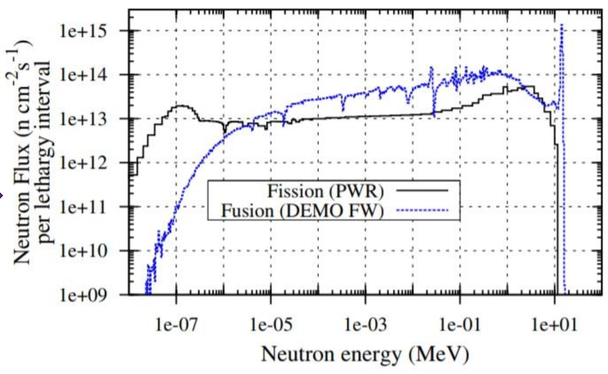
Assessment of mechanical properties of fusion materials by micro-mechanical testing

ChihCheng Chang[1], Dmitry Terentyev [1], Van Renterghem Wouter[1], Patricia Verleysen[2] & Thomas Pardoen [3]
[1] Belgian Nuclear Research Centre, SCK•CEN, Mol, Belgium; [2] Universiteit Gent, Gent, Belgium
[3] Université catholique de Louvain, Louvain-la-Neuve, Belgium
E-mail: chih-cheng.chang@sckcen.be

WHY?

Qualify materials for fusion reactor

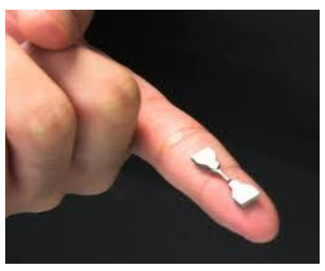


Irradiation condition can't be reach in mixed-spectrum MTRs

MYRRHA

IFMIF DONES GRANADA

Volume/cost



Small Specimen Test Techniques

Dedicated fusion neutron source, and application of Fast Spectrum reactors
Irradiation volume/cost/time – must be optimized

Source:
1.M.R. Gilbert, et al., An integrated model for materials in a fusion power plant: transmutation, gas production, and helium embrittlement under neutron irradiation (2012)
2. https://myrrha.be/
3. https://ifmifdones.org/

WHO?

The European Union organization managing Europe's contribution to ITER

FUSION FOR ENERGY

F4E

Safety rules

AUTORITÉ DE SÛRETÉ NUCLÉAIRE

French Nuclear Safety Agency

We need to develop SSTT whose results will be accepted by ASN. The safety file for Fast reactors is the basis.

Source:
1.https://fusionforenergy.europa.eu/
2.https://www.iter.org/
3.http://www.french-nuclear-safety.fr/

What to do?

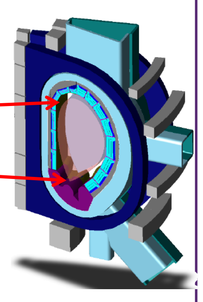
How to do?

Source:
1. W. Leysen, et al., Fusion target station on MYRRHA facility: Baseline concept (2020)
2. K.R. whittle, Nuclear materials science (2016)

