
Twin Astir: first tensile results of T91 and 316L after neutron irradiation in contact with LBE

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Outline

- Twin Astir irradiation: capsule A
- Tensile results:
 - at 450°C
 - at 350°C
 - at 200°C
- Conclusions & Outlook

Purpose of Twin Astir

Twin Astir

Tensile results at 450°C

Tensile results at 350°C

Tensile results at 200°C

Conclusions & Outlook

Parameterisation of factors leading to embrittlement:

At 350°C and at 450°C (1.25dpa/year)

SSRT, fracture toughness, crack growth in LBE
after irradiation in LBE/PWR water conditions.

Goal:

assess the separate and possible synergetic
effect of irradiation and liquid metal
embrittlement

Parametrisation

Twin Astir

Tensile results at 450°C

Tensile results at 350°C

Tensile results at 200°C

Conclusions & Outlook

- 4 identical capsules, each filled with
36 tensile samples, 20 corrosion plates
 - Capsule X: 0 dpa, PbBi environment -> LM corrosion
 - **Capsule A: 1.5 dpa, PbBi environment -> LMC + irr. damage**
 - Capsule B: 2.5 dpa, PbBi environment -> LMC + irr. damage
 - Capsule D: 2.5 dpa, PWR water environment -> irr. damage
- 2 identical capsules, each filled with
24 precracked mini CT specimens
 - Capsule 1: 2.5 dpa, PbBi environment -> LMC + irr. damage
 - Capsule 2: 2.5 dpa, PWR water environment -> irr. damage

Capsules cross section

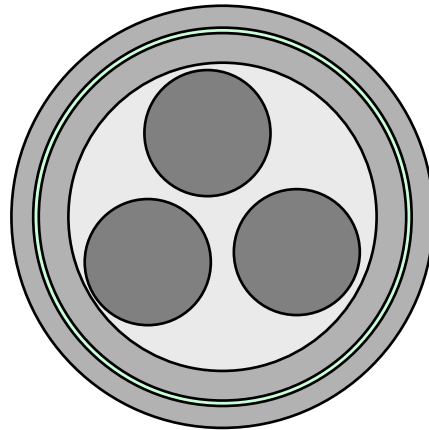
Twin Astir

Tensile results at 450°C

Tensile results at 350°C

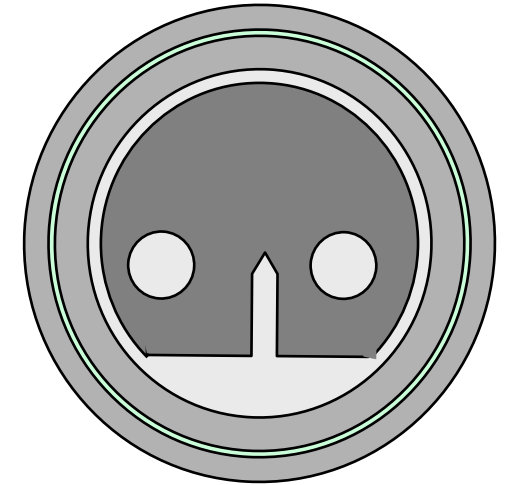
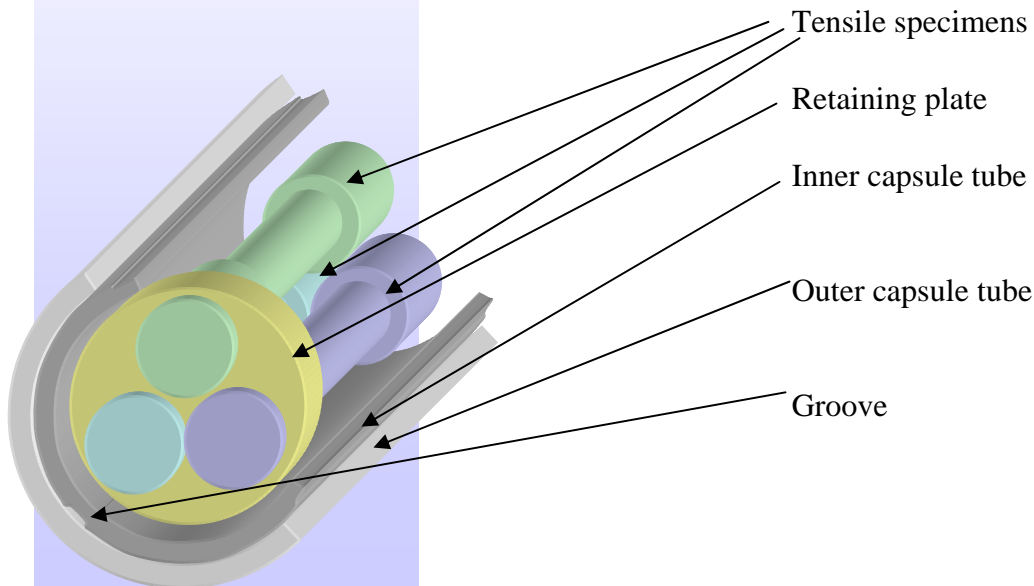
Tensile results at 200°C

