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Peening Increases Fatigue Strength of Welded Aluminum

*By G. E. NORDMARK**

The fatigue strength of longitudinal butt welds in aluminum plates can be increased significantly by peening the weld and the heat affected zone. Because of surface compressive stresses introduced by peening, the improvement in fatigue life is greater than that produced by thermal stress relief. (G23n, Q7a; Al-b, 7-51)

RESIDUAL STRESSES ARE PRODUCED in weldments by local thermal expansion, plastic deformation and subsequent shrinkage on cooling. In the region near the weld, the resulting tensile residual stresses have a magnitude approaching the yield strength.

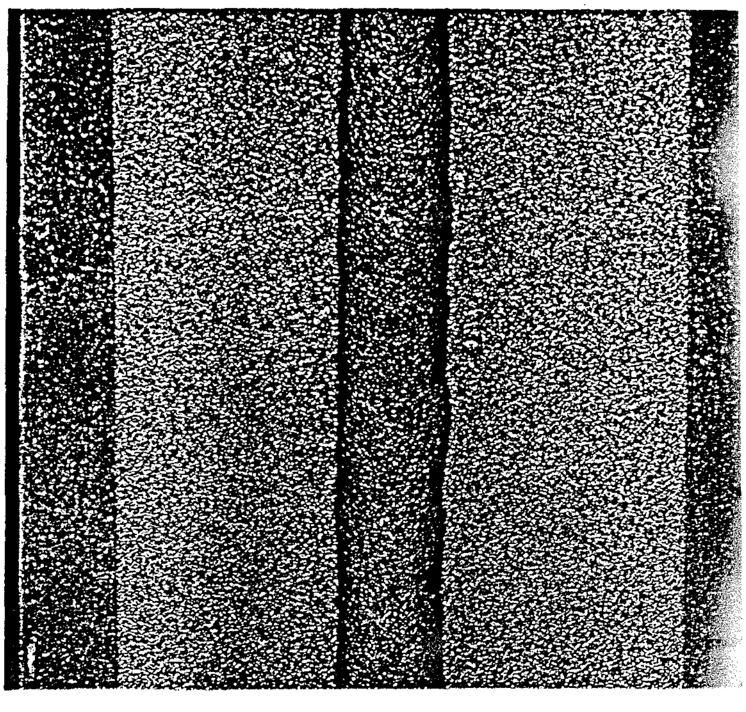
Welding stresses significantly reduce the fatigue strength of aluminum welds, particularly longitudinal butt welds. But because thermal treatments to relieve these stresses are impractical for many large welded assemblies, peening can and should be considered as an alternate method of improving the fatigue strength.

Butt Welded Samples

To determine how much peening increases the fatigue strength, we prepared longitudinal butt welded joints from 0.40 in. thick 5456-H321 plate. The abutting edges were beveled to provide a single V-groove, and the groove welded automatically in two passes employing 5556 electrode; then the weld was back chipped and filled with a third pass. Since removal of any material from the edges of the test section after welding would reduce the magnitude of the residual stresses (tensile residual stresses in the region of the weld are balanced by compressive stresses in regions away from the weld), the halves of the specimens were machined to size before welding.

Welded samples were shot peened on both

Fig. 1 — Shot peening (shown) or hammer peening significantly increases the fatigue life of welded aluminum.



*Research Engineer, Alcoa Research Laboratories, New Kensington, Pa.

