Thermomechanical Characterization of Joints for Blanket and Divertor Application Processed by Electrochemical Plating

Wolfgang Krauss, Julia Lorenz, Jürgen Konys, Widodo Basuki, Jarir Aktaa
KIT, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

Motivation

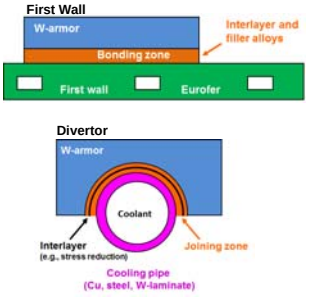
Fusion technology requires in the fields of first wall and divertor development reliable and adjusted joining processes of plasma facing tungsten to heat sinks or blanket structures.

Electroplating has the feature to generate layers acting as active interlayers and as brazing alloys which can overcome such lacks.

This work was performed to demonstrate that the electrochemical plating tool can be used for fusion relevant alloy combinations.

The joints were qualified by thermomechanical testing for the demonstration of future applicability in fusion development.

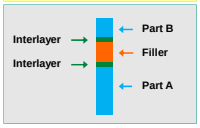
Application of electroplating technology for joints under blanket or divertor development



Joints processed by electroplating

Tools and filler development for adapted joints

Layout of sample processing for brazing of components



The development of joining technology by electroplating consists of the two main parts :

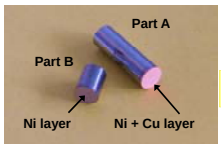
- Electroplating
- Joining by brazing or bonding

Interlayers may be Ni, Pd, Cr or Fe to improve reactions
Electroplating from aqueous electrolytes similar to the filler Cu

Surface conditioning, electroplating of interlayers and Cu filler component

Surface cleaned

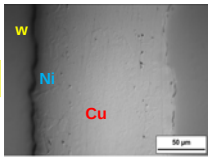
Deposited interlayers



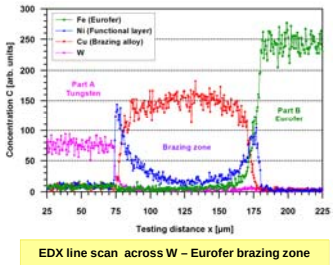
Ready for brazing with filler

Joined samples, characterization and thermal treatment

Brazed samples for thermomechanical testing



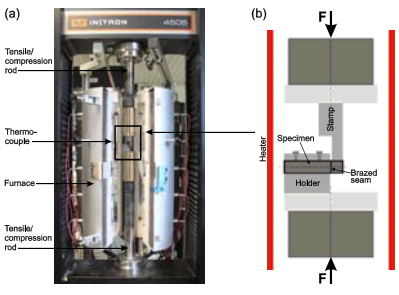
Reaction zone W – W joint



EDX line scan across W – Eurofer brazing zone

Mechanical qualification of joints

Shear testing of joints



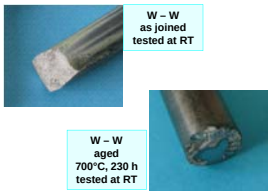
(a) Universal mechanical testing machine Instron 4505
(b) Schematic diagram of the experimental setup

Testing conditions:

Sample size:	Diameter 8 mm
Temperature range:	RT to 600°C
Atmosphere:	Air
During heating:	Preloading of 0.03 kN
Displacement rate:	0.01 mm/s

Thermomechanical characterization of samples

Behavior of joints at room temperature



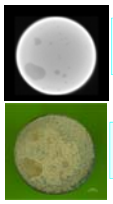
W – W as joined tested at RT

W – W aged 700°C, 230 h tested at RT

Material combination	Fracture characteritics	Highest Loads
W – W	Brittle fracture of W base material	11 kN
E – E	Shearing-off in the brazing zone	12 kN
S – S	Bending	9 kN
W – E	Shearing-off in the brazing zone	9 kN
W – S	Shearing-off in the brazing zone	9 kN

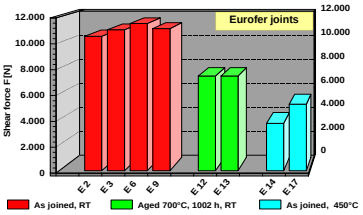
Impact of testing temperature and aging on joints

Impact of aging on defects

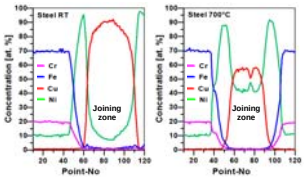


Joint E 12 as joined, X-Ray tomography

Joint E 12 aged, sheared surface



Impact of aging on element distribution



Observations

- Microstructure unchanged
- Homogenization of filler
- No defects generated by aging
- No brittle phase formation in contact zone of filler to base material
- Interlayer and filler are ductile

Behavior of mixed joints

W - E brittle at RT

W - E joint shear tested at 450°C

SS - W joint shear tested at 450°C

Mechanical behavior vs. testing conditions and temperature

- Shear strength is similar for all brazing combinations
- Softening at elevated test temperature as expected
- Pd interlayer increases strength compared to Ni

Materials / Shear force [kN]	RT	RT aged 200 h	RT aged 1000 h	RT aged 2000 h	300°C	450°C	450°C aged 2000 h	600°C
W – W	(11) C	3	-	-	-	3	1	1
SS – SS	(>9) B	9	8	9	-	6	7	-
E – E	12	4	7	6	5	5	5	-
W – E	(9) C	-	-	-	-	6	-	-
W – SS	6	-	-	-	-	6	-	-
W - W	-	-	-	-	-	9	-	-
E - E	-	-	-	-	-	16	-	-
B : Bending C : Cracking	Ni interlayer			Pd interlayer			Aging at 700°C	

Conclusions

The investigations showed that electroplating is an effective technology in the field of the joining of fusion relevant materials and components for divertor and blanket development.

- Reactive Ni and Pd layers were successfully deposited on tungsten, Eurofer and stainless steel by electroplating to obtain improved brazing by Cu
- Mechanical testing was performed in the temperature range RT to 600°C
- Shear strength decreases with temperature similar to yield strength of Cu
- Aging at 700°C showed diffusion in brazing zone but no significant weakening
- At 450°C and 600°C failure appeared as expected in the braze for all joints tested
- Higher strength of joints with Pd interlayer observed

Acknowledgment

This work has been partly carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.