THE IMPROVEMENT OF FATIGUE AND SURFACE CHARACTERISTICS OF ALLOY 7075-T6 BY SECONDARY PEENING WITH GLASS BEADS

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ABSTRACT

Metallic shot peening, first developed in the late 1920's, is recognized as an excellent process for increasing the fatigue life of metals. Glass bead peening is a newer technique for which quantitative data has been lacking. Consequently, a series of studies were initiated to determine the effects of glass bead peening on the fatigue life of aluminum alloys.

Previous studies at Potters showed that when 7075-T6 aluminum alloy sheet specimens were peened with either glass beads or steel shot, equal increases in fatigue life resulted, providing the operations were performed at the same arc height peening intensities.[1]

In this study, steel shot peened specimens were given a second peening operation with glass beads and the data showed that this technique resulted in a further improvement in fatigue life, as well as a significant reduction in surface roughness. The paper describes the methods used to obtain and evaluate these improvements and presents the fatigue life data, together with a discussion of the improved surface characteristics.

KEYWORDS

Shot peening, aluminum alloy, 7075-T6, glass beads, fatigue life, surface roughness, arc height.

INTRODUCTION

Shot peening, developed in the late 1920's with industrial applications by the 1940's,[2] has been recognized for many years as an excellent process for improving the fatigue life of metal parts. This increase in fatigue life is a result of the creation of compressive stresses which penetrate just below the metal surface. In reverse bending, peening causes the peak tensile stresses in the metal part to be reduced and moved away from the surface.

In the early stages of development, the process was haphazard, but by the 1960's it was an exact science capable of providing reproducible results. It had also been shown that glass beads could increase the fatigue life of various metals.[3,4]

An earlier study at Potters in the mid 1970's showed that there was an equal increase in fatigue life of aluminum alloy 7075-T6 strip when peened with either steel shot or glass beads at the same Almen arc height peening intensity.

In this series of experiments, steel shot peened aluminum specimens were given a secondary peening with glass beads to determine whether their surfaces could be smoothed and their fatigue life further increased.

EXPERIMENTAL DETAILS

A. Preliminary Testing

A sheet, 0.090 in (0.23 cm) thick of aluminum alloy 7075-T6 was used for these experiments. The mechanical properties were as follows:

Tensile Strength	81,500 lb/in^2 (562 MPa)
Yield Strength	73,700 lb/in^2 (508 MPa)
Elongation % in 2 in (5 cm)	9.75
Hardness (Rockwell)	92-94 R_B
Surface Finish	12-24 RMS

To study the affect of peening on surface finish, 2" wide (5 cm) X 6" long (15 cm) strips were cut in the rolling direction from a standard sheet. Optimum peening conditions were established for this study using these sheared specimens.

The peening media used were Potters size D (50-70 mesh) and size AE (100-170 mesh) glass beads and Alloy Metal Abrasives (45-70 mesh) steel shot. The sieve analyses were as follows:

D Beads			AE Beads			Steel Shot		
U.S. Sieve	Opening (μm)	% On	U.S. Sieve	Opening (μm)	% On	U.S. Sieve	Opening (μm)	% On
45	355	0	100	150	0.3	40	425	Trace
50	300	Trace	120	125	15.4	45	355	6.0
60	250	54.2	140	106	63.6	50	300	57.0
70	212	35.1	170	90	13.4	60	250	20.9
80	180	10.2	200	75	5.8	70	212	16.0
Pan		0.5	Pan		1.5	Pan		0.1

Peening was carried out with a direct pressure dry honer. Arc height peening intensities were determined under set conditions at a 6 in (15 cm) distance and a 90° angle between gun and test specimen. The gun nozzle was 3/16" (0.48 cm) I.D. and the grit stem was 1/8" (0.32 cm) I.D. Pressures were adjusted to result in intensities of 3A and 6A using the steel shot. The 5 X 15 cm test specimens, after preblasting with steel shot, were given a secondary peening with either size D or size AE glass beads. The peening intensities ranged from a high of 20N to a low of 2N with blasting times of 2, 1, and 0.5 minutes. This secondary operation was added to determine if any degree of improvement in surface characteristics could be obtained. The surface roughness was measured with a Profilometer.

Based on the sample test data, it was concluded that further evaluation of secondary glass bead peening with size AE beads was warranted. This was the basis for the fatigue testing program.

