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FRICTION STIR WELDING OF COMPOSITE, GRANULATED AND QUASICRYSTALLINE ALUMINIUM ALLOYS

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Structural peculiarities and mechanical properties of welded joints on strengthened aluminium alloys are studied. It is shown that the use of friction stir welding does not lead to any substantial phase-structural changes in the weld metal and adjoining regions.

Keywords: *friction stir welding, granulated aluminium alloys, composites, meta-stable quasicrystalline particles*

One of the important trends in current engineering is decrease in weight and dimensions of structures with retention of their functional capabilities. Particular emphasis is placed on these requirements in manufacture of aircraft and spacecraft engineering products, overland and water transport. During the last decades this problem has been addressed through a wider utilisation of new high-strength aluminium alloys with high indicators of specific strength, elasticity modulus, corrosion resistance and resistance to propagation of fatigue cracks in the process of operation. However, the possibilities for further improvement of properties of commercial aluminium alloys produced by the traditional methods of casting and subsequent rolling have practically been exhausted. Therefore, a substantial improvement of performance of parts can be achieved by manufacturing them from qualitatively new advanced materials based on aluminium alloys. Such materials include modern granulated aluminium alloys strengthened by dispersed intermetallics that contain oversaturated solid solution of transition metals, composite materials reinforced by dispersed nanosized particles, and alloys strengthened by metastable quasicrystalline particles produced at high solidification rates. However, realisation of potential capabilities of such advanced materials in fabrication of efficient welded structures depends to a considerable degree upon the quality of their joining.

Table 1. Composition and tensile strength of 2 mm thick sheets of composite materials based on aluminium alloys

Matrix alloy	Content and composition of reinforcing particles	Sizes of reinforcing particles, μm	Distance between reinforcing particles, μm	Tensile strength σ_t, MPa
AMg5	27 % Al_2O_3	3–.15	3–20	340
AL25	25 % Al_2O_3	5–20	5–60	267
D16	20 % SiC	3–5	1–5	512
AL25	18 % SiC	5–15	3–50	278
AD0	7 % Al_2O_3	≤ 0.1	0.1–2.5	148
D16	20 % SiC	≤ 0.1	0.1–2.5	574

The purpose of this study was to evaluate the efficiency of application of friction stir welding (FSW) for production of sound joints on composite, granulated and quasicrystalline aluminium-base alloys.

Investigations were conducted by using some composite materials based on aluminium alloys with dispersed reinforcing ceramic particles of aluminium oxide Al_2O_3 or silicon carbide SiC (Table 1). These structural materials hold much promise owing to their high values of elasticity modulus, wear and corrosion resistance, and low values of specific weight and thermal expansion and friction coefficients [1, 2].

Structure of a composite material consists of matrix grains of an aluminium alloy, intermetallic inclusions and particles of a reinforcing phase, which are more or less uniformly distributed in the bulk of the matrix (Figure 1).

Fusion welding of composite materials causes complete melting of some of their volume in the zone of formation of a permanent joint under the effect of a high-temperature heat source, solidification of this volume resulting in formation of the weld. Reinforcing particles that remain non-melted are very non-uniformly distributed in the solidifying weld metal (Figure 2, *a*). Moreover, if in welding of composite materials reinforced with silicon carbide particles the temperature of metal heating exceeds 660 °C, their interaction with aluminium may result in formation of acicular inclusions of aluminium carbide Al_4C_3 (Figure 2, *b*). This leads to substantial deterioration of properties of the weld metal and, hence, of the welded joints.

Characteristics of composite materials are greatly affected by fractional composition and uniformity of distribution of reinforcing particles in the matrix, in addition to mechanical properties of a filling compound and matrix alloy, proportion of the volume contents of components, structure of composite castings and character of heat or thermomechanical treatment. Sizes of the particles determine both their in-