Conclusions & Outlook



Tensile-loaded capsule

CT-loaded capsule



TWIN-ASTIR

Capsules detail

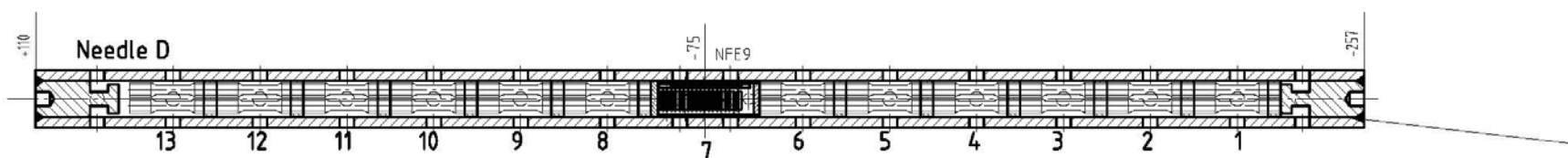
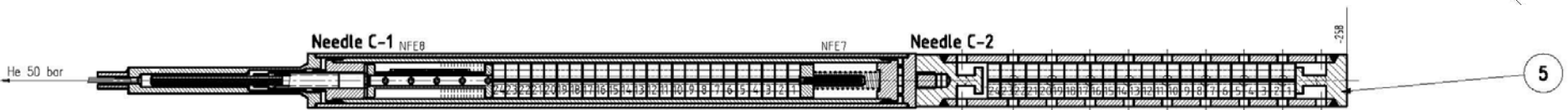
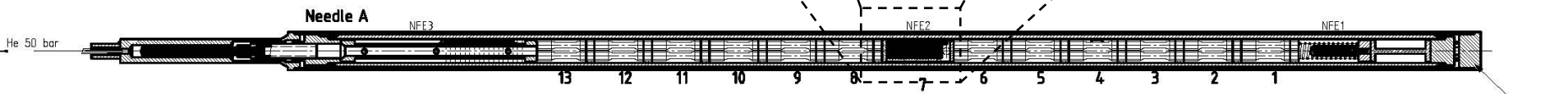
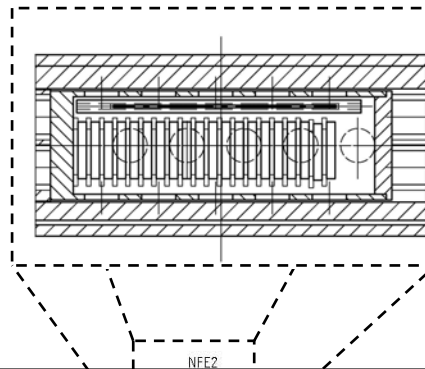
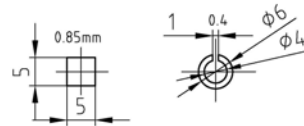
Twin Astir

Tensile results at 450°C

Tensile results at 350°C

Tensile results at 200°C

Conclusions & Outlook



TWIN-ASTIR

Capsules A & B detail

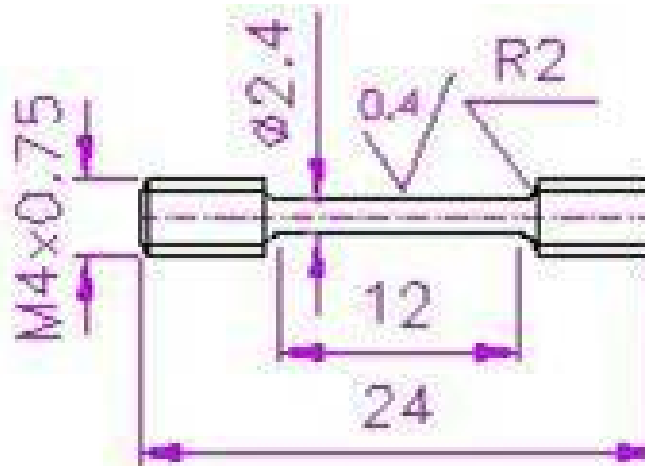
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Conclusions & Outlook



