Microstructural characterization of Ti6Al4V/Al₂O₃ joints produced using Ag-Cu sputtered coated Ti foil

Omid Emadinia*, Sónia Simões*, Carlos José Tavares**, Aníbal Guedes***

*CEMMPRE, Department of Metallurgical & Materials Engineering, FEUP, Portugal
*Centre of Physics, University of Minho, Portugal
***CMEMS, Department of Mechanical Engineering, University of Minho, Portugal

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Motivation

Increasing the applications of advanced ceramics for functional structures for:

- Having high thermal stability, stiffness and wear resistance
- Overcoming shortcomings related with high production costs of large or complex components used in
  - Aerospace, automotive, and chemical industries

Joining ceramic materials to metallic parts is a strategy

- However, it is not an easy task because metals & ceramics have different properties, e.g.:
  - Coefficient of thermal expansion
  - Wettability with liquid metal

Brazing technique is a method

- It requires lower temperature, pressure and holding time that it is required for diffusion bonding process
- Brazing has a merit of joining irregular dimensions
- Generally, it leads to the development lower residual stresses than other joining processes
Motivation

Brazing involves

• Joining two components by melting a brazing filler (> 450 °C) that wets and reacts with both base materials, it is traditionally carried out by a torch and the brazing filler

Shortcomings

• Reaction products formed at the interface may limit the operating temperature of joints to 300/350 °C, e.g. the extensive formation of (Ag), when Ag-based brazing fillers are used

Diffusion brazing involves

• Placing a brazing filler between two bases under optimized conditions:
  o Adequate heating apparatus
  o Proper heating temperature
  o Proper brazing filler

• During the heating period, the brazing filler material reacts with the components resulting in
  o the formation of phases with higher melting temperatures
Motivation

**Brazing fillers**
- Titatium base compositions like
  - Ti-Cu-Ni system
- Silver base compositions like
  - Ag-Cu system

**A comparison**
- Ti base brazing fillers require higher brazing temperatures (~1000 °C) than Ag base brazing fillers (~800 °C)
- Ag base brazing fillers induce the formation of (Ag) that can buffer residual stresses developed throughout the interface

**Shortcomings**
- Ag base brazing fillers leave (Ag) in the interface leading to a softening effect
- Therefore, for this study, some Ag content of the brazing filler was replaced by Ti expecting to the elimination of (Ag)
Objectives

This study involves

- Diffusion brazing of Al₂O₃ to Ti₆Al₄V by the use of a Ti(Ag/Cu) brazing filler

- Microstructural characterization of the brazed interface by scanning electron microscopy technique (SEM/BES/EDS)
  - Understanding the microstructure evolved at the joint interface
    - Evaluation of the formation of unwanted phases at the joint interface
    - Microstructure influences the mechanical properties of the joints and service life of the joined components
Materials

Bases have disk shape of \( \sim 5 \) mm height

- Ti6Al4V (\( \Phi 7.0 \) Mm)
- Al\(_2\)O\(_3\) (\( \Phi 6.0 \) mm)

brazing filler

- Ag-Cu sputtered coated Ti foil (Ti/Ag-Cu)
  - 82.8Ti-12.4Ag-4.8Cu in wt.% (produced at CF-UM-UP)
Processing

Cutting disks and grinding

- Ti base was ground by silicon carbide emery papers until 1000 mesh
- Alumina base was ground by the Aka disks until 6 µm diamond suspension

Brazing

- Pieces were washed with alcohol, and dried
- Arranged in a metallic fixture which is fixed manually
- Heated in a resistance furnace assembled with a high vacuum pump at
  - 980 °C for 10 min at ~8×10^{-4} Pa

Evaluations

- Visual observation of the joints
- Grinding and polishing for microscopic observations by
  - Optical Microscope
  - SEM/BSE/EDS technique for phase identifications
- Providing a microhardness map of the interface
Microstructural characterization

- A sound joint with a very complex microstructure was obtained by diffusion brazing at 980 °C for 10 min at \( \sim 8 \times 10^{-4} \) Pa.
Microstructural characterization

- SEM/EDS map of a selected zone of the Al₂O₃ - Ti(Ag/Cu) - Ti6Al4V interface
Microstructural characterization

- The pores are most probably inherited from the ceramic base.
Microstructural characterization

- Phase identification of interested zones
Microstructural characterization

- Phase identification of interested zones

![Diagram showing microstructural characterization at 700 °C and 800 °C](image)
Microhardness map

- $\text{Al}_2\text{O}_3$ - Ti(Ag/Cu) - Ti6Al4V interface
Conclusions

• The diffusion brazing process was successfully performed for joining Al₂O₃ to Ti₆Al₄V by using a Ti(Ag/Cu) brazing filler at 980 °C at high vacuum

• The brazing process did not cause any defect (such as crack or porosity) at the joint interface

• Diffusion at the joint interface resulted in the formation of several intermetallic phases (TiAg, Ti₃Al, and Ti₂(Ag,Cu))

• The formation of (Ag) was not detected

• The hardness transition from the alumina towards the Ti₆Al₄V base presents values larger or similar to the titanium base alloy
Future works

• Shear strength test

• SEM from fractured surfaces

• X-ray diffraction

• TEM & Electron diffraction pattern analyses

• Influence of thermal post treatments on the strength and microstructure
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