NASL MECHANICAL PEENING PROCEDURE
FOR IMPROVEMENT OF FATIGUE
PROPERTIES OF HY-80 BUTT WELDS

Lab. Project 9300-1, Technical Memorandum #34
SF 020-01-01, Task 0722
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MATERIAL SCIENCES DIVISION

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### FIGURES

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TABLES

1 - Chemical Analysis and Mechanical Properties of HY-80 Specimen Material

2 - Results of Fatigue Tests on HY-80 Butt Welds
ADMINISTRATIVE INFORMATION

Ref: (a) NAVAPLSCIENLAB Program Summary of 1 May 1965, SF 020-01-01, Task 0722, Fabrication of High Strength Steel Alloys
(b) NAVAPLSCIENLAB Lab. Project 9300-1, Progress Report 1 of 15 Apr 1964
(c) NAVAPLSCIENLAB Lab. Project 9300-1, Tech Memo #11 of 8 Jul 1964
(d) NAVAPLSCIENLAB Lab. Project 9300-1, Tech Memo #15 of 25 Aug 1964
(e) NAVAPLSCIENLAB Lab. Project 9300-1, Tech Memo #18 of 30 Sep 1964
(f) NAVSHIPYDNYK Lab. Project 6150-2, Progress Report 3 of 17 Jul 1961

1. In connection with its high strength steel program outlined in reference (a), the U.S. Naval Applied Science Laboratory is investigating the effects of weld treatment on the fatigue properties of HY-80 steel and methods for improving these properties. The NASL mechanical peening procedure was shown to be an effective post weld treatment for improving the bending fatigue properties of HY-80 tee-fillet welds in reference (b). The results of other fatigue improvement procedures applied to HY-80 tee-fillet welds were reported as follows:

   reference (c) - grinding
   reference (d) - shot peening
   reference (e) - grinding and shot peening

This memorandum presents a description of and the results obtained with the NASL tee-fillet weld peening procedure which has been modified for application to HY-80 butt welds.

OBJECTIVE

2. The primary objectives of the work reported herein were as follows:

   a. Modify the NASL mechanical peening procedure (previously developed for HY-80 tee-fillet welds) for application to HY-80 butt welds.

   b. Determine the degree of improvement in the bending fatigue properties of HY-80 butt welds obtained through the use of this procedure.

3. Additional objectives were:

   a. To determine the effects of weld reinforcement removal after peening on the bending fatigue properties of HY-80 butt welds.
b. To determine the explosion bulge properties of a peened HY-80 butt weld that had been subjected to extensive bending fatigue.

NASL MECHANICAL PEENING PROCEDURE (FOR BUTT WELDS)

4. The mechanical peening procedure developed for the improvement of the fatigue properties of HY-80 butt welds is illustrated in Figure 1. It involves the use of three separate peening tools:

   a. A hemispherical nose contouring tool for major metal movement.

   b. A dressing tool for removing spherical impressions and increasing the width of the peened area.

   c. A flattening tool for removing any sharp ridge that may appear at the base plate edge of the peened area.

This procedure is similar to the procedure for tee-fillet welds described in reference (b), differing principally in the following aspects:

   a. The shape of the dressing tool.

   b. The additional use of a flattening tool.

   c. The angle used between the tool and the plate surface.

A macro-section of a peened HY-80 butt weld illustrating the contour produced by peening is shown in Figure 2.

DESCRIPTION OF SPECIMENS

5. To determine the degree of improvement in bending fatigue properties obtained through the use of mechanical peening, six 1.1/2" x 28" x 52" HY-80 butt welded plate type fatigue specimens were prepared. The chemical analysis and mechanical properties of the HY-80 material used for these specimens are shown in Table 1. Each specimen was machined from a separate 32" x 40" weldment; the welding procedure and joint design for which are shown in Figure 3. After welding, the following treatments were applied.

   a. Two weldments were left in the "as welded" condition.

   b. Two weldments were peened (on all weld toes) using the procedure illustrated in Figure 1.
c. Two weldments were peened as in (b) above and then ground to remove weld reinforcement on both sides of each weldment.

The grinding for removal of weld reinforcement was done with hand-held compressed air grinders to simulate shipyard conditions. A horizontal grinder with a 7" x 1" straight wheel was used for rough grinding and a vertical grinder with a 6" cup wheel was used for finishing.