B. Fatigue Testing

The fatigue tests were performed at room temperature (21°C) on specimens with dimensions as shown in Fig. 1, that had been cut from the balance of the sheet. All tests were conducted at zero mean stress levels. The condition of the specimens tested were:

1. Unpeened.
2. Steel shot peened to 6A arc height with 200% coverage.
3. Peened as in (2) and overpeened with AE glass beads to 9N arc height with 200% coverage.

The test equipment used was a sheet fatigue test machine. To avoid premature failures, all specimens were given a light edge finish using 300 grit paper. To prevent failure in the grips of the unpeened specimens, it was necessary to peen the sections A and C while masking section B. (See Fig. 1). The fatigue tests were performed at stress levels ranging from 40% to 70% of the alloys yield strength. The load to be applied at the connecting pin of the fatigue machine to produce the desired stress was calculated from the flexure formula:

$$S = MC/I$$

where
- S = stress
- M = bending moment
- C = distance from centroid to outermost fiber
- I = moment of inertia

For samples of rectangular cross section, this formula may be modified to:

$$S = 6PL/bd^2$$

where
- S = bending stress (lb/in^2)
- P = load at connecting pin (lb)
- L = distance between connecting pin and point of stress application (in)
- b = width of specimen at length L from point of load application (in)
- d = specimen thickness (in)

EXPERIMENTAL RESULTS

The preliminary test data on surface characteristics produced by secondary peening with size AE and D glass beads is shown in Tables 1 and 2.

The test data in Table 3 compare the fatigue life of the unpeened sheet specimens with specimens that were either steel shot peened or steel shot peened followed by glass bead peening.

Figure 3 shows the typical S/N curves for reverse bending fatigue of the three conditions tested using the average values of the test data obtained.

Although there was some scatter in the data, this was considered typical of what one would expect if relatively few samples were run for any one test condition. The test loads selected were typical of what one would expect to find used in the industry.

DISCUSSION

Numerous failures of metals in the automotive, aircraft, and industrial fields are caused by fatigue, corrosion, or a combination of both. These failures are often due to residual tensile stresses or stress risers on the metal surface which generate cracks on that surface, propogate inward and grow from minute to critical dimensions when the metal is subjected to cyclic stresses. The failure rate may be increased if there is a corrosive environment at the surface to initiate additional cracks in the metal.

Peening with steel shot or glass beads is known to retard cyclic fatigue failures by inducing compressive stresses on the metal surface. In the case of reverse bending, the peak tensile stress in the peened specimen is reduced and moved away from the surface. These surface tensile stresses are created by various processing conditions, e.g., rolling or extrusion.

Because of their lower density, glass beads cannot always economically achieve the required arc height peening intensities. In such applications, the metal surfaces are peened with steel shot. However, this may cause considerable roughening of the metal surface and contamination problems if they are dissimilar metals, resulting in corrosion failures. One possible way of eliminating the problem is to peen with glass beads in a secondary operation, which was the objective of this study.

The results of the reverse bending fatigue tests shown in Fig. 3, indicated that there was a significant improvement in fatigue life with steel shot peening of the original specimens. The improvement averaged 300% overall. Similar improvements in fatigue life have been reported by Was and Pelloux.[5] However, the surface had been roughened considerably, deteriorating to 180-210 RMS from 12-24 RMS. It was of interest to note that when these steel peened samples were overpeened with glass beads, not only was the surface roughness decreased by over 50% to a level of 82-100 RMS, but there was also a significant improvement in fatigue life, averaging 50% over the range tested. This improvement was attributed to the smoother surface, which reduced the number of fatigue crack initiation sites, and to the glass beads. Similar improvements had been noted by T. F. Barton,[6] when shot peening Titanium alloys.

For comparison purposes, additional specimens were peened and then overpeened with steel shot to the same arc height peening intensity as the glass (9N). The test results showed that surface roughness and fatigue life were only marginally improved when compared with glass beads.

Additional work is planned at Potters to determine whether the secondary glass bead peening process will further improve the stress corrosion cracking resistance of this alloy.

