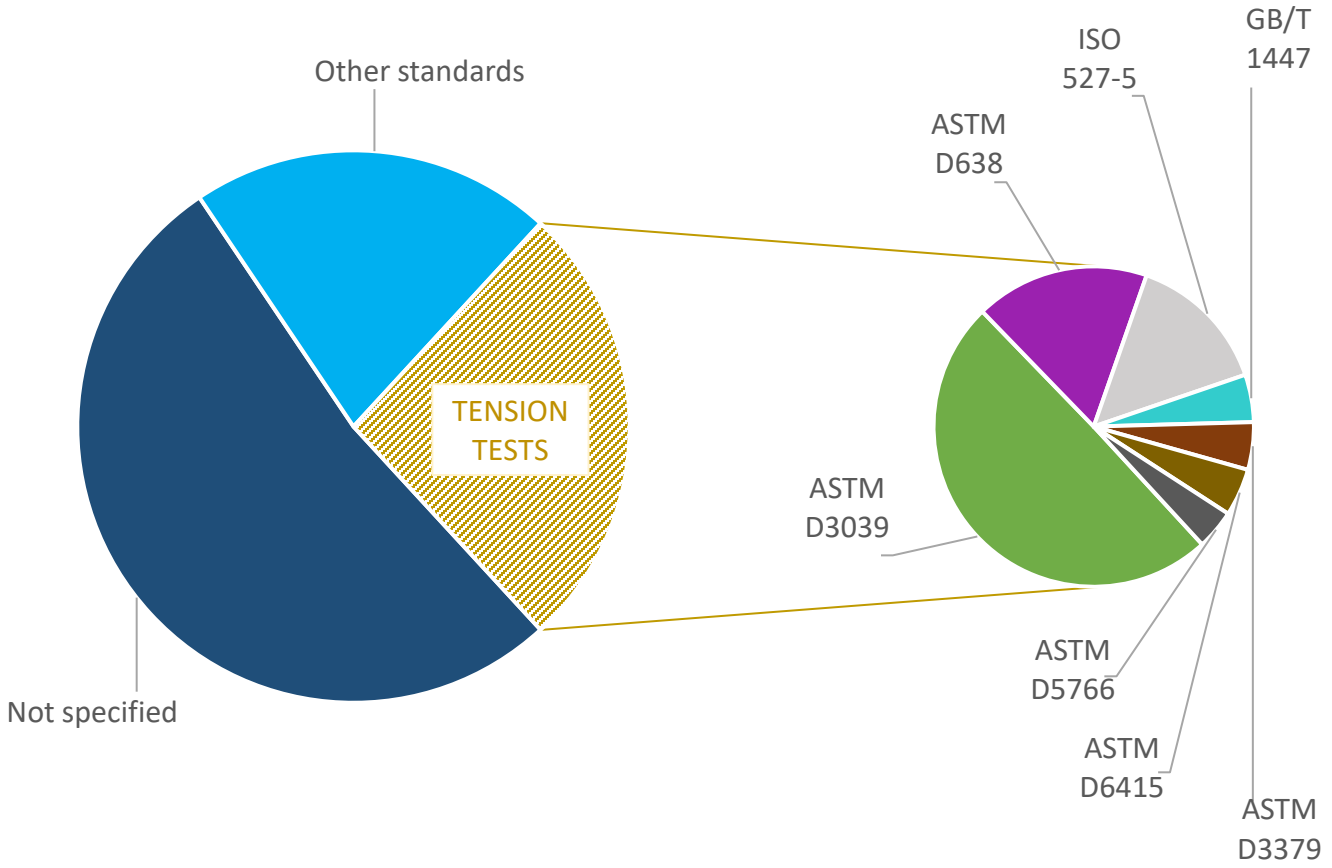


A literature review spanning across the last 15 years and covering more than 150 publications, revealed the most frequent test types at cryogenic temperatures, as well as the most common universal standards followed.

Introduction | Test Standards

The test standards commonly used are only typically valid at ambient temperatures.

Interestingly, more than half of the reviewed literature, did not specify following any standardization.