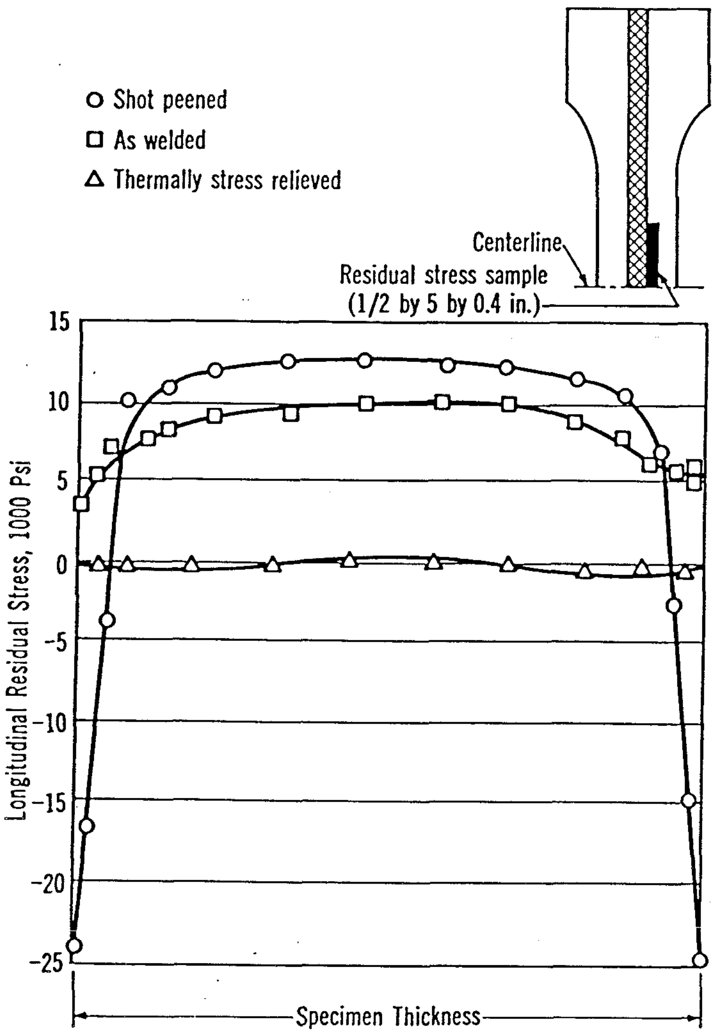


Fig. 2 — Shot peening produces relatively high compressive residual stresses at the surface; a thermal treatment reduces residual welding stresses to a low magnitude. Data were obtained on a residual stress sample (shown) of welded 5456-H321 plate.

sides by moving them at a constant speed under a nozzle (12 in. away) emitting S230 steel shot propelled by 90 psi air pressure. This treatment resulted in a maximum intensity of Almen 0.013A at the center of the weld. As shown in Fig. 1, the shot peened area did not extend to the edges of the welded plates. In a few instances, the shot peened samples were straightened by additional peening to a tolerance of ⅛ in. on center bow. Generally, warpage was within this limit if the side which was concave after welding was peened first.

Several samples were also hammer peened using rounded, single point chisels in impact hammers. A lighter peening was obtained with ⅛ and ¼ in. diameter tools in a pneumatic hammer, and a heavier hammer peening was obtained with a 3/16 in. diameter tool in an electric hammer.

Residual Stresses Measured

Typical residual stress levels were determined mechanically by saw cut and layer removal methods. Figure 2 shows how shot peening or thermal stress relief affects residual stresses at a location adjacent to the weld. Surface residual stresses at this location were about 25,000 psi (compression) for the shot peened specimen, zero for the specimen given a thermal stress relief, and 5000 psi (tension) for the as welded specimen. In the weld itself, the maximum residual stresses of the latter specimens were about 17,000 psi tension.

Failures Not in Peened Area

Axial-stress fatigue tests — conducted at minimum stress to maximum stress ratios of −0.5 and 0.0 in Templin structural fatigue machines (50,000 lb capacity) — produced failures outside the peened area in every instance. The loads were transmitted to the specimen through keys pressed into the specimen by tightening bolts through the butt ends. Because of this, it was necessary to machine the weld beads flush in the butt ends. This dressing usually removed most of the shot peened surface from these areas. The origin of failure was either at the edge of the bolt holes, or more commonly, at areas of fretting under the loading key (see Fig. 3). Failures in as welded and stress relieved fatigue specimens occurred in the weld within the test section.

Even when failures occurred prematurely in butt ends, both shot and hammer peening improved the fatigue strength more than did a thermal stress relief. This is shown in Fig. 4. For each stress ratio, the longest lived shot peened specimen had a fatigue strength about 100% higher than the curve for as welded material. Hammer peened weld metal subjected to a 0.0 stress ratio loading also was increased significantly in fatigue strength.