NFE2

13

12

11

10

9

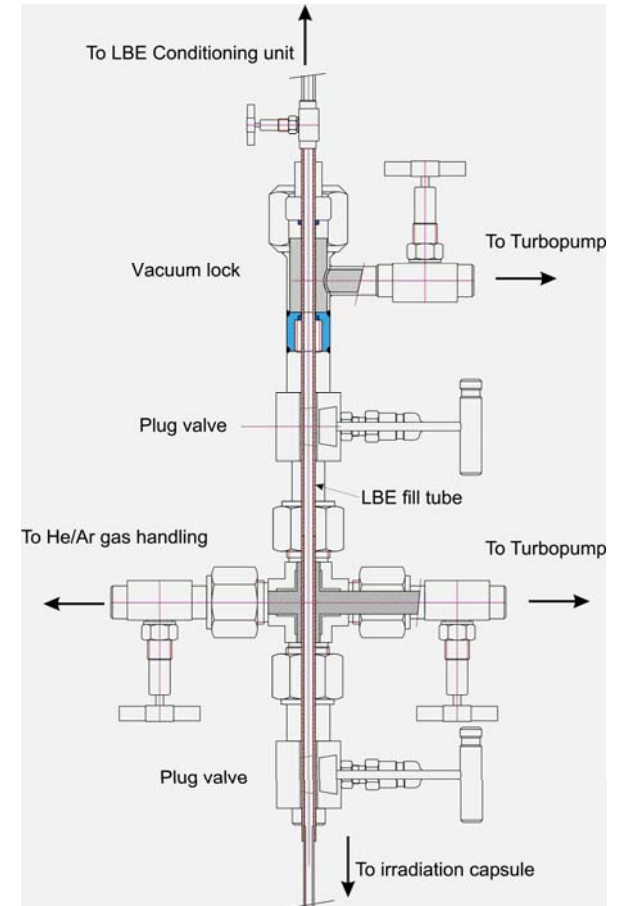
8

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Filling of the capsules



	<i>sample 001</i>	<i>sample 002</i>
Bi (%)	54.3%	54.3%
Pb (%)	45.7%	45.7%
Cu (µg/g)	3.6	4.6
Ag (µg/g)	13	13
Sn (µg/g)	4.2	4.3
Tl (µg/g)	2.3	2.2
Na (µg/g)	< 50	< 50
Ca (µg/g)	< 250	< 250
Cr (µg/g)	< 10	< 10
Fe (µg/g)	< 100	< 100
Ni (µg/g)	< 5	< 5
Mo (µg/g)	< 1	< 1
Cd (µg/g)	< 1	< 1
Th (µg/g)	< 0.5	< 0.5