Introduction | Main limitations

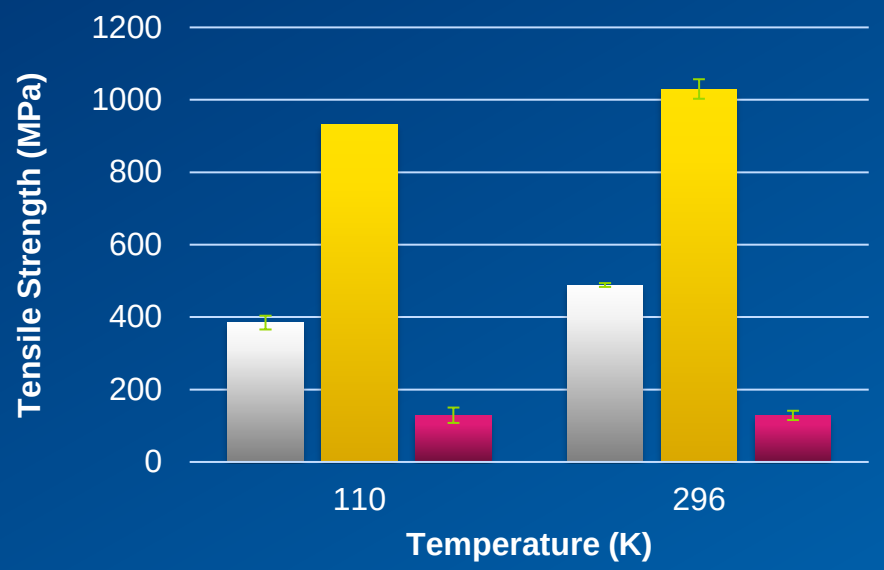
- Lack of standardized test methods
- Limited sources of materials data
- Need for bespoke equipment
- Significant investment
- High operational costs
- Unique expertise required

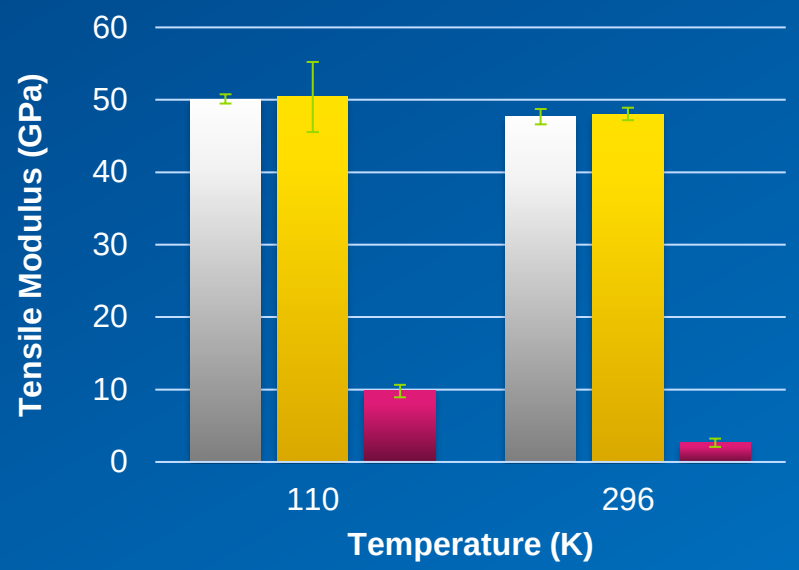
Testing at 110K | Overview

Tensile and compressive tests were performed for 5 different FRP material systems, potentially candidate for cryogenic storage and transportation applications:

System ID	Test Type	Material	Fibre	Matrix	Layup
FKR	Tension	CFRP	CF	Epoxy	Woven
1AAZZ	Tension	GFRP	GF	Epoxy	UD
1AIUW	Tension	GFRP	GF	Epoxy	UD
2AIUW	Tension	GFRP	GF	Epoxy	±45°
AJO	Tension	SPC	Thermoplastic	Thermoplastic	UD
2ADZM	Compression	CFRP	CF	Epoxy	UD
1AEAJ	Compression	GFRP	GF	Epoxy	UD

Testing at 110K | Tension





MAT-A MAT-B MAT-C

CFRP GFRP TP - SPC

Testing at 110K | Tension

MAT-A and –B tensile specimens tested at 110K showed a substantial reduction in strength when compared to room temperature trials.

