POST-WELD TREATMENT OF A WELDED BRIDGE GIRDER BY ULTRASONIC IMPACT TREATMENT

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ABSTRACT

This report is a follow up to demonstration of a new ultrasonic hammer peening technique (Ultrasonic Impact Treatment – UIT) held at the Federal Highway Administration's Turner-Fairbank Highway Research Center in McLean, Virginia on June 6, 1996. Representatives of Fenix Technology International, Inc. post-treated some of the fillet welds on a welded plate girder in the laboratory with the ultrasonic equipment. Following treatment, fatigue test specimens were cut from the plate girder to study the fatigue behavior of both treated and untreated weldments. Results indicate that the fatigue performance of the weldments was improved following the UIT treatment.

DISCLAIMER

This report presents research results from tests conducted at the Turner-Fairbank Highway Research Center. It is not an endorsement of any technology, company or process used during the demonstration. Information on the equipment used and the developing company are included for information only.

INTRODUCTION

On June 6, 1996, a demonstration of ultrasonic peening technology was held at the Turner-Fairbank Highway Research Center in McLean, VA. The demonstration was organized following discussions with representatives of Fenix Technology International who are attempting to introduce this new technology developed in Russia into the US. The demonstration was attended by a group of federal and state bridge engineers and representatives of the US Navy as shown in the attendance list in appendix A.

The goal of this demonstration was to gain exposure to this new technology that may offer the potential to improve the performance of welded joints in bridge structures. The developers of the equipment claim it increases the fatigue life of welded joints by up to 15 times compared to the as-welded condition. Appendix B contains the equipment specifications and performance claims that were provided to FHWA by the developers of the equipment. It is not the purpose of this report to confirm or deny these claims.

The demonstration consisted of treating some of the weldments on a welded plate girder with the ultrasonic peening equipment. Following the demonstration, the equipment developers offered additional information on the equipment to those agreeing to restrict disclosure.

Following the demonstration, fatigue testing of the treated weldments was conducted by FHWA research staff to determine what effect, if any, treatment had on the fatigue resistance of fillet welds in a typical bridge girder. This report presents the results of this testing.

TREATMENT PROCEDURE

A welded plate girder that was left over from a previous study was utilized as a test bed to try the ultrasonic treatment equipment. The girder is a little over 1 meter deep with 50-mm top and bottom flanges and a 10-mm web. Transverse stiffener details were welded to both sides of the web using 8-mm fillet welds using the SAW process. The girder was fabricated from 345 Mpa yield structural steel conforming to the ASTM A-572 standard.

The developers of the ultrasonic equipment treated the welds connecting one of the transverse stiffeners to the girder web. The process was used to treat only the toe of the weld, not the entire weld surface. All of the 8 weld toes (4 fillet welds x 2 toes/weld) were treated over the entire height of the girder. Records were not kept relating to treatment speed and number of passes made on each weld toe. The equipment developers controlled this. The process was repeated numerous times on each weld toe and overall treatment took several hours. No determination of the effect of repeated treatment was included in this demonstration. After the first treatment pass, a rounded, plastically deformed area was visible at each weld toe. Subsequent passes did not show much further change in appearance.

FATIGUE TEST PROCEDURE

For each of the two transverse stiffeners, a series of six cruciform-type fatigue specimens were cut and machined. The specimens were saw cut and finished in a milling machine to final dimensions. The specimens were gripped in a servo-hydraulic load frame using self-aligning grips and sinusoidal loading was applied at a frequency of 20 Hz. The load range was selected to produce a stress range of about 130 Mpa with the minimum / maximum load ratio (R-ratio) equal to 0.5. This loading was selected to be above the fatigue limit for category B and to simulate a bridge where dead load is about 50% of the total load. Cycling was continued until fatigue cracks developed and complete failure of the specimen was achieved.

FATIGUE TEST RESULTS

The stress range and number of cycles to failure for both the treated and untreated tests are shown in table 1. The stress range for all tests was approximately 130 Mpa. As shown, the fatigue life of the treated weldments was more than 8 times greater than the untreated weldments.

Table 1, Fatigue Test Results

Untreated Weldments		Ultrasonic Treated Weldments	
Stress Range (Mpa)	**Number of Cycles**	**Stress Range (Mpa)**	**Number of Cycles**
128.9	171,170[A]	131.6	3,537,628
129.6	524,935	129.9	5,325,878
129.7	707,290	130.9	2,408,050
129.8	576,080	131.9	3,555,607
129.5	451,606	131.0	1,689,043
130.0	475,709	131.4	10,212,307
Average: 547,124		Average: 4,454,752	

(A) This test was compressed and bent during setup. The test result is not included in the average number of cycles in this table or the statistical analysis of data.