**FATIGUE TESTING PROCEDURE**

6. The specimens were tested in the NASL Plate Fatigue Machine described in reference (f). This machine supports the specimen as a simply supported plate along two opposite edges and applies a pulsating, uniformly distributed pressure to the lower face of the specimen, thus producing cyclic stresses which vary from zero to a specified maximum. Nominal equivalent elastic stress is used for stresses greater than the yield strength of the test material. The test is conducted at a constant cyclic rate (12 cycles/min) and in an ambient environment. The fatigue life of a specimen is taken to be the number of cycles to a 10% increase in maximum deflection. Normally the test is continued until the maximum deflection has increased by 100% over the initial maximum deflection.

**RESULTS**

7. The fatigue results obtained from the six butt welded specimens tested are presented in Table 2 and Figure 4, and are compared to those of tee-fillet welds in Figure 5. All specimens were initially fatigue tested at a maximum nominal stress of 80,000 psi. A brief summary of the results obtained at this stress level is as follows:

a. "As Welded" specimens - Fatigue lives of 18,000 and 17,100 cycles; major crack at toe or weld in both specimens.

b. "As Peened" specimens - Subjected to fatigue for more than 10 times the fatigue life of the "as welded" specimens with no significant increase in deflection and no major cracks; tests stopped so that specimens could be used for supplementary tests.

c. "Peened-Reinforcement Removed" specimens - Fatigue lives approximating 30 times and 10 times "as welded"; major crack in weld deposit and toe of weld respectively.
SUPPLEMENTARY TESTS

8. Since the "as peened" specimens did not fail during fatigue testing at 80,000 psi, supplementary tests were performed. These tests and the subsequent results are as follows:

a. "As Peened" Specimen #58823MP (after 250,000 cycles at 80,000 psi) - subjected to additional bending fatigue at 100,000 psi.
   Results: (1) Reached 10% increase in deflection after 120,800 cycles and 100% after 131,780 cycles.
   (2) Cracking occurred in base plate away from weld - no cracks in weld area. - see Figure 6.

b. "As Peened" Specimen #58853MP (after 180,000 cycles at 80,000 psi) - explosion bulge tested at 0°F.
   Results: (1) Explosion bulge properties were below the expected performance of "as welded" unfatigued welds; however, an appreciable degree of toughness was retained (see Figure 7).

NOTE: Supplementary work to be reported at a later date indicates that two mechanically peened HY-80 butt welds, which were not subjected to fatigue, showed explosion bulge properties equivalent to current requirements.

CONCLUSIONS

9. A modification of the NASL mechanical peening procedure (previously developed for HY-80 tee-fillet welds) has been developed for application to HY-80 butt welds. This procedure is capable of increasing the bending fatigue life of an HY-80 butt weld to a significant degree. In addition, the procedure is rapid, inexpensive and readily applicable with current shipyard skills and equipment.

10. The occurrence of a weld deposit fatigue crack in a "peened-reinforcement removed" specimen (noted in paragraph 7), suggests that removal of weld reinforcement after peening increases the possibility that the fatigue crack, which eventually occurs during fatigue testing, will form in the weld deposit rather than at the toe of the weld. This may be attributed to the changes in stress concentration and residual stresses and the reduction in weld section thickness caused by removal of weld reinforcement.

11. The explosion bulge test of a peened HY-80 butt weld which had been subjected to extensive bending fatigue showed some loss of toughness.
RECOMMENDATIONS

12. It is recommended that the NASL mechanical peening procedure (for butt welds) described herein be considered as a practical and effective method for increasing the fatigue life of HY-80 butt welds. However, final recommendations relative to application of the NASL mechanical peening procedure to butt and fillet welds will be deferred until all scheduled work is completed relative to determination of any possible deleterious effects on toughness due to peening.

FUTURE WORK

13. Information relative to possible deleterious effects on HY-80 toughness due to mechanical peening will be forwarded in August 1965.

14. The application of the NASL mechanical peening procedure to HY-130/150 welds will be evaluated after basic fatigue data for welds in this material is acquired.

15. Axial fatigue tests of mechanically peened butt and fillet welds are currently being conducted at the University of Illinois under BUSHIPS contract NObs-92240.
ABOVE PASSES IN PLATE SURFACE & FED. SPEC. OO-H-
SECOND PASS: USE DRESSING TOOL 2.
THIS OPERATION REMOVES SPHERICAL
IMPRESSION & INCREASES WIDTH OF
PEENED AREA.