The moisture trapped between grip-faces caused the specimen to slip from the grips in some cases. Signs of tab debonding were also observed in some cases.

MAT-A

CFRP

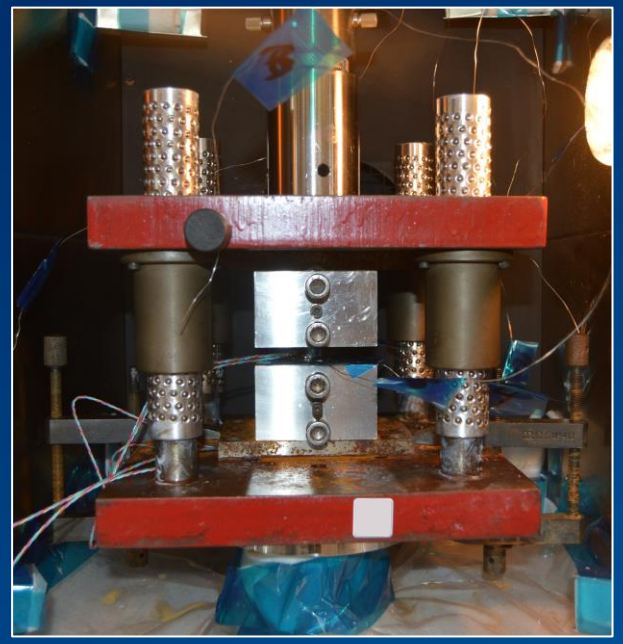
MAT-B

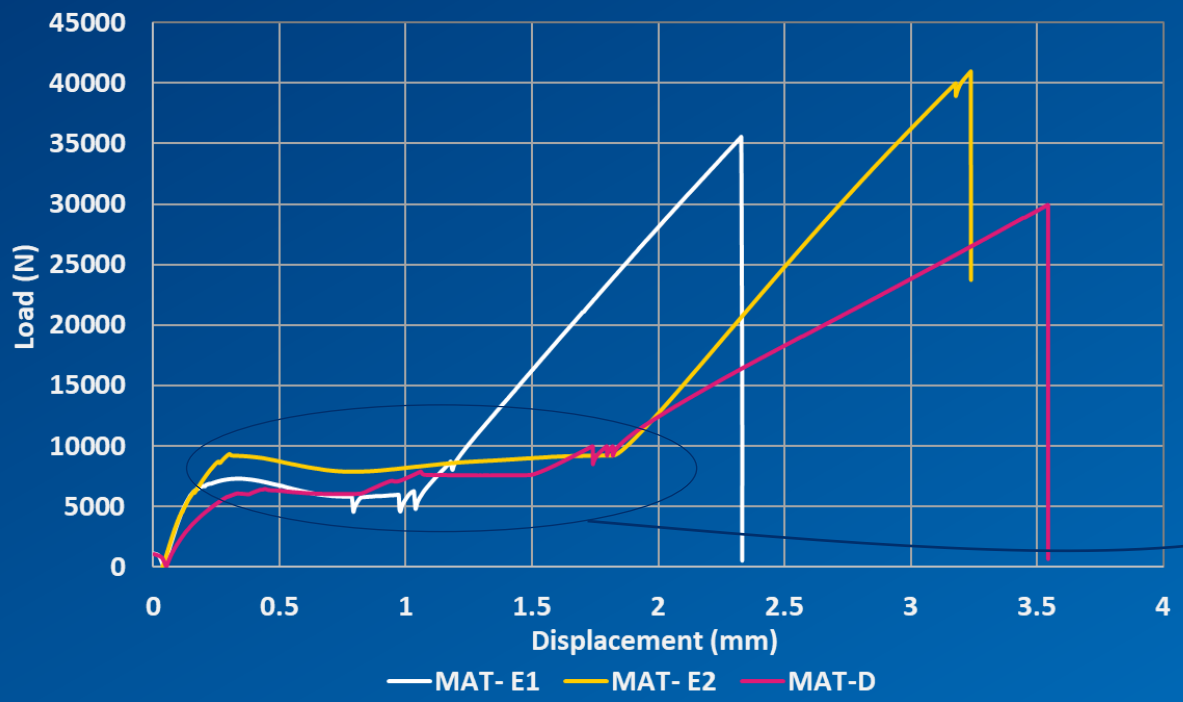
GFRP

MAT-C

TP - SPC

Testing at 110K | Compression



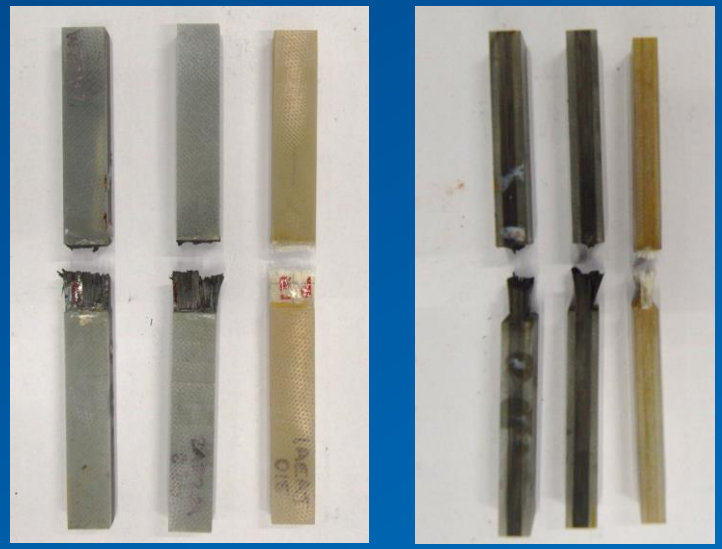


Artifacts created by fixture pillars freezing up.