SSTT assessment (for this PhD project) covers

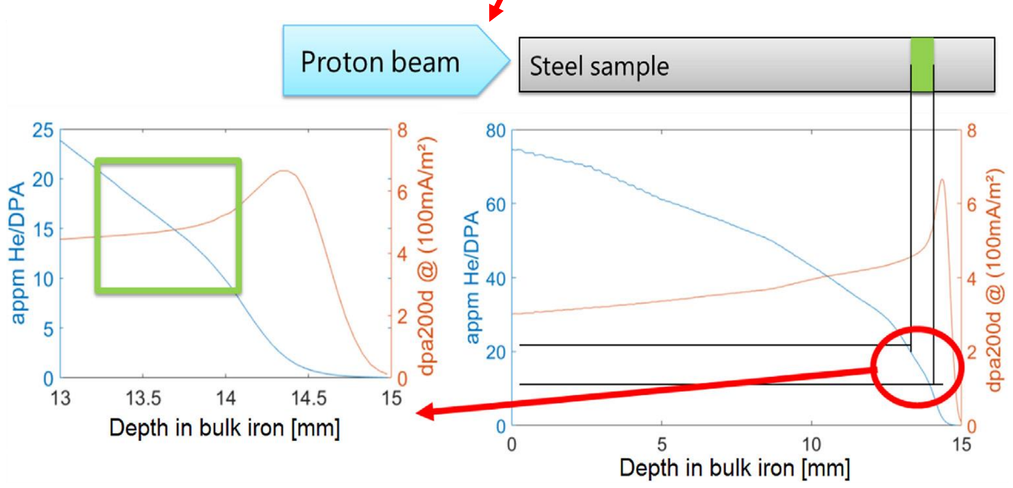
Properties : Tensile and Fracture Toughness

Materials : Eurofer97 (structural material)
Tungsten (Amour/structural material)



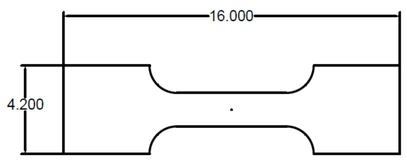
Geometry : standard/non-standard design of samples

Dimension : length, width, thickness

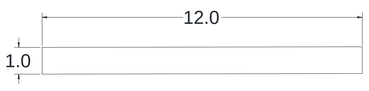


The irradiation conditions along the solid steel sample

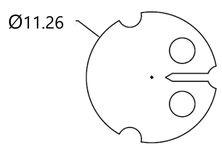
Standard



The miniaturized flat tensile sample
(to see tensile properties)

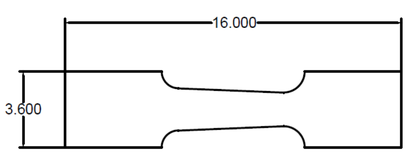


The miniaturized 3PB sample
(to see DBTT)

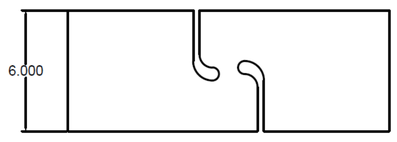


The miniaturized DCT sample
(to obtain fracture toughness)

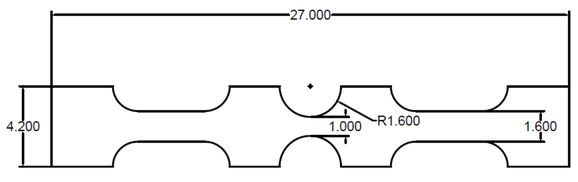
Non-Standard



The miniaturized tapred sample
(to see various strain alone the gauge)



The miniaturized shear sample
(to see the shear properties)



The notched flat tensile sample
(to obtain fracture toughness and reuse the broken half)

Objectives

The objective of this project is develop and validate the design of SSTT geometries capable to deliver tensile and fracture toughness results acceptable for design studies.

It will be important to establish a connection between sub-miniaturized sample geometry (1-2 mm) and conventional SSTT geometries (as recommended by F4E)

Current status of tasks

Tasks	Status
Literature study *(SSTT, Mechanical test standards,…)*	Ongoing
Learn to use mechanical equipment in cold lab *(universal test machine, fatigue precracking)*	Executed
Preparation of irradiation campaign with miniaturized samples *(Tungsten and Eurofer97)*	Executed (Irradiation will launch in March 2021)
Design of new sample holders for mini-testing *(SEM holder and Foil Bending stage)*	Executed
Learn FEM *(started with uniaxial tensile test)*	Ongoing
Setup matrix of standard tests *(Japanese Tungsten for divertor, E97 for TBM)*	Ongoing
Setup matrix of non-standard tests *(mini tapered, shear, notched tensile)*	Ongoing