Capsules were rinsed with acetone, ethanol and baked out for min. 2 days

Vacuum was of order 10^{-8} mbar; LBE oxygen concentration: $\sim 10^{-9}$ wt%

TWIN-ASTIR cross section

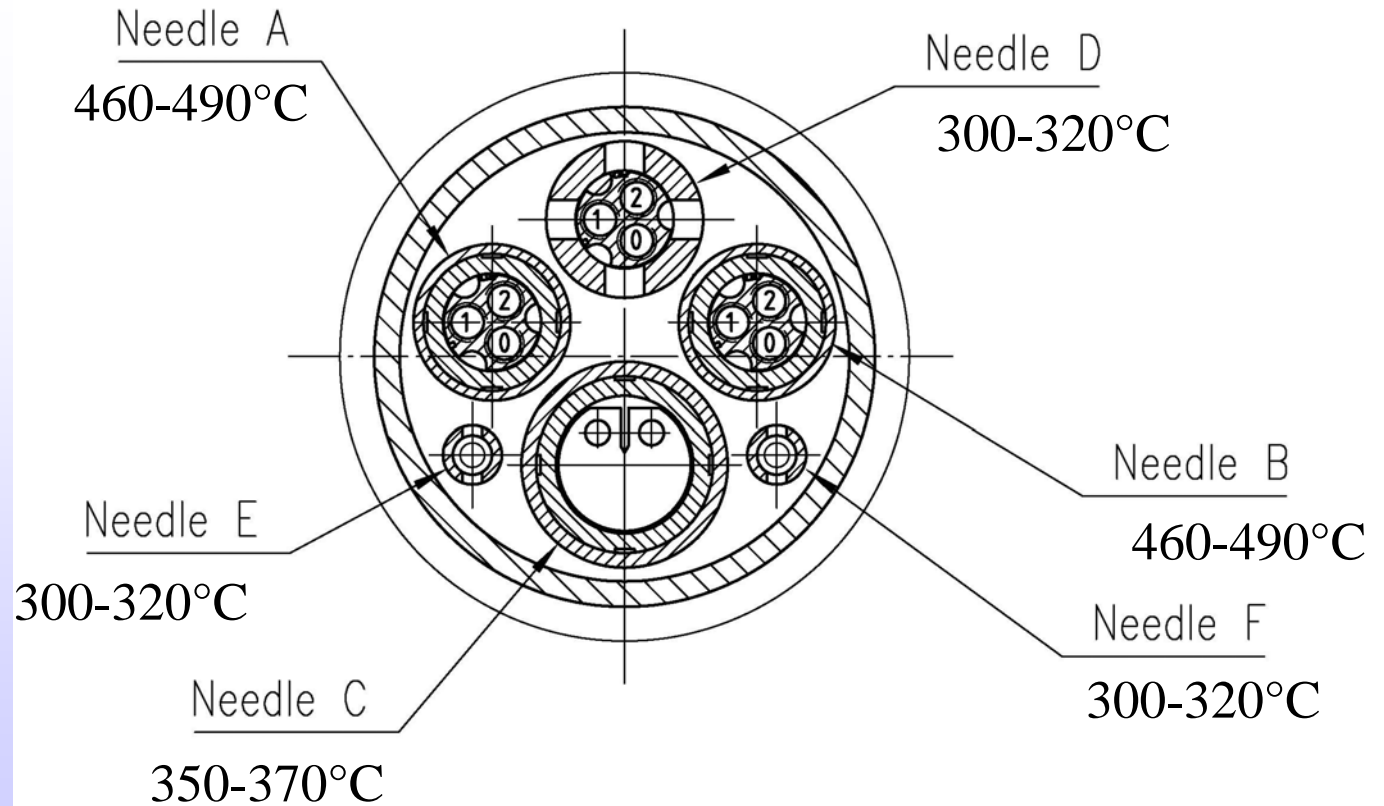
Twin Astir

Tensile results at 450°C

Tensile results at 350°C

Tensile results at 200°C

Conclusions & Outlook



Neutronics: fast and thermal flux

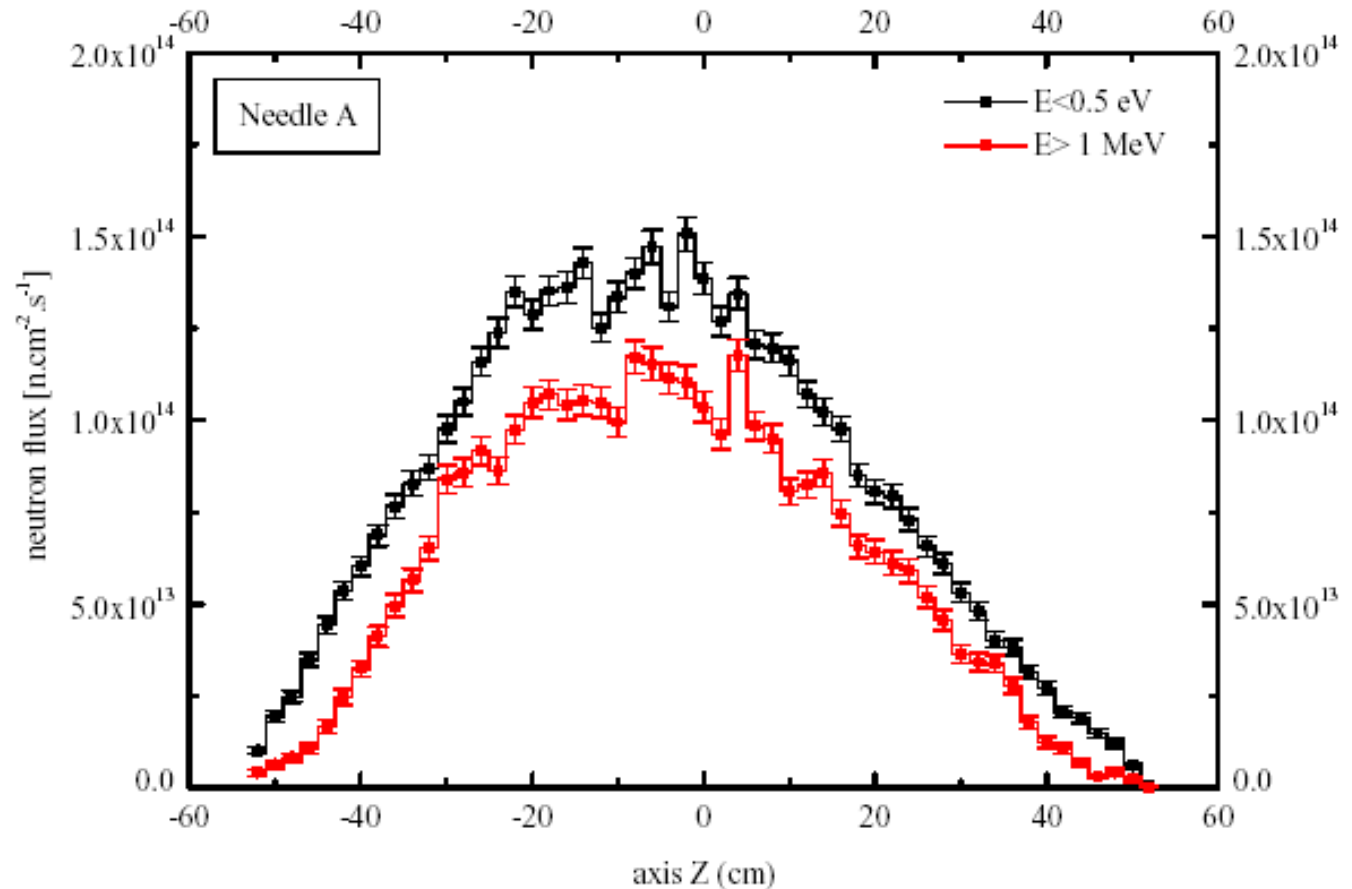
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Conclusions & Outlook