Testing at 110K | Compression

All compression specimens tested at 110K show maximum compressive strength and modulus increases at cryogenic temperatures, possibly due to the increased stiffness of the matrix and the fibre-resin interfacial strength.

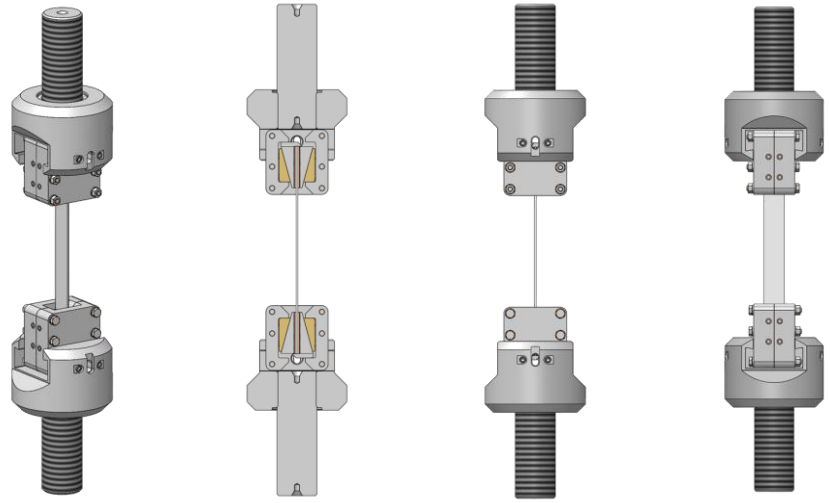
The fracture surfaces reveal fibre and matrix de-bonding failure, with negligible variation between specimens.

