28th IAEA Fusion Energy Conference, Virtual Event, 10-15 May 2021

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Advanced Multi-Step Brazing (AMSB) for Fabrication of the Divertor Heat Removal Component

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TECH/3-3

Introduction

"W/Cu alloy" divertor heat removal component

Reliable joint is required between "W" and "Cu alloy"
However, joint procedure is difficult

Reason: Large deviation of the CTE
W: 4.3 μ/K
Cu alloy : 16.5 μ/K

To absorb the large deviation of the CTE

Conventional structure (e.g., ITER)
W
Intermediate material (Cu)
Filler material (NiCuMan-37)
Cu alloy PH-Cu (CuCrZr)
Cooling water

Including many issues

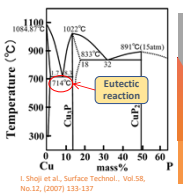
Direct brazing (this study)
W
Filler material
Cu alloy
Cooling water
Ideal structure

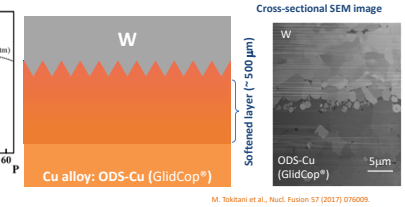
We challenged
Direct brazing

There are a lot of disadvantages
- Degradation of the physical and mechanical properties of Cu inter layer by the neutron dose.
- Degradation of the thermal conductivity due to the multiple interface between dissimilar materials.
- High manufacturing costs.

Advanced brazing technique (ABT)

Feature 1: Very narrow joint like a microscale welding
Feature 2: Softened layer is spontaneously created





1. During the bonding heat treatment with 960˚C, the ODS-Cu (GlidCop®) bulk only near the bonding surface satisfies the eutectic reaction (Cu-P) for a short time.
2. The surface of the ODS-Cu (GlidCop®) bulk is melted, and melted material tightly sticks to the W bulk through the anchor effect.

Results and discussions

Requirement for the "new type divertor heat removal component"

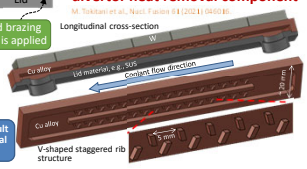
Structural limit to heat removal
Heat loading
W
Coolant
Cu alloy

Ideal cooling structure
T. Tsuneyoshi et al., JSFM 2015, C11-1.

(1) Rectangular-shaped cooling flow path
(2) V-shaped staggered rib structure
- Industrially applied technology, e.g., gas turbine blade etc.
- The swirling turbulent flow is generated due to the effect of the V-shaped rib structure.

"Advanced brazing technique" is applied

"New type divertor heat removal component"
M. Tokitani et al., Nucl. Fusion 61 (2021) 046016.



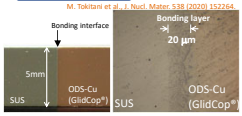
The leak-tight joint is difficult to create in the conventional technologies.

1. The joints are completely leak-tight.
2. The joints have areal contact, not line- or spot-like contact.
3. The joints withstand against "thermal stress" and "water pressure".
4. The joints do not degrade even after a repetitive (brazing) heat treatment.

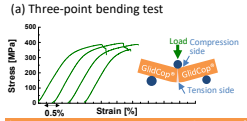
Quality of the leak-tight sealing joint

① GlidCop® / GlidCop®
M. Tokitani et al., Fusion Eng. Des. 148 (2019) 111274.

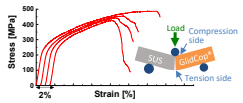
② SUS/GlidCop®
M. Tokitani et al., J. Nucl. Mater. 538 (2020) 152264.



(a) Three-point bending test



(a) Three-point bending test



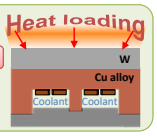
- Very narrow bonding layers of ODS-Cu/ODS-Cu and SUS/ODS-Cu were obtained.
- Strength of the bonding layers were as high as the original ODS-Cu (GlidCop®).
- Microstructures and joint strength does not show any sign of the degradation even after the 2nd time heat treatment.

Breakthrough: cleared the four conditions

1. The joints are completely leak-tight.
2. The joints have areal contact, not line- or spot-like contact.
3. The joints withstand against "thermal stress" and "water pressure".
4. The joints do not degrade even after a repetitive (brazing) heat treatment.

