Influence of Shot Peening with Different Peening Materials on the Stress Corrosion and Corrosion Fatigue Behavior of a Welded AlZnMg-Alloy

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ABSTRACT

Using the alloy AlZn4.5Mg2 as an example, the influence of shot peening on the stress corrosion resistance and corrosion fatigue behavior was investigated.
Welded tensile test samples of the alloy were shot peened with glass, steel and ceramic beads as well as granulated Aluminium material. The samples were tested in 2% and 3.5% NaCl-solution for stress corrosion resistance. With glass, steel and Granal, a significant improvement of life over 60 days without fracture was achieved in these tests.
Furthermore, a significant improvement of the corrosion fatigue behavior in 2% NaCl was achieved. For better understanding the mechanism involved, the residual compressive stresses were measured by X-ray methods. The individual results of the stress and fatigue corrosion tests and the effect of peening will be discussed.

KEY WORDS

AlZnMg-alloys, stress corrosion, corrosion fatigue, shot peening, residual stress.

INTRODUCTION

The results of the stress corrosion tests on welded AlZn4.5Mg2 peened with glass beads were reported at the first conference (W. Koehler, 1981). With optimized parameters and Almen intensity of 0.16 A2 mm a significant improvement of stress corrosion resistance was achieved. In addition to these experiments, further peening materials with different hardness and density such as steel, ceramic and granulated Aluminium were investigated.

The aim of the experimental work was to find the most suitable peening material and the best parameters to prevent stress and fatigue corrosion on welded seams as well as to establish a basis for the use of the high strength of the alloy AlZn4.5Mg2 for welded structures.

SHOT PEENING MATERIALS AND TREATMENT

For shot peening, four different peening materials were used (see table 1).

- Glass beads were used in the first part of the investigations (W. Koehler, 1981).
- Steel shot produce high Almen-intensities, but have the disadvantage that after peening the aluminium surface has to be cleaned by wet peening with glass or etching to remove the iron particles from the surface which would otherwise cause pitting corrosion.
- The ceramic beads consist of ZrO_2 and SiO_2 with high hardness. They have a longer life time during peening than glass beads (N. Niku-Lari, 1981).
- Aluminium (Granal S 120) consists of granulated cast Aluminium as it is used for surface treatment of light metals.

TABLE 1: Shot peening materials

peening material	particle Ø mm	hardness HV Kp/mm^2	density g/cm^3
glass	0.15-0.25	457	2.5
glass	0.42-0.84	457	2.5
steel	0.50-0.70	455	7.9
steel	3.15-3.50	480	7.9
ceramic ER 120	0.42-0.85	800-1000	3.9
aluminium	1.20-1.80	90-130	2.7

The shot peening treatment was performed at the Institute of Metal Forming, Prof. R. Kopp, Aachen, in compressed air chamber. Welded (MIG-method) tensile test samples of the alloy AlZn4.5Mg2 state T6 (HV = 125-150 Kp/mm^2) with 4 mm thickness were shot peened on all sides with defined parameters. To guarantee that the surfaces were hit vertically by the peening materials, the flanks of the weld seams were additionally peened at an angle of 70°.

Samples peened with steel were additionally wet peened with glass beads of 0.25 - 0.42 Ø mm and Almen intensity of 0.2 N2 mm to remove the impurities from the aluminium surface and to prevent pitting corrosion. Table 2 shows the different peening treatments and the depth of roughness on the aluminium surface.

The roughness depends primarily on the type of peening material used. The roughness increases with the Almen intensity concerning the ceramic material.

TABLE 2: Depth of roughness

peening material ⌀ in mm	peening C [%]	parameter I [mm A2]	R_t [µm]	R_a [µm]
steel 0.5-0.7 ⌀	98	0.21	30.1	4.3
+ glass (wet)	2x98	0.22	31.8	4.7
steel 3.15-3.5 ⌀	98	0.38	35.0	6.2
+ glass (wet)	2x98	0.42	33.6	5.7
ceramic 0.42-0.85 ⌀	98	0.14	18.5	2.9
	2x98	0.16	19.5	3.0
	98	0.24	36.8	6.1
	2x98	0.3	32.9	5.4
aluminium 1.2-1.8 ⌀	98	0.07	24.9	3.9
	2x98	0.085	25.2	4.3

C = coverage, I = intensity

RESIDUAL STRESSES

The residual compressive stresses caused by shot peening on the surfaces were measured by X-ray methods (W. Koehler, 1983). Major results are shown in fig. 1 for steel peened and in fig. 2 for ceramic and aluminium peened samples. For the samples peened with steel shot of 0.7 mm ⌀, the maximum residual stress lies about 0.1 mm under the surface. It is surprising that the sample with double surface coverage shows lower values of compressive stresses than the sample with single surface coverage. This indicates that the optimum peening intensity has been exceeded and a fatigue process has caused a slight decrease in compressive stress. (S.S. Birley 1972)

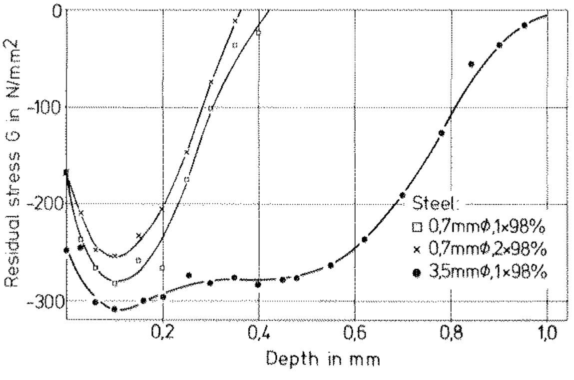

Fig. 1: Residual stresses at steel peened samples.

