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Laser processing of aluminum–titanium-tailored blanks

Michael Kreimeyer*, Florian Wagner, Frank Vollertsen

BIAS Bremer Institut für angewandte Strahltechnik, Klagenfurter Straße 2, 28359 Bremen, Germany

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Abstract

In the aircraft industry, hybrid structures of titanium (high strength, stiffness and corrosion resistance) and aluminum alloys could offer an advantage in comparison to conventional materials, e.g. in fuselage areas. Due to demand from the aircraft industry for new material combinations based on commercially available and qualified materials, research into the thermal joining of dissimilar materials has been initiated.

The use of the laser technique for joining aluminum–titanium-tailored blanks and structures offers some advantages compared with conventional thermal joining processes. The main goal is the control of intermetallic phase formation, which occurs during thermal joining of aluminum to titanium. Through locally restricted energy input and high joining speed, the thickness of these phases can be reduced to below 2 μm. This results in good tensile strength and therefore in promising forming behavior of the tailored blanks.

This paper presents a study for laser joining of aluminum–titanium in the butt joint configuration, including FEM simulation, process development, characterization of the seam morphology by optical and electron microscopy and mechanical properties.

Keywords: Intermetallic phases; Tailored blanks; Laser joining; Aluminum; Titanium; Simulation

*Corresponding author.
E-mail address: kreimeyer@brias.de (M. Kreimeyer).

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1. Introduction

The use of light weight structures is growing significantly in several areas of the civil and military transportation industry. However, the use of lightweight materials becomes problematic when two different kinds need to be integrated and connected to each other, for example in a car or aircraft body. Currently, the connection of dissimilar materials like aluminum (e.g. AA6016) and titanium (e.g. TiA16V4) can be achieved by riveting, clinching and screwing. These are still the most widely used techniques in the automotive and aircraft industries. An alternative for joining titanium and aluminum is the use of laser systems like Nd:YAG or CO_2 to realize joints with good properties. However, the key aspect during joining aluminum to titanium is the formation of intermetallic phases, which depends on process related temperature–time cycles [1,2]. Accompanying this phase formation, embrittlement of the joining zone is observed. Even though these cycles are obviously associated with non-equilibrium metallurgical phenomena, the equilibrium phase diagram of aluminum and titanium should be considered. The binary Ti–Al phase diagram (Fig. 1) shows the phase formation behavior. On the titanium-rich side, a slightly lower solubility for aluminum is clear. Exceeding an aluminum content of approximately 13 at% in the titanium results in Ti_3Al formation. With increasing aluminum content, phases like TiAl and then $TiAl_2$ are formed. On the aluminum-rich side of the diagram, the low solubility of titanium leads to early formation of the intermetallic phase $TiAl_3$ when the titanium content exceeds approximately 2 at%. Based on thermodynamic assumptions, it is predicted that in the first stage during the reaction of titanium and aluminum, the $TiAl_3$ phase forms preferentially [3] and this phase induces joint embrittlement. However, if material joints with high toughness and strength are required, the intermetallic phase layer has to be limited to a maximum thickness of less than 10 μm [4]. Some research concerning the joining of

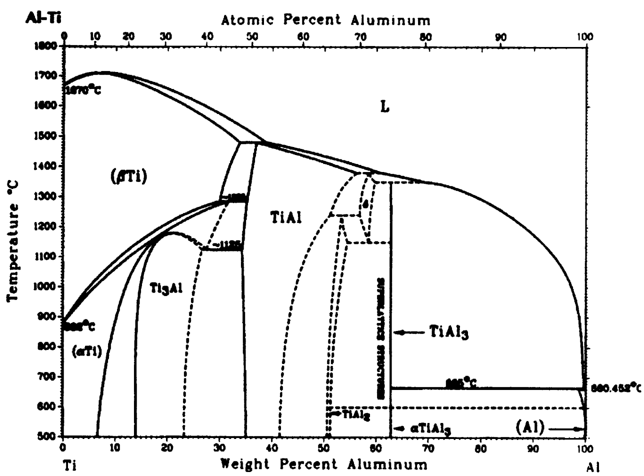

Fig. 1. Binary Ti–Al equilibrium phase diagram [2].