Temperature distribution

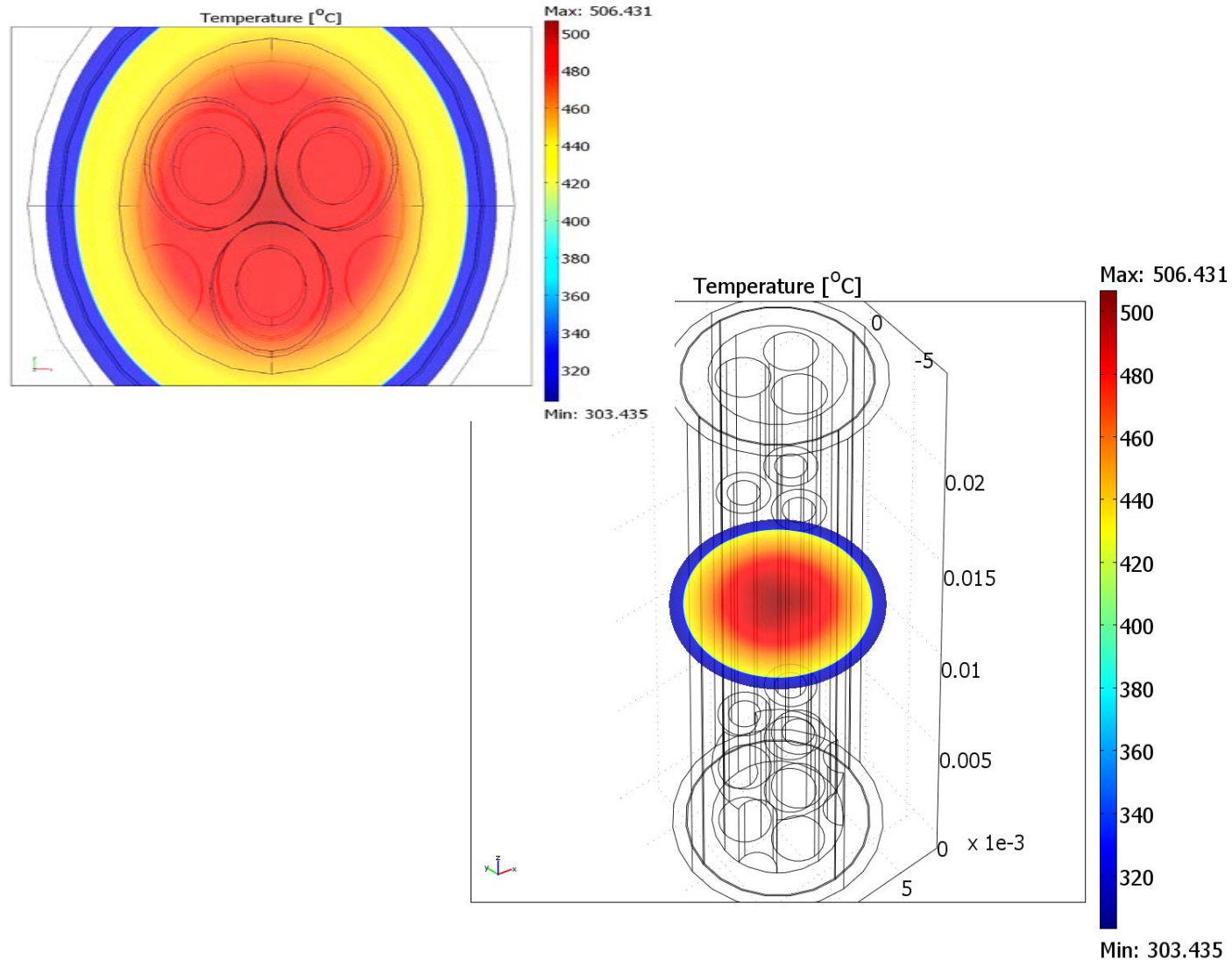
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Tensile results at 450°C

