Diffusion bonding of titanium to itself and to aluminium

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Symposium of World Experts in Diffusion Bonding
20-21 June 2017
The Open University
Can you see the bond-line?

Diffusion Bonded Stainless Steel

200 µm
Advanced Joining Methods

Patented in UK and USA

High Strength Joints
[Aerospace / Defence]
- Bond line
- Inconel 718
- Inconel 600
- Joint
- Hastelloy®
- Aluminium
- Titanium

Microjoining
[Medical Devices]
- Stainless Steel
- Thin Wall Steel Tube

Bonding Ceramics to Metals
[Automotive / Optics / Sensors]
- Steel
- Alumina
- Steel - Sapphire – Steel

High Precision Bonding
[Microelectronics]
- Microwave Guides & Filters
- Aluminium
- Joint
- Tube
- Plate
Cambridge diffusion bonding rig
New diffusion bonding rig & specimen setup
(The Open University)
Joining a 60-layer component

Conventional coil

Special coil
...all metals will bond

if

thoroughly cleaned surfaces are brought together within the range of interatomic forces.

Ref: Kazakof’s surface oxide hypothesis
Classical definition of diffusion bonding:
A process by which faying surfaces are brought into sufficiently close contact using an applied pressure at elevated temperature to allow bond formation by atomic interdiffusion across the joint interface.

But in reality:
surface oxides are brought into close contact not the alloys themselves!
Gallium-assisted solid-state diffusion

(UK and USA Patents)

- Al–SiC metal matrix composite
- Aluminium (Al6082)
- Titanium alloy
- Stainless steel (316)
- Cobalt base superalloy
- Nickel base superalloy (Inconel)
- Nickel base single crystal superalloy
- Nickel base single crystal superalloy
Gallium-assisted diffusion bonding of cobalt-base superalloy PWA647
Creep test result
Inconel 600 joined to Inconel 718

Joined sample failed in parent alloy and away from the bond line

- Temperature: 760°C
- Stress: 90 MPa
- Lifetime of dissimilar joint: 33 hours
- Lifetime of parent Inconel 600: 31 hours
Diffusion bonding Cu to Al

Endured 3000 thermal cycles
(Mitsubishi Project)
Room temperature tensile tests of solid-state diffusion bonds

Tensile test of Al 6082 samples

Parent alloy  Bond 1  Bond 2

Necking points
Bond line is in the centre of sample

Cambridge Joining Technology
Rolls Royce Trent 900 Engine

Titanium fan blades made by diffusion bonding
Bonded samples subjected to severe mechanical loads to assess joint integrity
Shear test results for Al-Ti solid-state diffusion bonds

Load (N)

Parent aluminium

Al-Ti bonds
Latest Development:

Aluminium to Stainless Steel
Bond Strength 96-102 MPa

Bending Test
Top-hat Tensile Test
Top Hat Tensile Testing
Joining aluminium to titanium

Reduction in the diameter of Al due to necking under tensile load

150 MPa
Stainless Steel / Titanium Diffusion Bond

Latest Results : 313 MPa
Aluminium – Titanium Adaptors & Flanges
Problem Definition

Turbocharger are made in 100,000s per year

- Air compressors
- Process gas compressors
- Natural gas expanders
- Refrigeration compressors
- Fuel cell compressors

- Problems:
  - High axial load prevents applications where pressure is high or leakage has to be minimised
  - High axial load can result in bearing power loss or failure of compressor

Alex Molyneaux
OFTTech Ltd
UK
www.oftech.com
Open & Shrouded Wheels

- Axial load is substantially reduced using shrouded wheels.
- Shrouded wheels are common in centrifugal pumps where pressures are high.
- Shrouded wheels are manufactured by casting or brazing a front plate.
- Selective laser sintering is one of the latest methods for manufacturing shrouded wheels.

Type of impeller

(a) Open impeller, (b) enclosed or shrouded impeller
Gas Bearing Supported Helium Wheel

Application: Helium circulators used in nuclear power plants

Axial load is too high for open wheels

- Solution was to add a front shroud and
- Resulting axial load ≈ 0
- Laser welded successful in 100mm Ø wheel with 2 mm high blades
- Surface roughness ~ 10-40 microns
- Max accuracy +/- 25 microns
Gas Bearing Supported Cryo Expander

Application: Cryogenic expander used in satellites

- 250,000 RPM gas-lubricated bearings
- 17 mm diameter expander wheel
- Blade height only 0.5 mm

- Laser welding is NOT possible,
- Roughness & accuracy are too poor

- Only solution is diffusion bonding
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High precision diffusion bonding of Ti-based shrouded turbocharger
Tensile strength = 1522 kg (334 MPa)

22 mm Ø
Alignment Accuracy

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<tr>
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Max error = +/- 13 micron
High precision diffusion bonding of Ti-based shrouded turbocharger
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Virtually invisible bond line
Any questions?
SYMPOSIUM OF WORLD EXPERTS IN DIFFUSION BONDING (WEDB)
The Open University, UK | 20–21 June 2017

ART OF JOINING UN-WELDABLES

"I cordially invite experts in Diffusion Bonding to join this non-commercial symposium in order to exchange ideas and present their research to potential users."

Dr Amir Shirzadi (Chairman)

Can you see the bond-line?

Sponsors & Contributors

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