REFERENCES

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FIG. 1

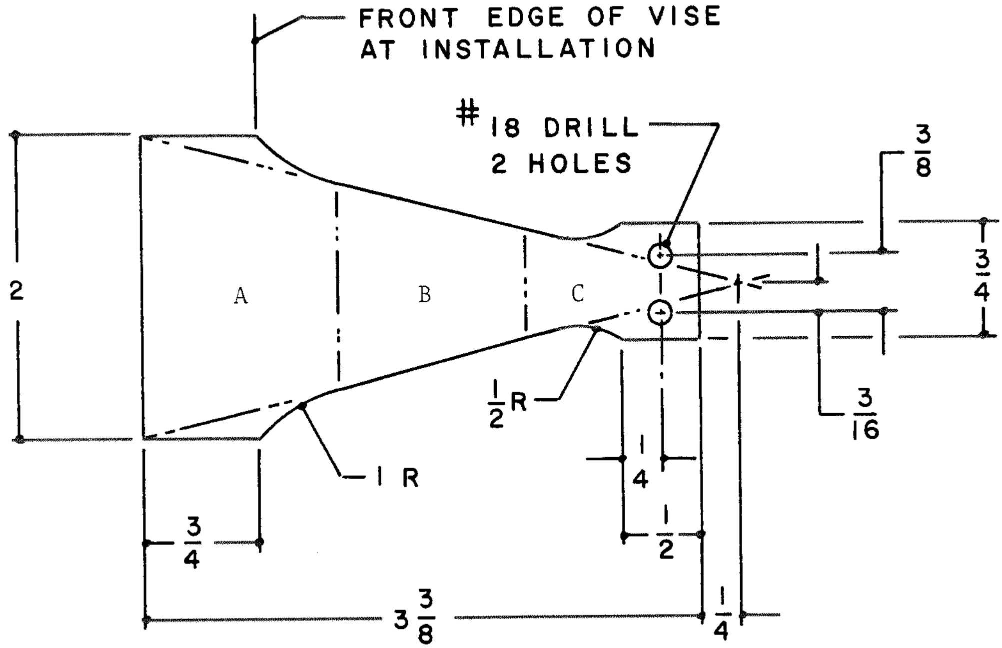

TABLE 3 7075-T6 ALUMINUM ALLOY SHEET
FATIGUE LIFE DATA

% Of Yield Strength	Stress Amplitude (lb/in^2)	AVERAGE NUMBER OF CYCLES TO FAILURE A	B	C
70	51,590	14,500	57,700	74,180
60	44,220	49,633	125,400	164,800
50	36,850	75,350	230,100	499,500
45	33,170	115,750	542,650	1,020,120
40	29,480	204,650	1,307,250	1,574,900

A = Unpeened

B = Steel Shot Peened

C = Steel Shot Peened and Glass Bead Peened

TABLE 1 PRELIMINARY PEENING DATA USING AE BEADS

Primary Arc Height	Secondary Peening Media	PSI	Secondary Arc Height	Blasting Time (min)	Surface RMS Before	Surface RMS After	% Change in RMS
6A	AE	40	10N	2	168-198	102-138	-39/28
6A	AE	40	10N	1	168-198	90-120	-46/38
6A	AE	40	10N	1/2	168-198	90-108	-46/44
6A	AE	30	9N	2	168-198	60-78	-64/59
6A	AE	30	9N	1	168-198	84-96	-50/50
6A	AE	30	9N	1/2	168-198	84-96	-50/50
6A	AE	10	4N	2	168-198	60-78	-64/59
6A	AE	10	4N	1	168-198	60-90	-64/53
6A	AE	10	4N	1/2	168-198	90-120	-46/38
3A	AE	10	4N	2	84-96	36-48	-57/44
3A	AE	10	4N	1	84-96	36-48	-57/44
3A	AE	10	4N	1/2	84-96	42-48	-50/44
3A	AE	7.5	3N	2	84-96	42-60	-50/38
3A	AE	7.5	3N	1	84-96	48-62	-43/35
3A	AE	7.5	3N	1/2	84-96	48-60	-43/38
3A	AE	5	2N	2	84-96	42-54	-50/44
3A	AE	5	2N	1	84-96	50-60	-40/38
3A	AE	5	2N	1/2	84-96	54-66	-36/31

TABLE 2 PRELIMINARY PEENING DATA USING D BEADS

Primary Arc Height	Secondary Peening Media	PSI	Secondary Arc Height	Blasting Time (min)	Surface RMS Before	Surface RMS After	% Change in RMS
6A	D	40	7A	2	168-198	150-186	-11/6
6A	D	40	7A	1	168-198	168-198	0
6A	D	40	7A	1/2	168-198	156-210	-7/6
6A	D	30	6A	2	168-198	138-168	-18/15
6A	D	30	6A	1	168-198	132-180	-21/9
6A	D	30	6A	1/2	168-198	138-168	-18/15
6A	D	10	12N	2	168-198	84-108	-50/45
6A	D	10	12N	1	168-198	96-120	-31/39
6A	D	10	12N	1/2	168-198	102-126	-39/36
6A	D	5	6N	2	168-198	78-108	-54/45
6A	D	5	6N	1	168-198	90-120	-46/39
6A	D	5	6N	1/2	168-198	120-150	-29/24