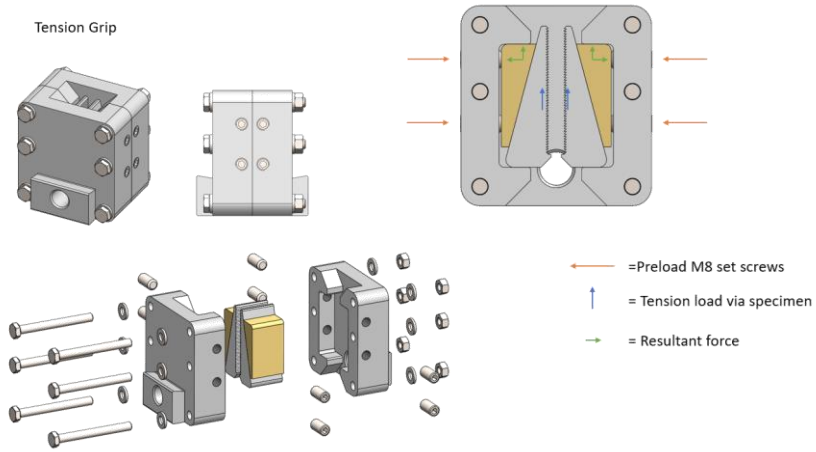


Towards testing at 4K | Grips & Fixtures

Two design variants were developed for the tensile and compressive test cases:

Cryogenic Tension Fixture (Cubic Variant) – 100kN rated



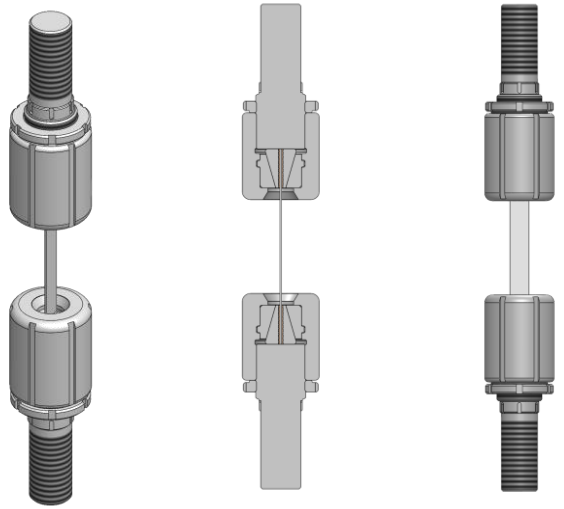


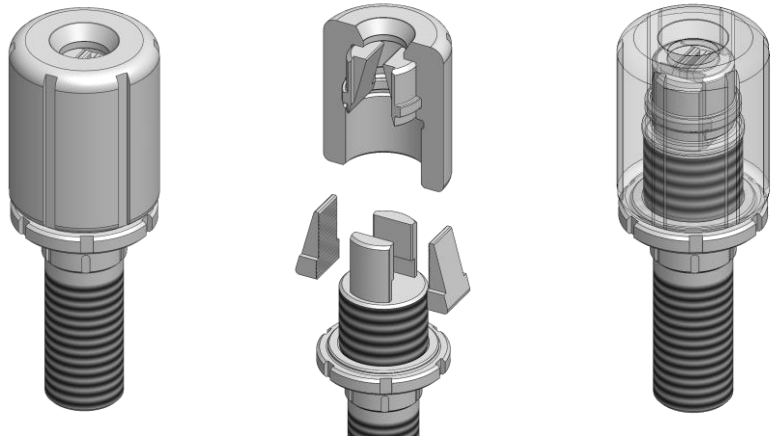
- Grip-preloading prior to mounting on test frame
- Specimen alignment using dowel pin
- Faster specimen change by slot-fitting interchangeable design
- Bulkier design with more components

Towards testing at 4K | Grips & Fixtures

Two design variants were developed for the tensile and compressive test cases:

