Advanced Qualification Methodology for Actively Cooled High Heat Flux Plasma Facing Components


Acknowledgements: Plansee company, FZJ, ENEA, Université de la Méditerannée, and Toulon
High Heat Flux Plasma Facing Components Challenge
Steady state power exhaust capability: 5 – 20 MW/m²

Heat flux

Erosion, melting

Plasma interaction material (« plasma acceptable »)

Transition armour/heat sink

Cooling

High T

Differ. expansion

Decohesion, debonding

T >> T_vap

Critical Heat Flux: water leak

Armour / heat sink joint is the key
The long and winding road towards reliable PFC...

R&D

Mock ups, prototypes
Need to be qualified destructive and Non Destructive Examination (NDE)

Industrial capability

Ensure, control manufacturing quality
NDE methods development

Operation

Adaptation of NDE (or develop others?) methods from ex to in-situ?
Outline

- Non Destructive Examination (NDE) methods for PFC characterisation and reception (developed at CEA)

- Towards PFC in-situ (health) monitoring
Characterising PFC

Many examination methods
However non functional
(X rays, US, …)

High heat flux tests:
Nearly full simulation
But costly, destructive…

Infiltration of the compliant copper layer: AMC® flat tile concept

[Escourbiac, SOFT 2004]
A functional NDE: SATIR

French acronym for Infra Red Acquisition and Data Processing device

Heat load generated by hot and cold water flowing successively in cooling tube

![Diagram showing heat flux and controlled zone](image)

Output: Mapping of quantitative criteria DTref

**Criteria**

- DT_ref_max (°C)
- Difference (Ref. – Contr. Zone)

**Graphs**

- Surface T (°C) over time (sec.)
- Mapping of quantitative criteria DTref
SATIR achievements, limitations and improvements

Achievements

good correlation with HHF tests

Limitations

Intrinsic variability ($\lambda$, $e$...)

+ uncertainties from NDE itself
  (camera, emissivity, reflexion, ....)

Measurements accuracy increased
however, marginally

Improved NDE development required
SATIR new developments through image processing

\[ T(x, y, t) = f(x, y, t) + g(x, y, t) \]

Energetical criterion of the autocorrelation function (AFE)

Spatial autocorrelation:

Installation noise + defect impact

No need of reference component

[Cismondi PFMC11 2006]

IAEA Fusion Energy Conference, Chengdu, October 2006, FT-1/5
Application to ITER CFC monoblock

Thermal discontinuities

SATIR + REF
100mm

SATIR REF “free”

DTref cartography

HHF testing
(FE200 facility)

TSurf @ 5 MW/m²

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Complementary tool: Lock-in thermography

- **LOCK-IN principle**: periodic thermal excitation

Magnitude and phase-shift of surface temperature depending on thermal path modification: defect or thermal properties variation.

**Validation** on component with calibrated defects

Pros: Easier to operate (no cooling), more versatile

Cons: High sensitivity to experimental parameters

*IAEA Fusion Energy Conference, Chengdu, October 2006, FT-1/5*
Improving statistics through data merging

Will increase confidence in flaw detection by use of different data source

Needs however a good statistical analysis to be previously achieved

[IAEA Fusion Energy Conference, Chengdu, October 2006, FT-1/5]
Operational assessments: In-situ lock-in

Lock in system installed on Tore Supra limiter (during vents)

Health monitoring: investigations towards in situ damage detection

[X. Courtois et al., PFMC wshop 2006]

IAEA Fusion Energy Conference, Chengdu, October 2006, FT-1/5
Tore Supra in situ monitoring

**Phase-shift**

IR image (disruption)
Summary

- **Qualification improvements** are essential element for PFCs development, industrialisation and operation (long term programmes).

- « Variabilities » during series production cannot be ruled out
  ⇔ Need of **reliable non-destructive examination** methods to be developed and qualified before series manufacturing

- **NDE thermographic methods** proved to be well adapted; they nevertheless require a « stubborn » development for an efficient use.

- **Major recent development** based on **image processing and data merging**

- **Adaptation of these methods and development of others for in situ PFCs monitoring** are now under investigation.