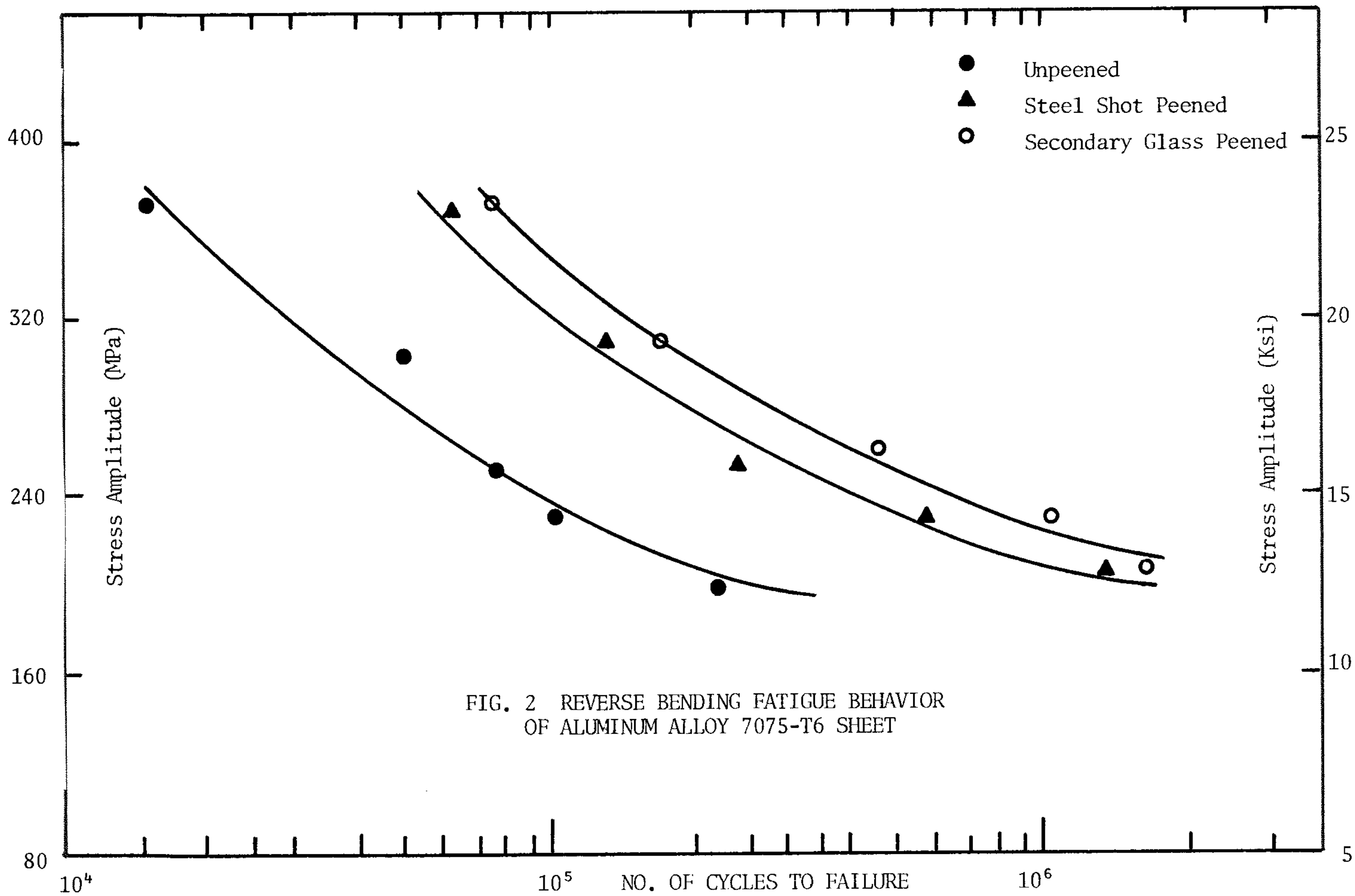

FIG. 2 REVERSE BENDING FATIGUE BEHAVIOR OF ALUMINUM ALLOY 7075-T6 SHEET