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Infrared thermography for monitoring heat generation in a linear friction welding process of Ti6Al4V alloy

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HIGHLIGHTS

- Infrared thermography applied to the linear friction welding process of Ti6Al4V alloy.
- Thermal field on the outer wall of the two parts to be joined during welding.
- Maximum temperature characterizing the process before and after the flash formation.
- Maximum mean temperature variation across the joint during welding.
- Maximum temperature history.

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ABSTRACT

The increasing use of titanium alloys in a wider range of applications requires the development of new techniques and processes capable to decrease production costs and manufacturing times. In this regard welding and other joining techniques play an important role. Today, solid state friction joining processes, such as friction stir welding, friction spot welding, inertia friction welding, continuous-drive friction welding and linear friction welding (LFW), represent promising methods for part manufacturing. They allow for joining at temperature essentially below the melting point of the base materials being joined, without the addition of filler metal.

However, the knowledge of temperature is essential to understand and model the phenomena involved in metal welding. A global measured value represents only a clue of the heat generation during the process; while, a deep understanding of welding thermal aspects requires temperature field measurement. This paper is focused on the use of infrared thermography applied to the linear friction welding process of Ti6Al4V alloy. The attention is concentrated on thermal field that develops on the outer wall of the two parts to be joined (i.e. heat generated in the friction zone), and on the maximum temperature that characterizes the process before and after the flash formation.

1. Introduction

Joining is one of the most critical processes in industrial manufacture and assembly due to both the development of new materials and the improvement of design techniques. The realization of a good joint is demanded to the welding process which has to guarantee a suitable strength together with an high reliability. Today technologies capable to produce joints of metal alloys with reduced permanent deformations and residual stresses in the final parts are available. Among them, friction welding (FW) processes have recently gained importance in the fabrication industry and they are now assuming a determinant role. The FW [1–3] is an efficient manufacturing solution because it allows joining two parts of different metals without melting them, but through the frictional heat which is generated when they are placed in contact and kept in reciprocal motion under pressure.

The friction between the rubbing surfaces coupled with the strong applied pressure heats up the materials and creates the necessary conditions, in the contact zone, to soften the individual components and to form metallic bonds. When welding is obtained by forcing a stationary part against a part that is reciprocating in a linear manner (so as to generate frictional heat), the process is called *Linear Friction Welding* (LFW) [4].

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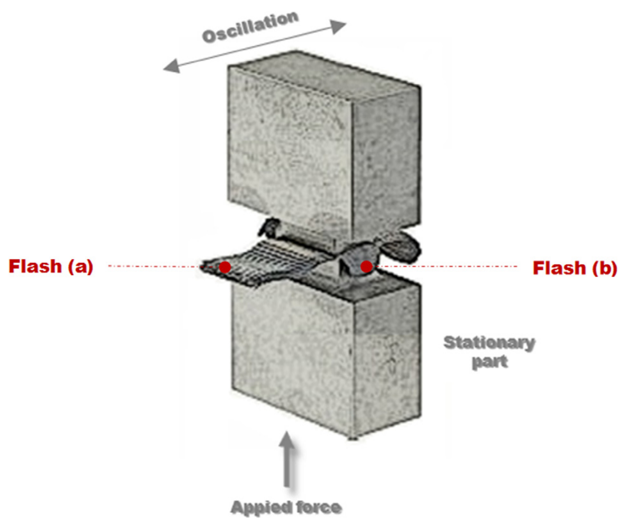

Fig. 1. Linear friction welding schematic. Flash formation parallel (a) and transverse (b) to direction of motion. In the oscillation direction the amount of ejected material is greater.

The main advantage of LFW lies in the fact that the temperature remains below the melting point of the materials being joined. Other benefits, over conventional welding methods, are: the absence of solidification defects, low shrinkage and minimal component distortion, low porosity, possibility to weld dissimilar materials, lack of consumables, limited and easy preparation of parts, easiness of automation and so high reproducibility, limited energy requirements, low production of fumes, short production times and therefore high eco-compatibility. Filler metal, flux, and shielding gas are not required with this technology resulting in reduced weld-joint contamination and a small number of process variables to control. Moreover, mechanical properties of the joint are excellent and often better than those of the parent materials [5].