SECTIO

THIRD PASS: USE
THIS OPERATION
CROWN.

SESB MADE WITH TOOLS HELD PERPENDICULARLY TO
FACE & ATTACHED TO PNEUMATIC HAMMER,
500-M-116A, SIZE 2, TYPE 2, & 90 P.S.I. AIR SUPPLY.
THIRD PASS: USE FLATTENING TOOL. THIS OPERATION REMOVES "RAISED CROWN".
NASL PEENING PROCEDURE

I. EQUIPMENT:
(a) 90 P.S.I. AIR SUPPLY
(b) PNEUMATIC HAMMER
(c) CONTOURING TOOL
(d) DRESSING TOOL
(e) FLATTENING TOOL

II. PROCEDURE:
(a) DIRECT CONTOURING
(b) FOLLOW TOE OF WELD TO APPROXIMATE CENTER OF WELD
(c) DIRECT DRESSING: THIS OPERATION WILL REDUCE THE AMOUNT OF CONTOURING TO REMOVE UNNECESSARY METAL: ONE PASS AS IN SECTION 5.8
(d) DIRECT FLATTENING: RIDGE OF UPSET METAL AND THIS WILL BRING THE PLATE AD IN SECTION 5.3

NOTE: ALL DIMENSIONS ARE APPROXIMATE. SOME VARIATIONS ARE TO BE EXPECTED.
NASL PEENING PROEDURE FOR THE IMPROVEMENT OF
Fatigue Properties (as shown for butt welds)

INSTRUCTIONS

I  EQUIPMENT:
(a) 90 P.S.I. AIR SUPPLY.
(b) PNEUMATIC HAMMER, FED. SPEC. 00-H-116a, SIZE 2, TYPE 2

1. CONTOURING TOOL
2. DRESSING TOOL

3. FLATTENING TOOL (CHISEL BLANK, HARDEN TO RC 58-62)

II  PROCEDURE:
(a) DIRECT CONTOURING TOOL 1 AS SHOWN IN SECTION A-A.
(b) FOLLOW TOE OF WELD AT A SPEED OF 15 INCHES/MINUTE
to approximate contour shown in section A-A.
(c) DIRECT DRESSING TOOL 2 AS IN SECTION B-B.

This operation will remove spherical impressions
of contouring tool 1 and leave two ridges of
upset metal: one on each side of peened length,
as in section B-B.
(d) DIRECT FLATTENING TOOL 3 AS IN SECTION C-C ALONG
ridge of upset metal on base metal side.
This will bring ridge back to level of base
plate as in section C-C.

NOTE: All dimensions and speeds are
approximate. Job conditions may make
some variations advisable.
1. Contour Tool

2. Dressing Tool

Tool 1 2 4 (3): Make from chisel blank. Harden to R & 56-60
PROCEDURE FOR
OF FATIGUE
( FOR STEEL )

FRIBB
4
1/2
1/2
FLATTENING TOOLS

SATISFACTORY TO CODE
DATE
CHECKED BY
INSPECTED 
IN CHARGE

SK.M.1286
SHEET 1 OF 10
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<th>APPROVED</th>
<th>DATE</th>
<th>AUTHORITY</th>
<th>BY</th>
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</table>

**ALTERATIONS**

NASL REENING PROCEDURE FOR THE IMPROVEMENT OF FATIGUE PROPERTIES (FOR STEEL BUTT WELDS)

---

**SCALE** 1/4 (12 IN. = 1 FT.)  
**DATE** 1 DEC. 1964

DRAWN BY:  
A. FREY

APPROVED:

INDUSTRIAL DEPARTMENT HEAD

IN CHARGE:  
J. Howard

SKETCH NUMBER:  
SK.N.1886

BUREAU SHIPS FILE NUMBER:  
INDEX | GROUP | FILE NUMBER

SHEET 1 OF 1 SHEET
NASL PEENING
PROCEDURE FOR THE IMPROVEMENT
OF FATIGUE PROPERTIES
FOR STEEL BUTT WELDS

SCALE 1/8 (12 IN. = 1 FT)
DATE 1 DEC. 1964

DRAWN BY: A. FREY
APPROVED: ________________
DATE: 1/31/65

TRACED BY: J.G.

