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Shot peening and the intergranular corrosion of sensitized welds in type 430 stainless steel

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Shot peening is a mechanical process of hammering the surface of a metal with shot, carried typically, in a blast of air [1]. When applied over the surface of a metal with an intensity sufficient to cause plastic flow, shot peening has three major effects: it produces a residual compressive stress in the surface, it results in work hardening of the surface, and it produces a roughened surface [2]. The surface stresses are very effective in resisting stress-corrosion cracking [3] and cavitation erosion [4], and they are widely used to resist fracture by fatigue and corrosion fatigue [1, 5]. However, it should be noted that not all metals respond equally to shot peening. Thus shot peening reduced the cavitation erosion of an austenitic stainless steel by 0.08 times, whereas under the same conditions, shot peening reduced the cavitation erosion of pure iron by only 0.7 times [4].

Stainless steels are widely used for their excellent corrosion resistance, but they may be susceptible to intergranular corrosion (IGC) caused by incorrect heat-treatment [6]. An important case of IGC occurs in the heat-affected zone (HAZ) of welds, where it is considered that precipitation of chromium carbides at grain boundaries creates an adjacent layer denuded of chromium which cannot maintain a protective film of Cr_2O_3 and along which rapid corrosion occurs [6]. Shot peening before sensitization has been found to eliminate IGC of an austenitic stainless steel, apparently by providing a large number of dispersed nucleation sites and thus avoiding the almost continuous network of carbides at grain boundaries [7], but there does not appear to be any information on the effect of shot peening on the IGC of sensitized stainless steels.

There is only a small amount of information generally on the increasingly used, cheaper, ferritic grades of stainless steel [6, 8–10], and the present work investigates the effect of shot peening on the intergranular corrosion of sensitized welds in type 430 ferritic stainless steel.

Flat coupons and U-bends in the TIG (no filler metal) welded condition were commercially supplied with a 180 grit finish [11]. The compositions are given in Table I. Intergranular corrosion was measured using a modified ASTM A262-E test [12]. This consisted of immersion for 24 h in a boiling solution of 6% $CuSO_4$–16% H_2SO_4–25 g Cu in 500 ml of solution.

The microstructure of the corroded heat-affected zones of the flat specimens in the unpeened and peened conditions are shown in Fig. 1a and b, respectively. It is seen that shot peening substantially reduces the average depth of intergranular corrosion from 0.38 to 0.18 mm (Fig. 1). While it is clear that the compressive stresses induced by shot peening should reduce the damaging tensile stresses inherent in stress corrosion failure [3], it is less obvious that they should also reduce the extent of intergranular corrosion where galvanic action between the precipitates and the associated denuded zones is considered to be the main cause of failure [6], and it may be that the tensile stresses suggested to be present in the process of IGC [6] are being reduced by the compressive stresses of shot peening. Various other tests on the unpeened and peened welded flat plates were inconclusive. Weight losses during the chemical tests were approximately the same (about 50 mg), and electrochemical potentiodynamic reactivation (EPR) tests using the ratio of the reactivating current to passivating current, that had been used successfully to detect the presence of intergranular attack in the HAZ of type 405 stainless steel [10], gave results (not presented) that were difficult to interpret.

Welded U-bends in both the unpeened and peened conditions were tested in the solution. The unpeened specimen separated at the HAZ after 3 h, whereas the U-bend that had been shot peened, although severely corroded (it broke in handling), remained intact for 24 h. It is seen that the effect of shot peening the U-bends is considerable, and in this case the induced compressive stresses appear to be actively opposing the damaging tensile stresses present in the bent metal.

In summary, we have shown for welded type 430 stainless steel with a sensitized HAZ, that shot peening reduces the depth of intergranular corrosion of flat coupons by (0.20 mm/0.38 mm) × 100 = 53%, and increases the resistance of U-bends to intergranular corrosion by (24 h/3 h) × 100 = 800%. Thus while shot-peening does not prevent intergranular corrosion of the sensitized HAZ of welded type 430 stainless

TABLE I Composition of the materials (wt %)

	C	S	Mn	Ni	Cr	Mo	Al	Ti
Flat plate	0.040	0.011	0.43	0.39	16.21	0.13	< 0.01	< 0.02
U-bend	0.055	0.007	0.43	0.39	16.11	0.079	< 0.01	< 0.02

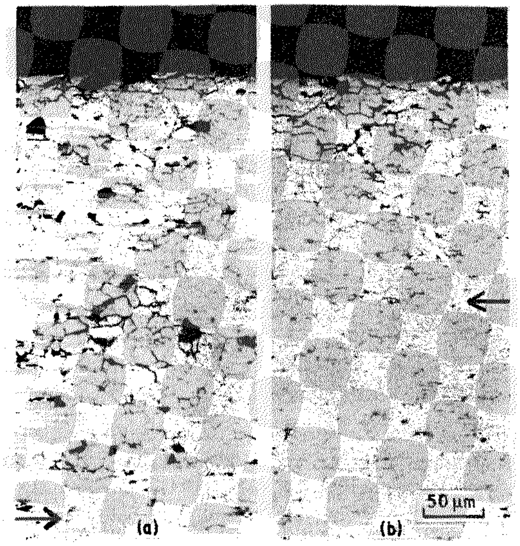

Figure 1 Intergranular corrosion of the HAZ of welded flat plate: (a) unpeened, and (b) shot peened. The arrows show the position of the maximum depth of intergranular corrosion. Etched alcoholic acid ferric chloride.

steel, it nevertheless reduces considerably the amount of damage.

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