



A literature review of Ti-6Al-4V linear friction welding



Anthony R. McAndrew^{b,c,*}, Paul A. Colegrove^a, Clement Bühr^a, Bertrand C.D. Flipo^c, Achilles Vairis^d

^a Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK

^b Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK¹

^c TWI Ltd, Granta Park, Great Abington, Cambridge CB21 6AL, UK

^d Technological and Educational Institute (TEI) of Crete, Heraklion 71004, Greece

ARTICLE INFO

Article history:

Received 16 January 2017

Received in revised form 21 May 2017

Accepted 11 October 2017

Available online 25 October 2017

Keywords:

Linear friction welding

Titanium alloy

Literature review

Ti64

Ti6Al4V

Microstructure

Mechanical properties

Modelling

Residual Stress

Energy

Advantages

ABSTRACT

Linear friction welding (LFW) is a solid-state joining process that is an established technology for the fabrication of titanium alloy bladed disks (blisks) in aero-engines. Owing to the economic benefits, LFW has been identified as a technology capable of manufacturing Ti-6Al-4V aircraft structural components. However, LFW of Ti-6Al-4V has seen limited industrial implementation outside of blisk manufacture, which is partly due to the knowledge and benefits of the process being widely unknown. This article provides a review of the published works up-to-date on the subject to identify the “state-of-the-art”. First, the background, fundamentals, advantages and industrial applications of the process are described. This is followed by a description of the microstructure, mechanical properties, flash morphology, interface contaminant removal, residual stresses and energy usage of Ti-6Al-4V linear friction welds. A brief discussion on the machine tooling effects is also included. Next, the work on analytical and numerical modelling is discussed. Finally, the conclusions of the review are presented, which include practical implications for the manufacturing sector and recommendations for further research and development. The purpose of this article is to inform industry and academia of the benefits of LFW so that the process may be better exploited.

© 2017 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Contents

1. Introduction	226
2. Background and process fundamentals	228
2.1. Background	228
2.2. Process phases	228
2.3. Process parameters	228
2.4. Process advantages and limitations	229
3. Industrial usage of LFW	229
3.1. Bladed disk (Blisk) manufacturing	229
3.2. Future concepts	229
3.3. LFW machine manufacturers	230

* Corresponding author at: TWI Ltd, Granta Park, Great Abington, Cambridge CB21 6AL, UK.

E-mail address: anthony.mcandrew@twi.co.uk (A.R. McAndrew).

¹ Formerly.

4.	Ti-6Al-4V linear friction welds	231
4.1.	Microstructure and thermal observations	234
4.1.1.	Texture	237
4.2.	Mechanical properties	237
4.3.	Flash morphology	238
4.4.	Interface contaminant removal	239
4.5.	Residual stresses	241
4.6.	Energy usage	244
4.7.	Tooling effects	244
5.	Process modelling	245
5.1.	Analytical modelling	245
5.1.1.	Phase 1 thermal modelling	245
5.1.2.	Phase 3 (Steady-State) thermal modelling	246
5.1.3.	Phase 3 (Steady-State) strain rate modelling	247
5.2.	Numerical modelling	247
5.2.1.	Reference frames and meshing	248
5.2.2.	LFW modelling approaches	248
5.2.3.	Coupled analysis and process efficiency	249
5.2.4.	Constitutive data	250
5.2.5.	Validation	250
6.	Conclusions	251
6.1.	Summary	251
6.2.	Practical implications	252
6.3.	Recommendations for further research	252
	Disclosure statement	253
	Data access	253
	Funding	253
	References	253

1. Introduction

Linear friction welding (LFW) is a solid-state joining process that works by oscillating one workpiece relative to another while under a large, compressive force; see Fig. 1(a). The friction between the oscillating surfaces produces heat which causes the interface material to plasticise. The plasticised material is then expelled from the interface causing the workpieces to shorten (burn-off) in the direction of the compressive force [1–4]. During the burn-off the interface contaminants, such as oxides and foreign particles, which can affect the properties [5,6] and possibly the service life of a weld [7], are expelled from

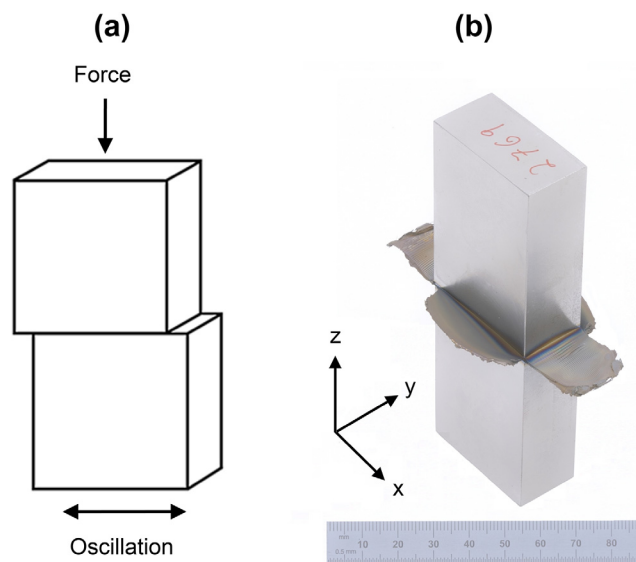


Fig. 1. (a) LFW process schematic and (b) a completed Ti-6Al-4V weldment showing the expelled interface material (flash), where the oscillatory motion occurred in the 'x' direction [16].

Download English Version:

<https://daneshyari.com/en/article/8023095>

Download Persian Version:

<https://daneshyari.com/article/8023095>

[Daneshyari.com](https://daneshyari.com)