3D Modelling of Material Flow in Stir Friction Welding Using Movable Cellular Automaton Method

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ABSTRACT

An important achievement of the last decades in the field of material joining is the development of friction stir welding (FSW) [1–4]. Recent studies have shown that FSW is an effective way to obtain high quality joints for structures of various dimensions and shapes. The main feature of the FSW is the ability to weld without melting of the joined materials, which allows avoiding changes in material properties due to hot temperatures and joining dissimilar alloys and materials including those that impossible to join by traditional welding technology [2, 3].

The main problem in the industrial application of FSW technology consists in finding the correct technological parameters of the process (such as the tool shape and size, rotation and travel speed, etc.) [2]. It is impossible to define the optimal technological parameters without full understanding the fundamental processes occurring in the material during FSW. The main fundamental problem here is to understand the mechanisms of severe plastic deformation that enable plastic flow, mass mixing and material coalescing behind the tool (i.e. plasticized material behaviour in FSW).

This paper is devoted to the theoretical investigation of the peculiarities of material flow taking place in FSW. The investigation was based on 3D computer simulation by the movable cellular automaton (MCA) method [5], which is a representative of the particle methods in mechanics of materials. Usually, material flow in FSW is simulated based on computational fluid mechanics, which assumes that the material is a continuum and does not take into account the material structure. MCA considers a material as an ensemble of bonded particles. Breaking of inter-particle bonds and formation of new bonds enables simulation of crack nucleation and healing, as well as mas mixing and microwelding.

The simulation results showed that using pins of simple shape (cylinder, cone, pyramid) without shoulder results in small scattered displacements of the plasticised material in the workpiece thickness direction. Nevertheless, the optimal ratio of the longitudinal velocity to the rotational speed allows transporting of the welded material around the pin several times and producing the joint of good quality. Applying additional ultrasonic vibration to the pin may lead to better mixing of the plasticized material behind the pin.

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