Theoretical investigation of the dynamics of friction stir welding process by movable cellular automaton method

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ABSTRACT

Friction stir welding (FSW) is a relatively new method of obtaining non-detachable joints of materials. Recent year studies have shown that FSW is an effective way to obtain high quality joints for structures of various dimensions and shapes, including sheets, 3D profile structures, and pipes. Possessing the broad technological capabilities for obtaining permanent joints of details or units, it can be used as an alternative to riveted joints, electric arc welding, electron beam and laser welding as well as for welding the dissimilar materials. Thus, FSW becomes a perspective technology that has a great potential in various industries, including aerospace area.

The FSW technology is based on the friction of the rotating cylindrical or specially shaped tool between two connected or overlapped faces (ends) of metal plates. The rotating tool is introduced into the joint of two metal plates to a depth approximately equal to their thickness. As a result of sliding friction (while rotating of the tool) a frictional heating the metal takes place. This leads to plastic deformation, flow and mixing of the material and, consequently, to formation of welded joint. The main problem when using FSW technology for producing of welded joints is the determination of an optimal regime (optimal parameters) of the rotating tool movement (in particular, the ratio of the angular and traslational velocities of the tool). These parameters are determined by a wide range of factors, among which are the physical and mechanical properties of welded materials, the thickness of the connected plates, etc. Note, that incorrect determination of welding parameters is likely to cause of a large amount defects at different scales (pores, microcracks, etc.) in a weld seam and, consequently, to decrease of the quality of the joint.

Experimental determination of the parameters of FSW process is quite difficult task, because it requires obtaining and analysis of large amounts of data. In this regard, it is promising to use computer-aided simulation of process of formation of the welded joint. Since FSW processes are inseparably linked with the intensive formation of discontinuities, the generation of structural defects of different levels, the mass transfer, etc. the most preferable one is to use methods of discrete description of the simulated technology. In this paper, the dynamics of the FSW process of duralumin plates was investigated on the base of computer-aided simulation by the movable cellular automaton method. To achieve the objectives of the paper the two-dimensional model of elastic-plastic interaction of cellular automata is used. This model is based on the use of many-particle potentials/forces of interaction of cellular automata. An incremental theory of plasticity of isotropic medium with von Mises plasticity criterion was used to model deformation of intermetallic alloy. Radial return algorithm of Wilkins was adopted for this purpose. Using the developed approach allowed to investigate the features of the dynamics of of formation of welded joint. It is shown, in particular, that in a certain range of the ratio of the angular and traslational velocities of displacement of the rotating tool it is possible to obtain a welded joint with a minimum content of pores and microcracks.