For the samples peened with steel shot of 3.5 mm ⌀, a pronounced maximum of compressive stresses was measured between 0.1 and 0.5 mm and a stress penetration depth of 1.0 mm.

The samples peened with ceramic beads show the maximum compressive stresses to be about 0.1 mm and the penetration depth 0.7 mm.

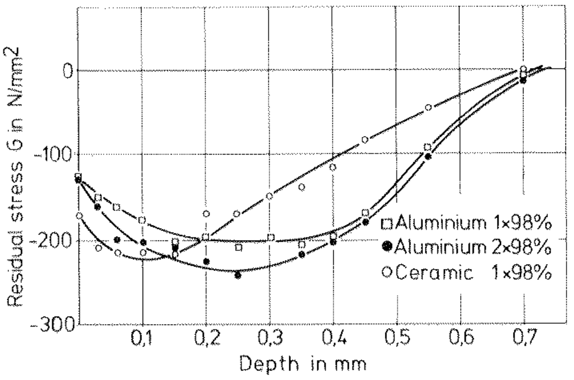

Fig. 2:

Residual stresses at Aluminium and Ceramic peened samples.

Samples peened with aluminium show the maximum compressive stress at 0.25 mm. The stress penetration depth of 0.7 mm is surprising compared with the low Almen intensity of 0.085 A2 mm. The measured caracteristic values of stress are listed in table 3. For comparison, the table contains also the former measured values for glass.

TABLE 3: Measured characteristic residual compressive stresses

peening material	sample mm ø	C [%]	I [A2 mm]	surface stresses [N/mm^2]	max. stresses [N/mm^2]	depth of max.stress [mm]	penetrat. depth of stresses [mm]
steel	0.7	98	0.21	-166	-282	0.1	0.42
steel	0.7	2x98	0.22	-166	-252	0.1	0.37
steel	3.5	98	0.38	-248	-309	0.1-0.5	1.0
ceramic	0.85	98	0.24	-170	-220	0.1	0.7
aluminium	1.8	98	0.07	-130	-200	0.25	0.72
aluminium	1.8	2x98	0.085	-130	-240	0.25	0.72
glass	0.84	98	0.16	-189	-198	-	-
glass	0.84	2x98	0.18	-190	-280	0.08	0.35

STRESS CORROSION TESTS

The stress corrosion tests were carried out under constant load in individual corrosion test devices. The loads were applied by tensioned helicoidal springs.

As corrosion medium a 2% NaCl and 3.5% NaCl-solution with 0.5% Na_2CrO_4 (as corrosion inhibitor against exfoliation) with pH = 3 was used. The loads were 75% of the yield strength.

For comparison, unpeened samples were tested for stress corrosion resistance. The average life in the stress corrosion test of these samples was 8 days in 3.5% NaCl and 20 days in 2% NaCl. The cracks in all samples proceeded

along the border of the weld seam. The samples cracked because of so called "weld seam boundary corrosion" (H. Cordier, 1977; M. Pirner, 1975) as it is known from AlZn4.5Mg1.
Samples which were shot peened with the different peening materials showed a significant increase of life in the stress corrosion test (see fig. 3).
The samples peened with steel shot of 0.7 ∅ and 3.5 ∅ mm plus wet glass beads reached lives of more than 60 days in 2% NaCl. Samples peened with aluminium also survived for more than 60 days in 3.5% NaCl without cracks. This means for the aluminium peened samples, a life improvement of more than 8 times as compared with the unpeened samples.

Ceramic peened samples achieved only average lives between 6 and 25 days in 3.5% NaCl depending on the Almen intensity.

The unbroken samples were taken from the test device after 60 days and the residual strength was determined. The strength proved still to be sufficient for all samples.

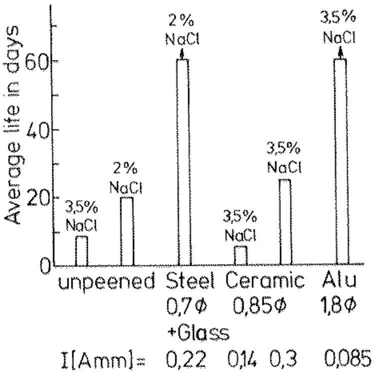

Fig. 3:

Average life of MIG-welded samples in stress corrosion tests with different shot peening treatment.