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Conclusions & Outlook



Materials under investigation

Twin Astir

Tensile results at 450°C

Tensile results at 350°C

Tensile results at 200°C

Conclusions & Outlook

- Base structural materials:
 - **T91**
 - **316L**
- 4 experimental High Si steels
 - Heat 2439
 - Heat 2440
 - Heat 2441
 - Heat 2442
- Welds:
 - EB welds:
 - ♣ T91/T91
 - ♣ T91/316L
 - TIG welds:
 - ♣ T91/T91
 - ♣ T91/316L

Tensile results at 450°C

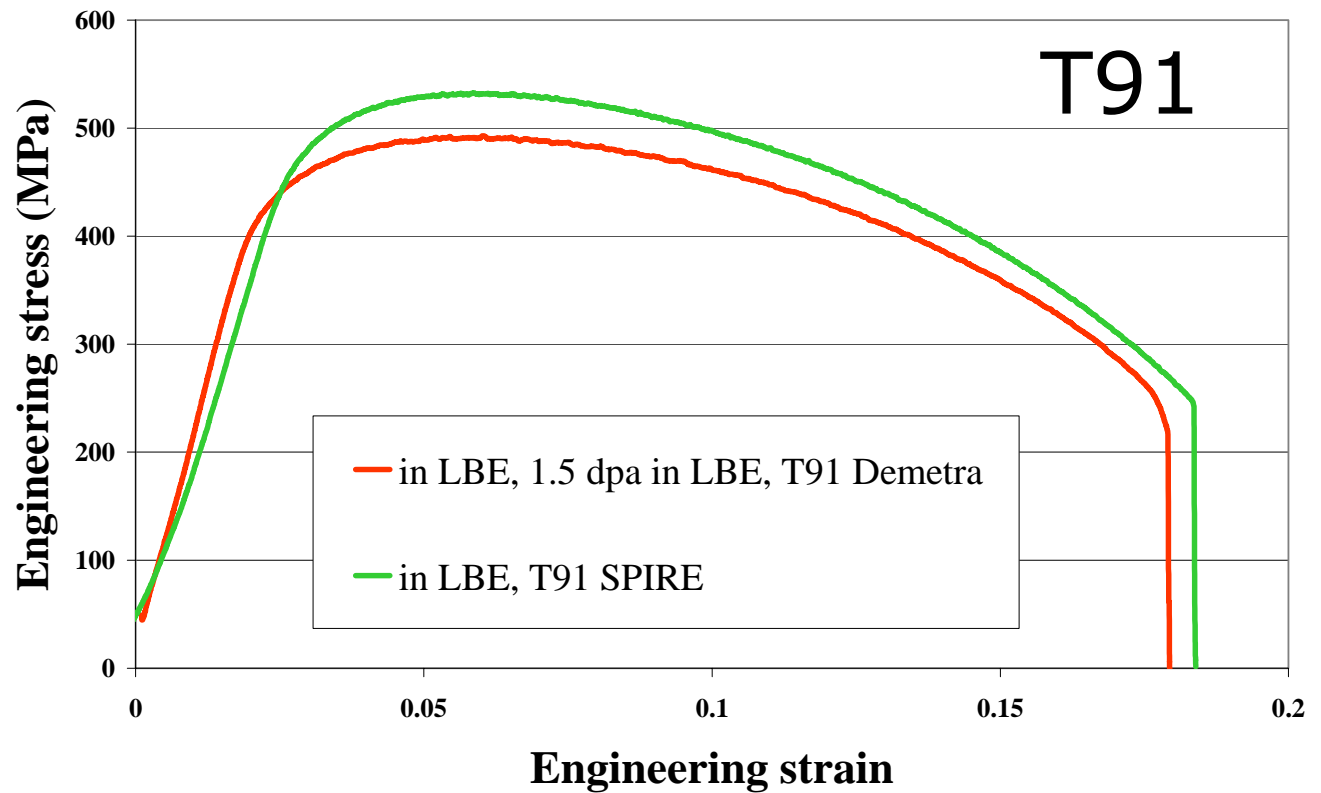
Twin Astir

Tensile results at 450°C

Tensile results at 350°C

Tensile results at 200°C