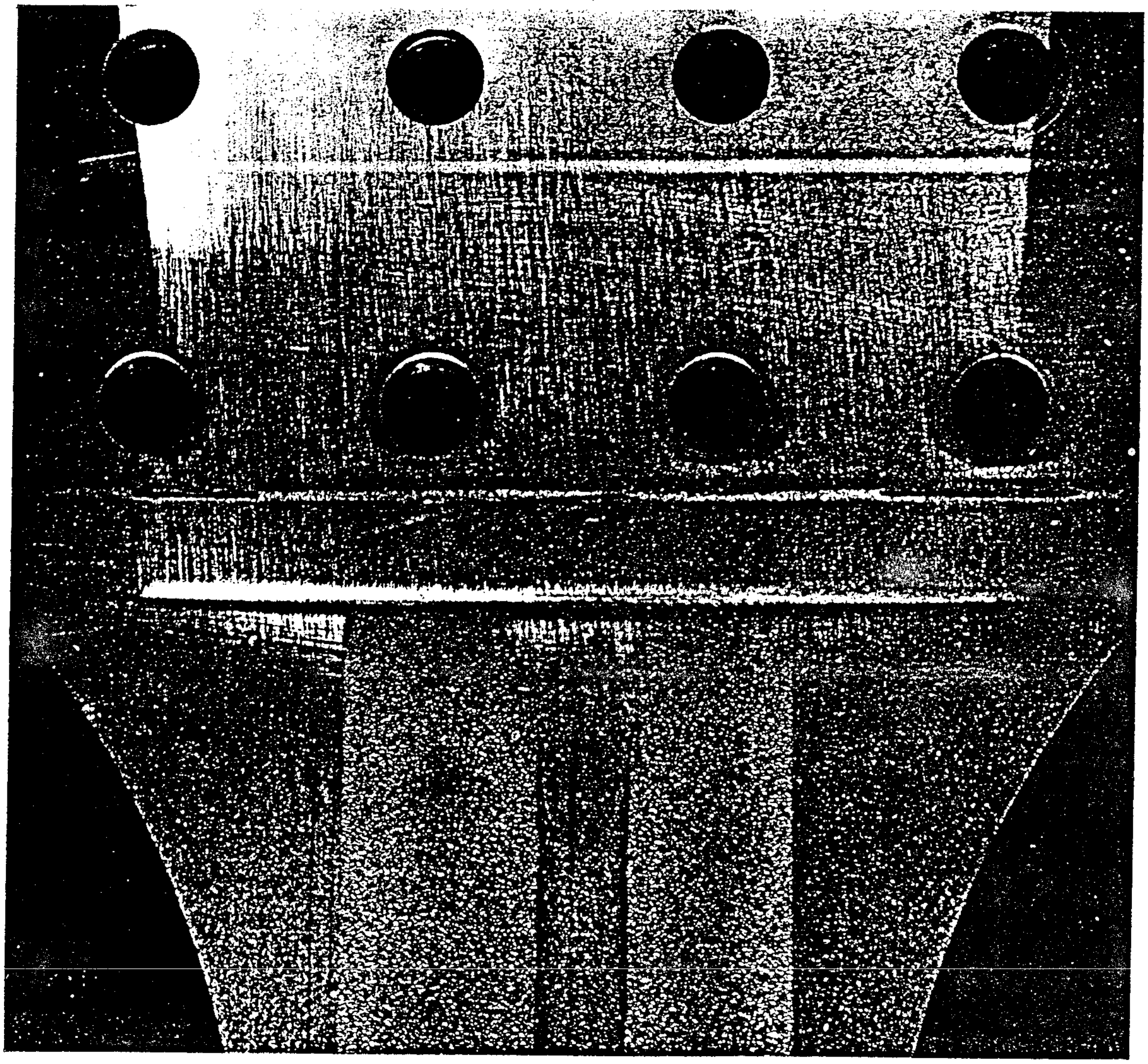


Fig. 3 — Fatigue failures of all shot peened test specimens were outside the peened area, and most were caused by fretting under the loading key.

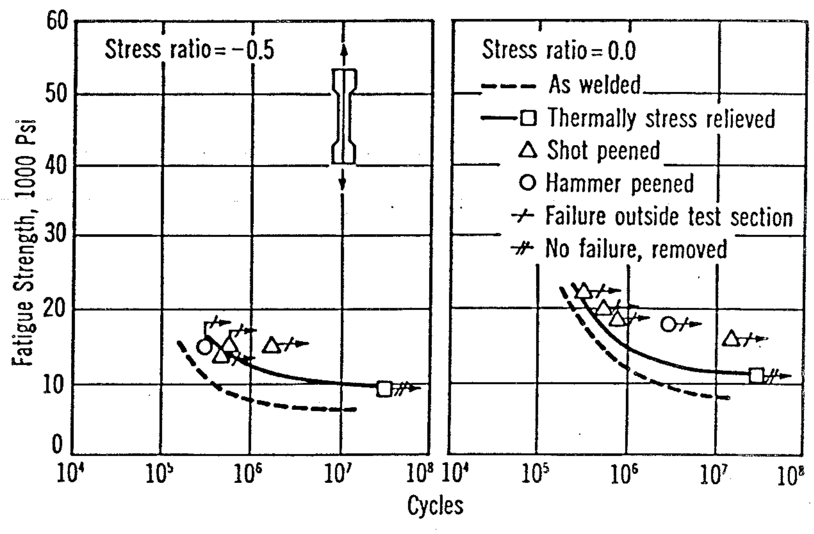


Fig. 4 — The effect of shot peening, hammer peening or thermal stress relief on the fatigue life of longitudinal butt welds in 5456-H321 aluminum is shown here. Stress ratio $= \frac{\text{minimum stress}}{\text{maximum stress}}$. Strength values represent maximum stress applied in testing cycle.

