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THE EFFECT OF ULTRASONIC TREATMENT ON THE STRUCTURE AND PROPERTIES OF WELDED JOINTS IN THE AMg6 ALLOY

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SYNOPSIS

Investigations were made into the effect of ultrasonic treatment on the structure and properties of aluminium alloy AMg6. The reduction in residual welding stresses in treatment is caused by the plastic deformation of the surface of metal, and by the rearrangement of the atomic structure.

The ultrasonic treatment of welded structures of sheet materials is a promising method of increasing their strength properties as a result of surface hardening and the redistribution of residual welding stresses (1,2). Since the high-frequency energy of mechanical oscillations is transferred by means of the impact interaction of the striker with the workpiece, the technique can be termed the impact ultrasonic technique. It is employed in the surface hardening of working surfaces of cylindrical components (3,4) to increase fatigue strength. The aim of this work was to examine changes in the structure of the AMg6 alloy during ultrasonic treatment, and to determine the optimum conditions of this treatment so as to improve the mechanical properties of the alloy.

Specimens were treated in equipment for semiautomatic welding containing a special device with an ultrasonic head with a changeable striker. Strikers were in the form of quenched spheres, cylinders and needles from needle bearings. The welded joint and the heat affected zone (HAZ) were cooled to room temperature and were then subjected to the effect of impact high-frequency loading. Magnetostrictive sources of type PMS-15A-18 were fed by a UZG-10M generator. The oscillation amplitude of the output end of the striker of the magnetostriction device was maintained constant at 30 ± 3μm. The speed of travel of the acoustic head in relation to the specimen was approximately 20m/hr.

The residual stresses were determined after sectioning ring-shaped specimens (thickness 6mm, diameter 450mm, with an aperture 150mm in diameter), and right-angled specimens with a thickness of 3-8mm, by measuring the strains using paper strain gauges of the 2PKB type. Prior to the measurements, the external edge of the specimens was penetrated. The distribution of the residual stresses along the radius of the specimen in the initial condition corresponded to the curve shown in Fig.1a (see

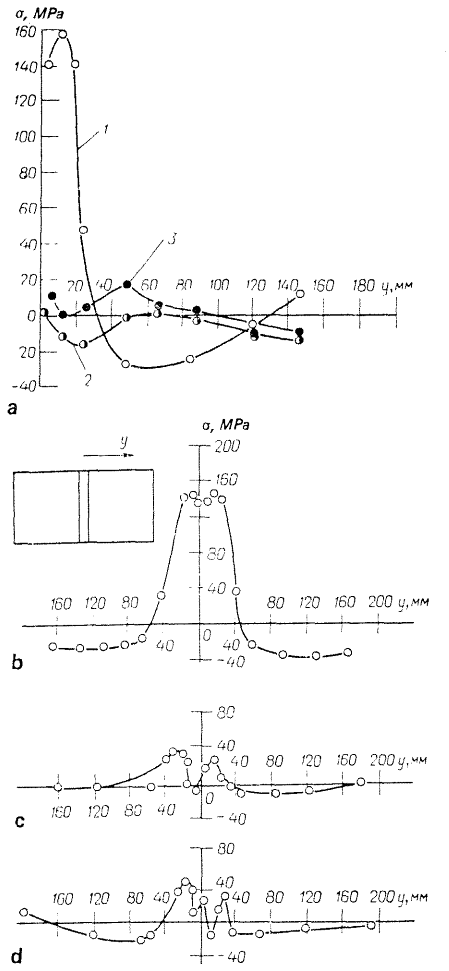

Fig.1. Curves of residual stresses in the AMg6 alloy: a) ring-shaped specimen; b,c,d) right-angled specimens.

curve 1). As indicated by the graph, the zone positioned approximately 20mm from the welded joint contains residual tensile stresses whose magnitude is similar to the yield stress of the alloy.

The weld and the weld zone on both sides of the specimens were subjected to ultrasonic treatment. In treatment with a 12mm dia. sphere, the width of the zone treated in a single pass was around 4mm, and consequently 10 consecutive passes were required to treat the weld zone. In treatment with a cylindrical striker, with a diameter of 12mm and a length of 18mm, the number of passes was reduced to two.

Treatment with the sphere was characterised by the considerable deformation of the surface of the alloy. This is indicated by the change in the sign of the residual stresses (see Fig.1a, curve 2). Treatment with the cylindrical striker also resulted in a reduction in the magnitude of the tensile stresses, but the impact force decreased in this instance. Consequently, after a single pass of the instrument the residual stresses decreased by approximately 60-70%. The repeated treatment of the specimen on both sides greatley smoothed out the stresses (see Fig.1a, curve 3). The uniformity of the distribution of the residual stresses can be increased by the selection of suitable treatment conditions.

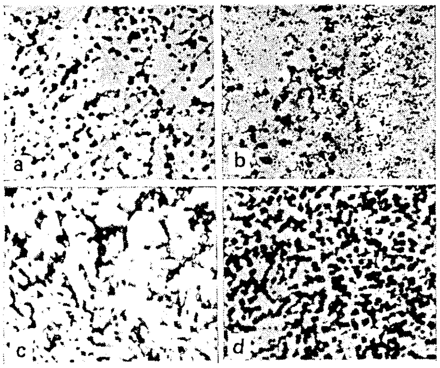

Fig.2. The welded joint (a,c) and the transition zone (b,d) in the initial condition after welding (a,b) and after ultrasonic treatment with a sphere (c,d); x 200, reduced 2/3).

Subsequent investigations were conducted on 1000 x 600 flat specimens of various thicknesses produced by argon-arc butt welding. The distribution of the weld in relation to the axis of the co-ordinates is shown in Fig.1b. The residual stresses σ_0 were determined in the centre of the specimen. Resistance strain gauges were bonded at 10mm intervals along axis y. Strains were determined after sectioning the specimen, and residual stresses were subsequently calculated from the strains.