Conclusions & Outlook



Tensile results at 350°C

Twin Astir

Tensile results at 450°C

Tensile results at 350°C

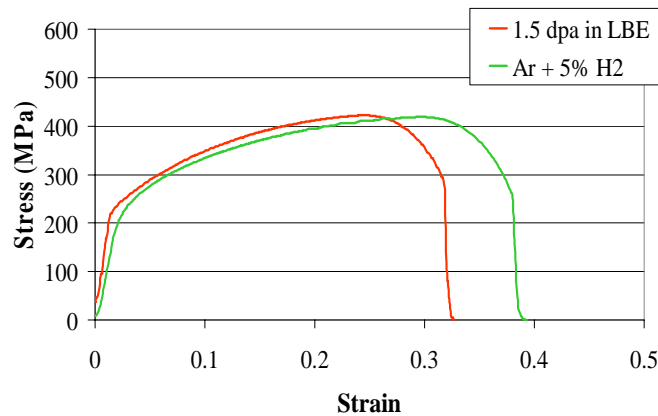
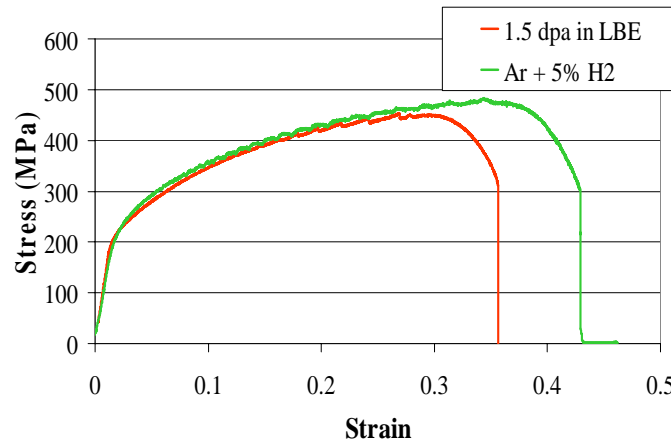
Tensile results at 200°C

Conclusions & Outlook

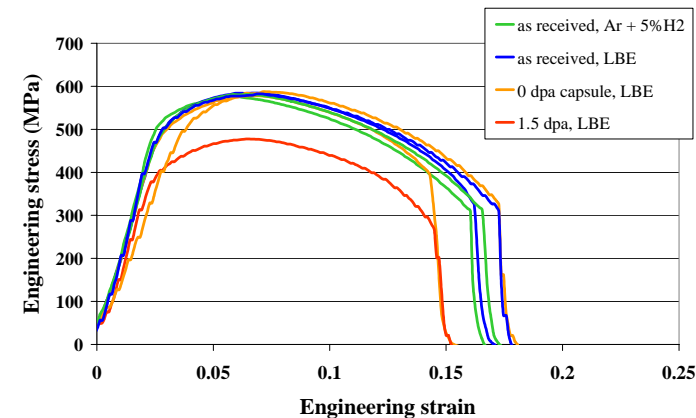
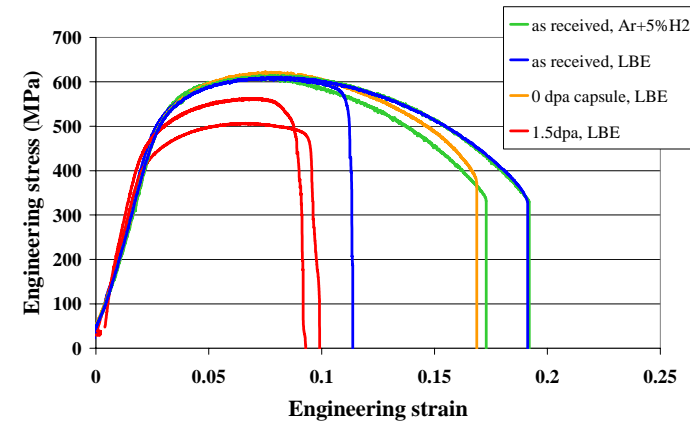
$1 \cdot 10^{-6} \text{ s}^{-1}$

$1 \cdot 10^{-3} \text{ s}^{-1}$

316L



T91



Tensile results at 200°C

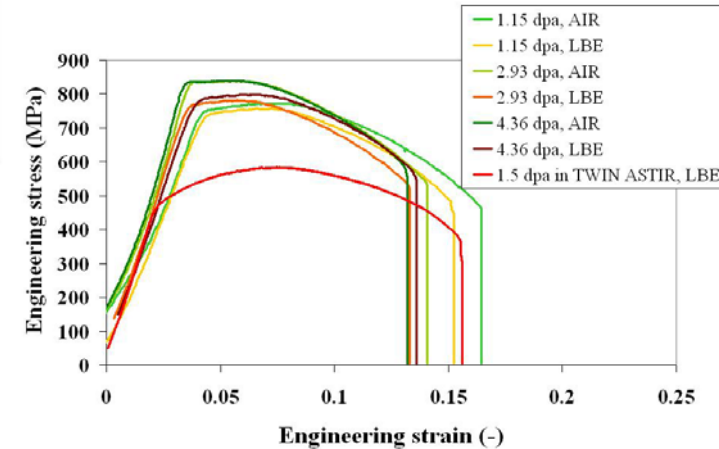
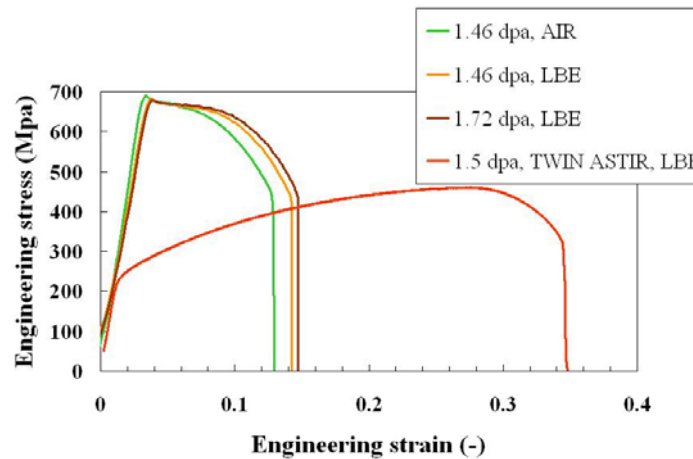
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Tensile results at 450°C