CORROSION FATIGUE TESTS

Under cyclic loads in corrosion media, the weld seams of AnZn4.5Mg2 may be susceptible to corrosion fatigue. Therefore, the influence of shot peening on corrosion fatigue was investigated. The tests were made on a hydropulse machine at frequency of 15 Hz and $R = \frac{\sigma min}{\sigma max} = 0.1$. During the tests, the samples were surrounded by a cylinder containing 2% NaCl solution with a pH of 4 buffered by sodium acetat.
At first, unpeened samples and then samples shot peened with ceramic beads with I = 0.14 and 0.24 A2 mm and aluminium with I = 0.085 A2 mm were tested. The Whoehler curves are shown in fig. 4 and 5. By shot peening with ceramic and also aluminium, an improvement of the fatigue corrosion of more than an order of magnitude was obtained compared with the unpeened samples. For comparison, fig. 5 also contains the fatigue strength in air of samples shot peened with aluminium.

No significant difference exists between the two peening parameters of the samples peened with ceramic. The improvement in fatigue corrosion is probably compensated by the increase in roughness from $R_t = 18.5$ to $R_t = 36.8$ µm.

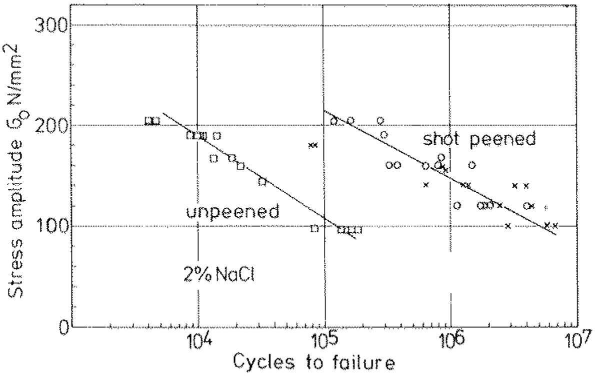

Fig. 4:

Corrosion fatigue behavior in 2% NaCl of unpeened and ceramic peened (o I=0.14 mm; x I=0.24 mm A2) MIG-welded samples.

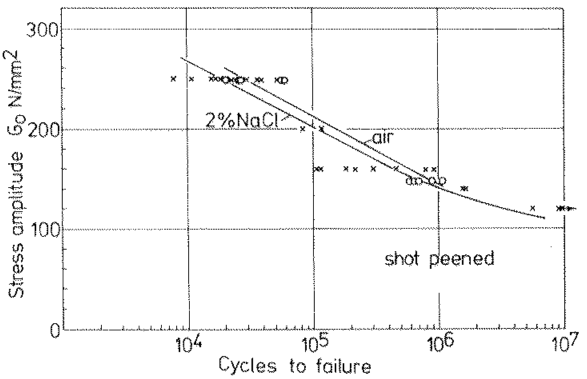

Fig. 5:

Corrosion fatigue behavior in 2% NaCl of aluminium (I=0.085 mm A2) peened MIG-welded samples.

DISCUSSION

For the welded high strength alloy AlZn4.5Mg2, which can exhibit a high sensivity to stress corrosion in the state T 6, it was shown that shot peening significantly improves the stress and fatigue corrosion behavior.
By means of shot peening with steel, lives of more than 60 days without crack in the stress corrosion test were obtained. The disadvantage of steel shot is, however, that because of the remaining contamination on the aluminium surface, an additional peening treatment with wet glass (TMSH-method) for cleaning is necessary.

By peening with ceramic beads, only a small improvement in stress corrosion resistance in spite of high Almen intensities was achieved. The high surface roughness is probably responsible for the low result. The peening material contained, in addition to the spherical beads, a portion of longish particles which break during peening and caused sharp notches in the surface.

Samples peened with aluminium achieved lives of more than 60 days in spite of the low Almen intensities. The Almen intensity is probably unsuitable as a measuring unit for peening materials with low hardness. The impact mechanism of the soft aluminium is quite different from steel, ceramic or glass. This seems to be responsible for relatively high compressive stresses in spite of low Almen-intensities.

At the present state of knowledge for improvement in stress corrosion of Aluminium, glass beads and granulated aluminium (Granal) are the most suitable peening materials.
Shot peening with ceramic and with aluminium also increased the corrosion fatigue behavior. The increase for both materials is of the same order of magnitude. Concerning the ceramic material, it seems advisible to peen with lower intensities to reduce the surface roughness which has a negative effect. The influence of glass beads on fatigue corrosion is being investigated at present time.

The beneficial effects of shot peening on corrosion behavior depends on various factors. Peening produces a deformed surface layer with increased hardness. The grain boundaries directly on the surface also become smeared. In addition, compressive residual stresses are induced in the surface. The value of the compressive stresses depends upon the hardness of the peening materials. The penetration depths of stresses increase with impression diameters (K.P. Hornauer, 1982) which depends on the diameter and velocity of the beads and the yield point of the peened surface.

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