METAL IMPROVEMENT COMPANY, INC.
SUBSIDIARY OF CURTISS-WRIGHT CORPORATION

EXECUTIVE OFFICE
10 Forest Avenue
Paramus, New Jersey 07652
Tel: (201) 843-7800
Telex: 62911203

CALIFORNIA

3239 East 46th Street
Vernon, CA 90058
Tel: (213) 585-2168
Telex: 62911792

San Fernando Valley
12510 Montague Street
Pacoima, Calif. 91331
Tel: (818) 896-2441

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CONNECTICUT

P.O. Box 487
145 Addison Road
Windsor CT 06095
Tel: (203) 688-6201
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33 Peters Road
Bloomfield, CT 06002
Tel: (203) 243-2220

FLORIDA
1940 N.W. 70th Avenue
Miami, FL 33126
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Telex: 62911810

ILLINOIS

678 Winthrop Avenue
Addison, Ill. 60101
Tel: (312) 543-4950
Telex: 62911814

KANSAS

1019 South McLean Blvd.
Wichita, KS 67213
Tel: (316) 267-0239
Telex: 62911880

1618 Ida
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LOUISIANA

116 Southpark Road
Lafayette, Louisiana 70508
Tel: (318) 837-9273
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MASSACHUSETTS

26 Alley Street
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Tel: (617) 599-4165

MICHIGAN

41200 Coca Cola Drive
Belleville, MI 48111
Tel: (313) 397-8400
Telex: 62922290

NEW JERSEY

472 Barell Avenue
Carlstadt, N.J. 07072
Tel: (201) 935-1800
Telex: 62911821

NEW YORK

105 Wyandanch Ave.
Wyandanch, N.Y. 11798
Tel: (516) 491-5030

80 Blaisdell Road
Orangeburg, N.Y. 10962
Tel: (914) 359-4736

NORTH CAROLINA

10,000 Old Pineville Road
P.O. Box 519
Pineville, N.C. 28134
Tel: (704) 889-7656
Telex: 62911833

210 Crowatan Road
Castle Hayne, NC 28429
Tel: (919) 675-3316
Telex: 62911834

OHIO

5791 Creek Road
Blue Ash, Ohio 45242
Tel: (513) 891-0001
Telex: 62911861

18683 S. Miles Road
Cleveland, Ohio 44128
Tel: (216) 662-8408
Telex: 62911859

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Columbus, Ohio 43207
Tel: (614) 444-1181
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TEXAS

1450 Avenue S
Grand Prairie, TX 75050
Tel: (214) 641-8011
Telex: 62911879

714 Avenue R
Grand Prairie, TX 75050
Tel: (214) 641-9656

9410 East Hardy
Houston, Texas 77093
Tel: (713) 691-0257
Telex: 62911870

WISCONSIN
5801 North 94th Street
Milwaukee, Wisc. 53225
Tel: (414) 466-3151
Telex: 62911866

CANADA
105 Alfred Kuehne Blvd.
Brampton, Ontario, Canada
L6T 4K3
Tel: (416) 791-8002
Telex: 06-97763

EUROPEAN OPERATIONS OFFICE

Sussex Chambers
90 High Street
Heathfield, E. Sussex
TN21 8JD, England
Tel: (4352) 6022
Telex: 957384

EUROPEAN MARKETING OFFICE

Zone Industrielle d'Amiily
45200 Montargis, France
Tel: (38) 855807
Telex: 780082

UNITED KINGDOM

Ascot Drive
Derby, England DE2 8ST
Tel: (0332) 756076/7/8
Telex: 37348

Hambridge Lane
Newbury, Berkshire RG14 5TU, England
Tel: (0635) 31071
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Park Way
Deeside Industrial Park
Clwyd CH5 2NS
Wales
Tel: 0244-821 888
Telex: 61627

FRANCE
Zone Industrielle d'Amiily
45200 Montargis, France
Tel: (38) 855807
Telex: 780082

Zone Industrielle de St Etienne
Rue de Cazenave
F64100 Bayonne, France
Tel: (59) 55.42.52
Telex: 541816

WEST GERMANY
Otto-Hahn-Strasse 3
4750 Unna, West Germany
Tel: (02303) 8593
Telex: 8227708

PEENAMATIC FACILITY

472 Barell Avenue
Carlstadt, N.J. 07072
Tel: (201) 935-1200
Telex: 62911821