Tensile results at 350°C

Tensile results at 200°C

Conclusions & Outlook



Irradiated in water at 200°C
vs.
Irradiated in LBE at 460-490°C

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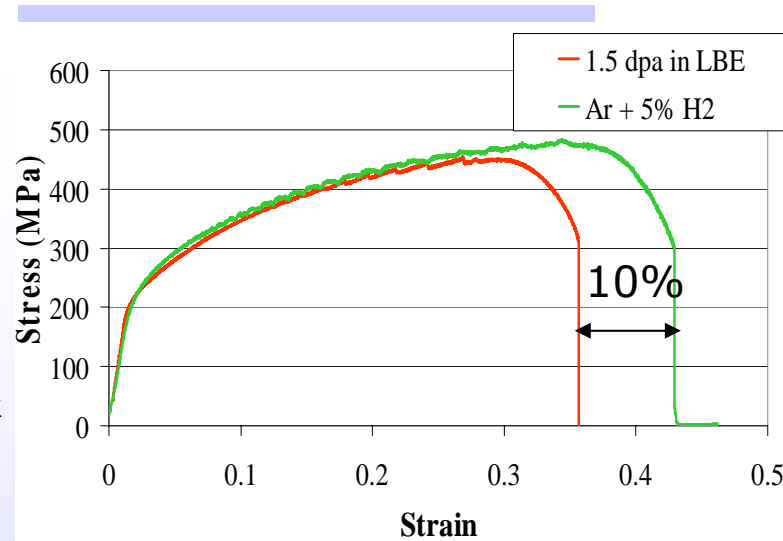
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Tensile results at 200°C

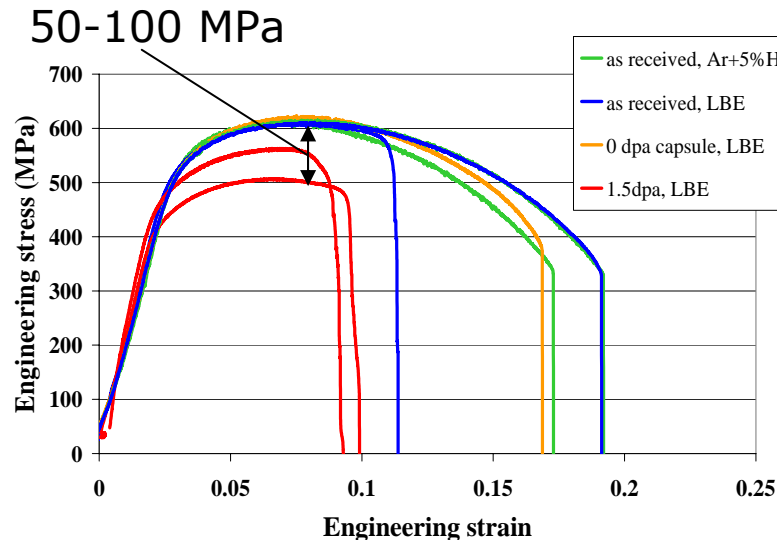
Conclusions & Outlook

Conclusions



316L

- 10 % decrease in ϵ_{tot}
- High ductility (>30%) after irradiation and testing in contact with LBE
- Work hardening capabilities remain high



T91

- Softening by 50-100 MPa after irradiation
- Reduction in ϵ_{tot} due to LME more reproducible after irradiation in contact with LBE
- No LME observed at 450°C

Twin Astir

Tensile results at 450°C

Tensile results at 350°C

Tensile results at 200°C

Conclusions & Outlook

Continuation of TWIN ASTIR:

- Fracture surface examination of Po contaminated specimens;
- Surface interface examination of materials irradiated in contact with LBE;
- Characterization and analysis of material irradiated in contact with LBE up to higher doses.