Cryogenic Tension Fixture (Cylindrical Variant) – 100kN rated



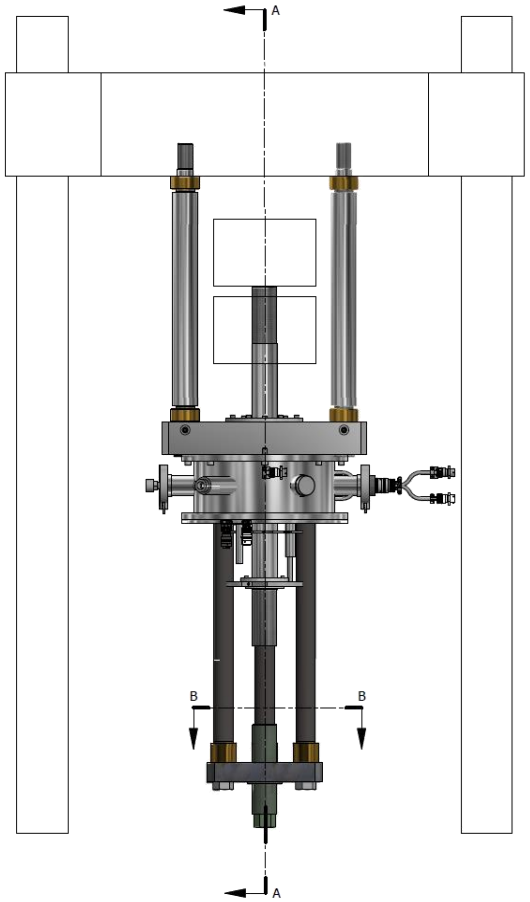


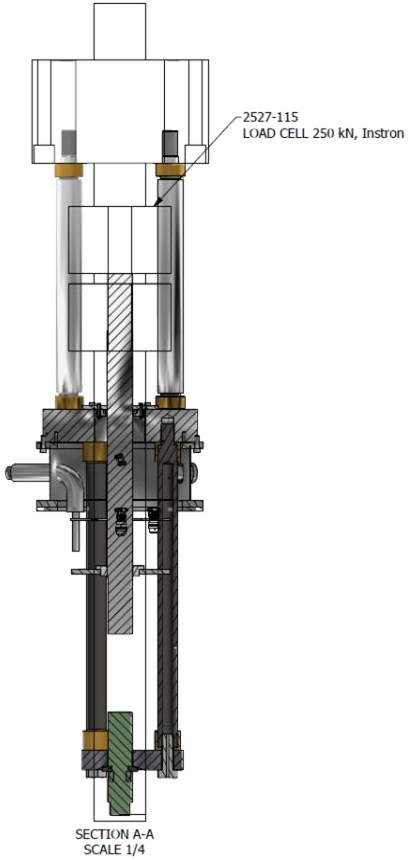
- Most components between tension and compression are shared
- Self-aligning gripping design

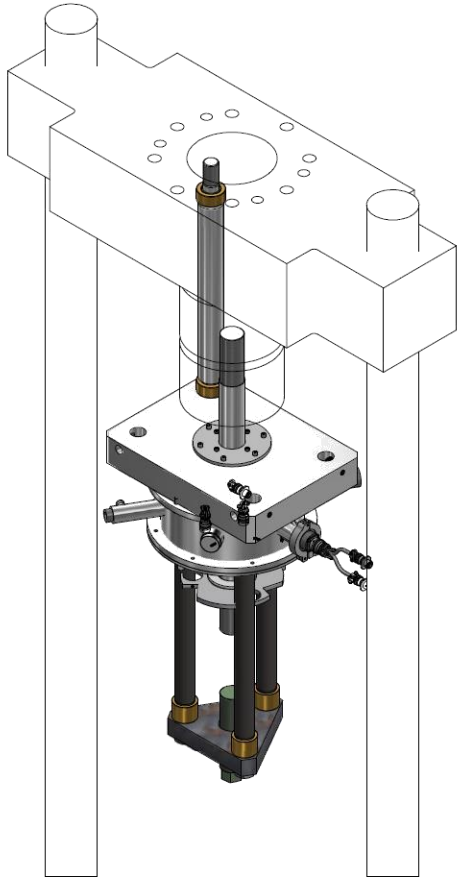
- Minimized size and mass
- Specimen change more time-consuming

Towards testing at 4K | Cryostat

A 250kN rated cryostat has been commissioned to enable a wide range of mechanical tests down to 4K:







- Mounted on a 250kN servo-hydraulic test machine
- Modular design allows for conversion to compression and full reverse-cycle fatigue tests
- Temperature control unit for testing in the range of 20K to 300K within ±1K control
- Maximum test space: Ø150mm x 350mm

Thank you for your attention.

Questions?

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