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Original Research Article

Modelling the friction welding of titanium and tungsten pseudoalloy

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ABSTRACT

During friction welding, temperature, stress, strain, and their variations govern welding parameters, and knowledge of them helps determine optimum parameters and ways to improve the design and manufacture of welding machines. The finite element method was used to model the titanium–tungsten pseudoalloy joint. Coupled thermomechanical model was built, the Johnson-Cook equation was used to define material properties. The calculated results of temperature distribution were in good agreement with measured ones. The numerically calculated results for the shape of the welded joint also showed a good fit with the experimental observations. The effects of friction coefficient variation with temperature are discussed.

1. Introduction

Friction welding is one of the state-of-the art methods of bonding solid state materials (used, e.g., in the aircraft and car industries). The method consists in converting via friction the kinetic energy of the moving element into thermal energy needed to bond the materials (Fig. 1). It is a very high-yield and energy-efficient way of bonding materials. Its major advantage is that both similar and dissimilar materials can be bonded. Until recently the process parameters have been selected only by trial and error. Owing to the development of IT, especially programmes for finite element computations, it has become possible to simulate friction welding by means of FEM models.

The friction welding process began to be modelled in the 1980s. Among others, Służalec [1] presented the results of an FEM analysis of a thermal field. As the computing power of computers increased, FEM modelling was increasingly often applied to friction welding processes. For the purposes of modelling, Liwen [2] proposed to divide the friction welding process into two stages, for which he determined the correlations between the friction coefficient and temperature. Duan [3] determined the distributions of temperature, stress and strain in the inertial welding process. Using the FORGE 2 software D'Alvise [4] modelled the inertial welding of dissimilar materials and managed to determine the shape of the flash. This shape was also studied, using the MSC MARC software, for the friction welding of aluminium in [5] and the analytical results were compared with the experimental results. Also an equation describing the flux of heat released during friction was proposed, however, in order for the analytical results to agree with the experimental ones it had

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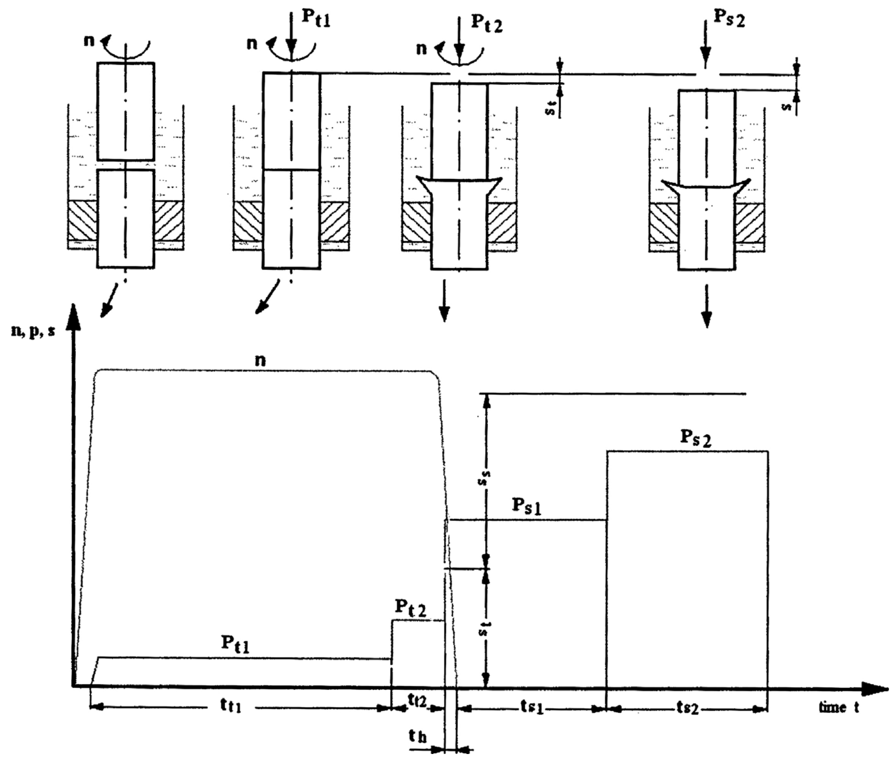

Fig. 1 – Schematic of friction welding.

to be modified. Zimmerman [6] computed temperature, stress and strain fields for ceramics (Al_2O_3-Al)-metal joints.

The aim of the present research was to create a numerical model of the friction welding process in which the modelled heat is released as a result of friction between the two surfaces being bonded and, as opposed to all the above models, the heat source is not described by an equation. A 3D model in which one of the specimens performs the rotational motion while being pressed against the other motionless specimen was developed. The friction welding model was used to compare the processes of bonding titanium specimens with tungsten pseudoalloy specimens. The model was experimentally verified.

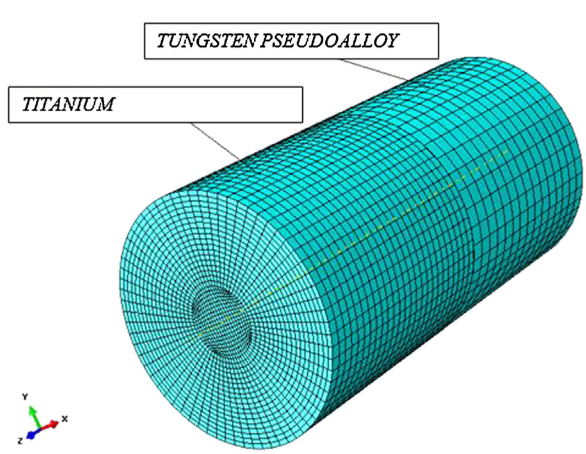

Fig. 2 – Discrete model of titanium–tungsten pseudoalloy joint.

2. Structure of model

2.1. *Discrete model*

The 3D model was created in Abaqus/Explicit (Fig. 2). The Explicit method is suitable for highly dynamic processes (to

Table 1 – Process parameters [7].

Titanium–tungsten pseudoalloy		
Stages	1	2
Time [s]	3	6.15
Pressure [MPa]	24	31
Revolutions [rpm]	1500	

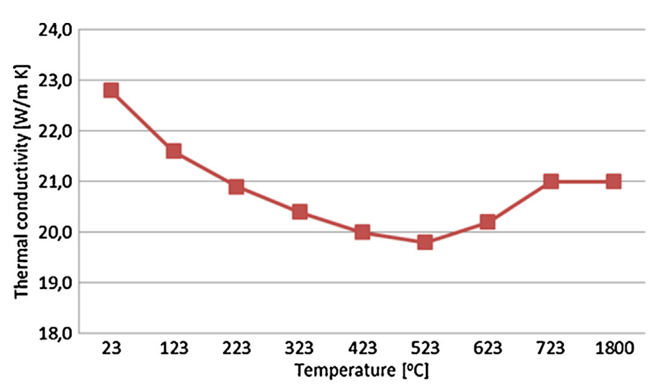

Fig. 3 – Thermal conductivity coefficient versus temperature for Ti [10].