– Judgement:
The "new type divertor heat removal component"

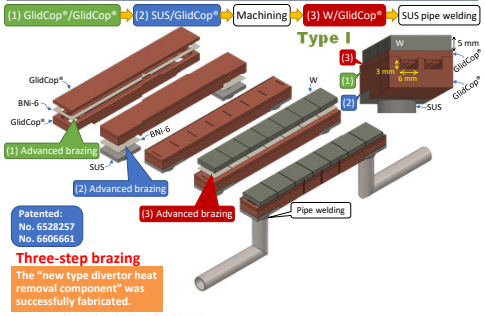
Ideal cooling structure
(1) Rectangular-shaped cooling flow path
+
(2) V-shaped staggered rib structure



→ can be fabricated

Advanced Multi-Step Brazing (AMSB) was developed

(1) GlidCop®/GlidCop® → (2) SUS/GlidCop® → Machining → (3) W/GlidCop® → SUS pipe welding



Patented:
No. 6528257
No. 6606661

Three-step brazing
The "new type divertor heat removal component" was successfully fabricated.

M. Tokitani et al., Nucl. Fusion 61 (2021) 046016.

Advanced Multi-Step Brazing (AMSB) was developed

(1) GlidCop®/GlidCop® → (2) SUS/GlidCop® → Machining → (3) W/GlidCop® → SUS pipe welding

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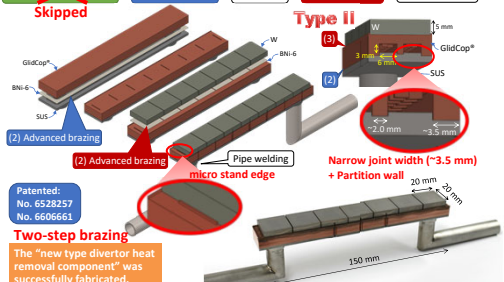


Patented:
No. 6528257
No. 6606661

Two-step brazing
The "new type divertor heat removal component" was successfully fabricated.

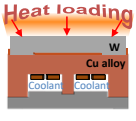
M. Tokitani et al., Nucl. Fusion 61 (2021) 046016.

Advantages of AMSB

– Manufacturing advantages:
1. The joints are completely leak-tight.
2. The joints have areal contact, not line- or spot-like contact.
3. The joints withstand against "thermal stress" and "water pressure".
4. The joints do not degrade even after a repetitive (brazing) heat treatment.

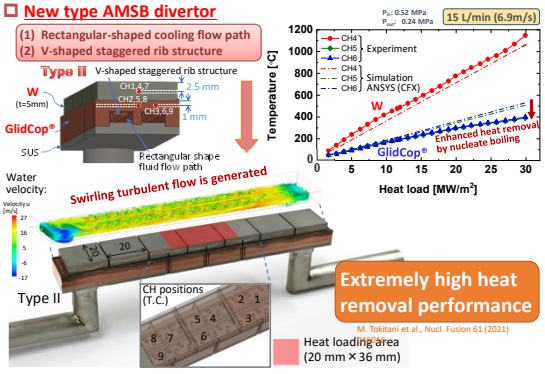
"Structural advantages" can be realized by "Manufacturing advantages"

– Structural advantages:
1. Rectangular-shaped cooling flow path + V-shaped staggered rib structure
2. Micro stand edge structure
3. Narrow joint width (~3.5 mm) + Partition wall



Extremely high heat removal capability: ~30MW/m²

New type AMSB divertor
(1) Rectangular-shaped cooling flow path
(2) V-shaped staggered rib structure



Extremely high heat removal performance

M. Tokitani et al., Nucl. Fusion 61 (2021) 046016.

Summary

1. The concept of the new type divertor heat removal component was proposed.
2. The leak-tight joint method of GlidCop®/GlidCop® and SUS/GlidCop® was developed by applying the advanced brazing technique (ABT).
3. Advanced Multi-Step Brazing (AMSB) was developed, and the new type divertor heat removal component was successfully produced. (Patented: No. 6528257, 6606661)
4. The new component demonstrated an extremely high heat removal capability under the ~30 MW/m² steady state heat loading.