Once the material has softened sufficiently because of the produced heat, the two workpieces, moving relatively to each another, plastically displace material from the center outward (ejection from the rubbing plane) to form, with the combined action of the force applied perpendicular to the weld interface, the characteristic "flash", as depicted in Fig. 1. The flash, plasticized material expelled from the contact interface, is the most important macroscopic feature of the linear friction weld. The its shape usually depends on the materials being welded [6,7] (e.g. titanium alloys usually produce flash in a wing like structure [7]).

Surface-oxides and other impurities are removed, along with the plasticized material, and this allows metal-to-metal contact between parts and the joint to form [8–12]. The process ends when the motion is stopped and a forging force is applied.

LFW is particularly suited to join materials that have good properties at high temperature, especially compressive yield and shear

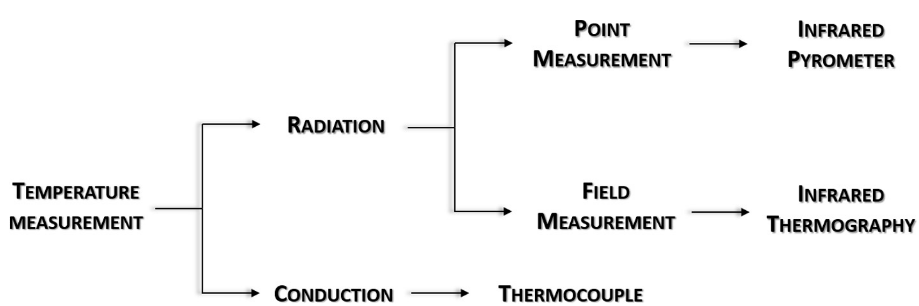

Fig. 2. A scheme of temperature measurement techniques.

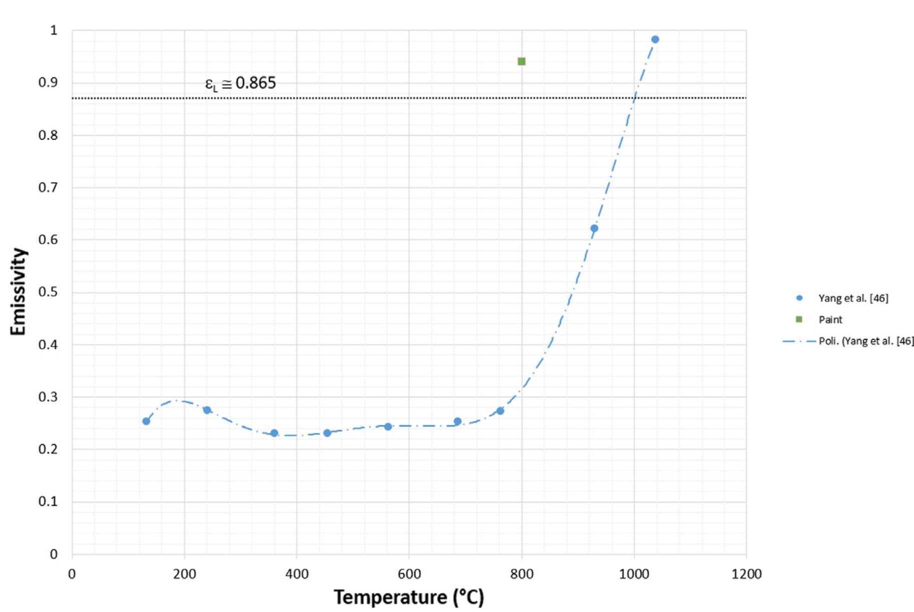

Fig. 3. Emissivity trend to changes in temperature for Ti6Al4V [45] and ε values for black paint and for data by the literature.