CHECKED BY: ________________

INSPECTED: ________________

IN CHARGE: ________________

SHEET NUMBER: SKN-1886

BUREAU SHIPS FILE NUMBER: ________________

INDEX: ___________ GROUP: ___________ FILE NUMBER: ___________
FIGURE 2 - MACRO-SECTION OF PEELED HY-80 BUTT WELD

PHOTO L19985-1
Base Metal: HY-80 steel
Preheat: 200°F
Interpass Temperature: 200-300°F
Current & Polarity: Direct current, reversed polarity
Position: Flat
Heat Input: 5/32" dia. electrodes - heat input to suit
3/16" dia. electrodes - 45,000 ± 5,000 joules/inch

Sequence:

Side 1
Two layers, 5/32" dia. electrodes, block technique

Side 2
Grind root
Two layers, 5/32" dia. electrodes, continuous welding
Two layers, 3/16" dia. electrodes, continuous welding

Side 1
Finish welding side 1 using 3/16" dia. electrodes & continuous welding

Side 2
Finish welding side 2 using 3/16" dia. electrodes & continuous welding
NOTE: AS PEELED (55824P) - Stress raised to 100 ksi after 250,000 cycles at 80 ksi

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FIGURE 4 - VARIATION OF DEFLECTION WITH NUMBER OF FATIGUE CYCLES - 80 KSI
NOMINAL STRESS
Cycles to 10% Increase in Deflection at 80,000 PSI (except where noted)

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Figure 5 - Comparison of Fatigue Results for HY-80 Tee-Fillet Welds and Butt Welds
### SHOT #1

<table>
<thead>
<tr>
<th>SIDE A</th>
<th>SIDE B</th>
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<tbody>
<tr>
<td>% REDUCTION IN THICKNESS</td>
<td>6.56</td>
</tr>
<tr>
<td>DEPTH OF BULGE</td>
<td>3.34</td>
</tr>
<tr>
<td>LENGTH OF CRACKS</td>
<td>11&quot;</td>
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</table>

*FIG. 7a - Close-up of specimen after first shot showing cracks at toe of weld*

### SHOT #2

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<td>% REDUCTION IN THICKNESS</td>
<td>11.72</td>
</tr>
<tr>
<td>DEPTH OF BULGE</td>
<td>6.15</td>
</tr>
<tr>
<td>LENGTH OF CRACKS</td>
<td>23&quot;</td>
</tr>
</tbody>
</table>

*FIG. 7B - Specimen after second shot*

**TEST CONDITIONS:** Stand-off distance, 17"; Pentolite charge, 24 lb; Temperature of specimen, 0°F

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**FIGURE 7 - EXPLOSION BULGE RESULTS OF "AS PEENED" BUTT WELD AFTER 180,000 CYCLES IN FATIGUE AT 80 KSI**

**PHOTO L-19985-3**
<table>
<thead>
<tr>
<th>Chemical Analysis Element</th>
<th>Determined by NAVAPLSCIENLAB</th>
<th>Specification MIL-S-16216G</th>
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<tr>
<td>C</td>
<td>0.14</td>
<td>0.18</td>
</tr>
<tr>
<td>Mg</td>
<td>0.27</td>
<td>0.10-0.40</td>
</tr>
<tr>
<td>P</td>
<td>0.009</td>
<td>0.025</td>
</tr>
<tr>
<td>Maximum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0.021</td>
<td>0.025</td>
</tr>
<tr>
<td>Unless %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Si</td>
<td>0.25</td>
<td>0.15-0.35</td>
</tr>
<tr>
<td>Range is</td>
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<td></td>
</tr>
<tr>
<td>Na</td>
<td>2.72</td>
<td>2.50-3.25</td>
</tr>
<tr>
<td>Shown</td>
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<td></td>
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<tr>
<td>Cr</td>
<td>1.47</td>
<td>1.00-1.80</td>
</tr>
<tr>
<td>Nb</td>
<td>0.41</td>
<td>0.20-0.60</td>
</tr>
<tr>
<td>Ti</td>
<td>0.002</td>
<td>0.02</td>
</tr>
<tr>
<td>V</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td>Cr</td>
<td>0.14</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Mechanical Properties

- **Yield Strength**: 81,100 (L) 80,000-85,000
- **0.2% Offset (psi)**: 90,800 (T) 0.00
- **Ultimate Tensile Strength (psi)**: 107,900 (L) 107,000 (T)
- **Elongation in 2 inches (%)**: 27.5 (L) 25 (T)
- **Reduction in Area (%)**: 72.1 (L) 66.1 (T)
- **Charpy V-Notch Impact at -120°F (FT-lbs)**: 92.5 (L) 90 (T)

(1) Longitudinal (parallel to direction of roll).