The results of the measurements of the residual stresses are shown in Fig.1b, 1c, 1d. After welding in the specimen, σ_0 = 140 MPa (see Fig.1b). The weld was treated under various conditions using various strikers. In some cases, two-side treatment was employed (both the reinforcement and the root of the weld were treated). But the residual stresses in one-side and two-side treatments differed only slightly. The level of the residual stresses was influenced mainly by the oscillation amplitude of the source.

Figure 1c shows the results of the measurements of the residual stresses after the two-side treatment of a flat specimen, with a 40mm long cylindrical striker, with a total number of passes of eight (four passes on either side). Under these conditions, the tensile stresses decreased on average by 80%. The magnitude of the compressive stresses in regions 20-300mm from the centre of the weld also decreased, despite the fact that these regions had not been treated with ultrasound.

The use of a multi-striker tool with needle strikers also reduced the residual stresses. The advantage of the multi-striker head is the fact that the area that can be treated per unit time is considerably greater than in treatment using single spheres or cylinders. In addition to this, the needle striker tool is less sensitive to the quality of the preliminary treatment of the surface, and it satisfactorily treats both the reinforcement and the root of the weld. But the impact force of a single needle is lower (because of its small mass) than the impact force of a sphere or a cylinder. Therefore, no gain in productivity is obtained. To acquire comparable data on the reduction in the residual stresses at the same oscillation amplitude and travel speed of the acoustic head, the total number of passes would have

Alloy	Sheet thickness, mm	σ_B (MPa) of specimens		Treatment
		Initial	Treated with ultrasound	
AMg6	4	291	302	With a sphere on both sides, 10 passes
	8	305	308	With a cylindrical striker on both sides, 8 passes
	8	302	304	With a multi-striker tool, 10 passes (weld reinforcement removed)
AMg6NN	8	378	406	With a sphere on both sides, 10 passes
	3.5	378	400	The same (weld reinforcement removed)

to be increased to ten. The curve of the distribution of the residual stresses after treatment with the multi-striker tool is shown in Fig.1d. In this case, the magnitude of the tensile stress is approximately identical with that after treatment with the cylindrical striker.

To clarify the dependence of the strength properties of the weld on the ultrasonic treatment conditions, experiments were conducted on 20mm wide specimens cut from the welded sheets of the AMg6 and AMg6NN alloys (double cold hardening) in the direction normal to that of the weld. The specimens were tested in a tensile machine. The test results are presented in the Table.

The Table indicates that the tensile strength of the specimens after the treatment is slightly increased. In the case of the AMg6NN alloy this increase is approximately 20MPa. It is evident that this nature of variation in the strength characteristics is associated with the fact that only thin surface layers of metal are hardened in ultrasonic treatment.

The structure of the welded joints in the AMg6 alloy was studied in the determination of certain relationships governing the ultrasonic treatment. Metallographic analysis revealed the heterogeneity of the structure of the welded joint in the initial condition (see Fig.2a, 2b). The precipitates of the second phase Al_2Mg_3 in the welded joint are finer than in the weld zone. In addition, this zone contains a large number of pores. After ultrasonic treatment, the structure becomes more homogeneous (see Fig. 2c, 2d), the grains on the surface of the weld are slightly refined, and the pores in the weld zone are 'healed'. But these changes take place only in a thin near-surface layer approximately 0.5-0.7mm thick.

The distribution of microhardness in the welded joint in the AMg6 alloy before and after ultrasonic treatment was also examined (see Fig.3). Surface plastic deformation increases the microhardness of the welded joint by 60-70%. The microhardness of the parent metal increases after the treatment by only 15-20%, and the absolute values of microhardness in the weld zone are higher than in the region not subjected to the thermal effect (see Fig.3). The thickness of the hardened layer on the parent metal is also smaller, and it amounts to 0.2-0.3mm.

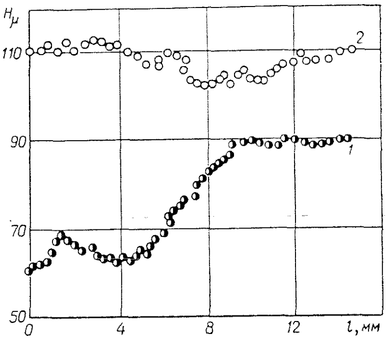

Fig.3. The distribution of microhardness in the welded joint (the origin of the co-ordinates in the centre of the penetrated zone): 1, initial condition; 2, after ultrasonic treatment.

Thus, the ultrasonic treatment of the AMg6 alloy is accompanied by a marked reduction in the residual welding stresses. The strength properties of the welds change only slightly, because the rearrangement of the structure, caused by plastic deformation, takes place only in thin surface layers. When the striker hits the surface of metal, high pressures are developed in the contact area. The magnitude of these pressures depends on the mass and speed of the striker; and shock waves form. The high frequency of impacts in ultrasonic treatment facilitates the formation of vibrations within a wide frequency range. The frequency spectrum of the vibrations depends on the geometry of the specimen or the workpiece. The highest amplitude of the oscillations in the specimens is obtained at a bais basic frequency of 18kHz. Relative strains in this case reach 10^{-4}. This alternating deformation results in the development of stress sufficient to separate dislocations from pinning points, or to redistribute the latter along dislocation lines (5). Therefore, in addition to the variation of the residual macrostresses as a result of plastic deformation of the surface, high-frequency impact treatment leads to the rearrangement of the atomic structure associated with the effect of ultrasound. Thus, this type of rearrangement also reduces the residual stresses.

The advantage of the ultrasonic technique is the possibility of the partial or complete automation of the process in the treatment of large welded components.

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