(1) Transverse (perpendicular to direction of roll).
<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Specimen Type</th>
<th>Nominal Cyclic Stress (psi)</th>
<th>Avg Thickness (in.)</th>
<th>Calculated Deflection (in.)</th>
<th>Applied Uniform Pressure</th>
<th>Initial Deflection (in.)</th>
<th>Location of Initial Crack</th>
<th>Increase in Deflection (in.)</th>
<th>Increase in Deflection (in.)</th>
<th>Major Crack Location</th>
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<tr>
<td>S982MP As Welded</td>
<td>80,000 79,600</td>
<td>1.497 1.499</td>
<td>305</td>
<td>0.302</td>
<td>5,000</td>
<td>5,000</td>
<td>18,000</td>
<td>19,160</td>
<td>Side B</td>
<td>2-1/2 From End C</td>
</tr>
<tr>
<td>S984MP As Welded</td>
<td>79,900 80,000</td>
<td>1.499 1.499</td>
<td>306</td>
<td>0.302</td>
<td>4,500</td>
<td>9,400</td>
<td>17,100</td>
<td>18,630</td>
<td>Side B</td>
<td>3 From End A</td>
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<td>S985MP As Peened</td>
<td>80,000 80,000</td>
<td>1.485 1.485</td>
<td>301</td>
<td>0.307</td>
<td>30,000</td>
<td>36,000</td>
<td>*</td>
<td>*</td>
<td>Side B</td>
<td>1/2 From End C</td>
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<tr>
<td>S982MP As Peened</td>
<td>80,000 79,400</td>
<td>1.485 1.492</td>
<td>301</td>
<td>0.307</td>
<td>8,300</td>
<td>8,300</td>
<td>**</td>
<td>**</td>
<td>Sides B &amp; D</td>
<td>3 From End A</td>
</tr>
<tr>
<td>**</td>
<td>100,000 99,900</td>
<td>1.485 1.492</td>
<td>376</td>
<td>0.352</td>
<td>54,000</td>
<td>8,000</td>
<td>120,800</td>
<td>131,780</td>
<td>Side D</td>
<td>8 From Plate</td>
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<tr>
<td>Specimen Type of No.</td>
<td>Specimen</td>
<td>Calculated Nominal Cyclic at Critical Stress (psi)</td>
<td>Avg Thickness Side B</td>
<td>Avg Thickness Side D</td>
<td>Applied Uniform Pressure (psi)</td>
<td>Initial Deflection Side B</td>
<td>Initial Deflection Side D</td>
<td>1st Observation of Crack Deflection Side B</td>
<td>1st Observation of Crack Deflection Side D</td>
<td>No. of Stress Cycles to Increase 10% Deflection</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------</td>
<td>---------------------------------------------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>-------------------------------</td>
<td>-------------------------</td>
<td>-------------------------</td>
<td>---------------------------------------------</td>
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<tr>
<td>Peened S88KMP</td>
<td>Reinforcement Removed</td>
<td>79,200 80,000 1.475 1.469</td>
<td>294</td>
<td>0.310</td>
<td>37,500 39,000 537,100 561,700</td>
<td>Side B</td>
<td>End C</td>
<td>Weld Deposits</td>
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<td></td>
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<tr>
<td>Peened S88KMP</td>
<td>Reinforcement Removed</td>
<td>80,000 79,800 1.487 1.490</td>
<td>302</td>
<td>0.302</td>
<td>13,000 14,400 275,200 180,000</td>
<td>Side B</td>
<td>17&quot; From End A</td>
<td>Toe</td>
<td></td>
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</tr>
</tbody>
</table>

*Less than 1% increase in deflection and no major crack after 180,000 cycles - fatigue test stopped and specimen subjected to explosion bulge test.

**Less than 1% increase in deflection and no major crack after 250,000 cycles - specimen subjected to additional bending fatigue at 100,000 psi.