Figure 1 shows both the treated and untreated data plotted in log-log format. Because only one stress range was tested, an S-N line could not be directly fitted from the data. The dashed lines in figure 1 were fitted to the two data sets by linear regression with the slope fixed at -3. The long dashed line represents the mean of the data while the short dashed lines represent ?2 standard deviations from the mean. Table 2 shows the regression statistics for the two data sets based on the following equation:

$$\Delta F = \left(\frac{10^{b \pm 2s}}{N} \right)^{\frac{1}{m}}$$

Where ? F is the stress range in Mpa, N is the number of stress cycles, and b, s, and m are regression constants.

Figure 1. SN Graph

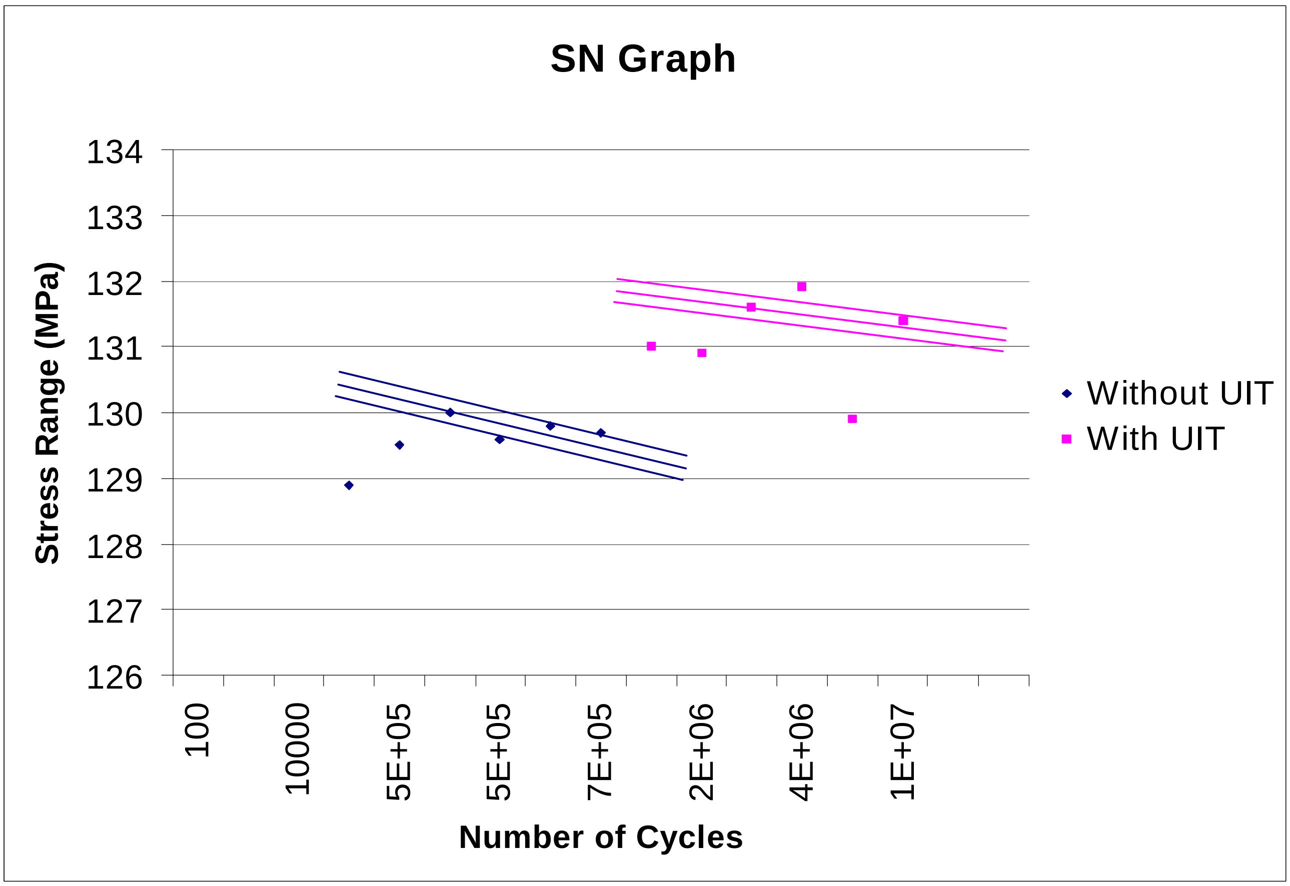

Table 2, Regression Constants

Data Set	Intercept b (Mpa)	Slope m	Standard Deviation s
Untreated	12.072	3.000	0.089
Treated	12.927	3.000	0.304
Category C'	12.810	3.097	0.158
Category B	13.696	3.372	0.147

STATISTICAL ANALYSIS

Table 3 shows the results of performing the T-test of significance to compare the two test data sets and to compare to the existing data base on fatigue data for bridge details[(1)] . Based on the statistical analysis, the non-treated weldments were not statistically different from the existing database on Category C' details. The treated specimens were not statistically different from the category B database. Based on these results, it can be concluded that the Ultrasonic Impact Treatment increased the fatigue resistance of the original category C' detail to category B at the stress range and under the conditions tested.

Table 3, Results of Statistical Analysis

Variable	Population	Number of Data Points	T-statistic for Intercept	Critical (Delta T) Value	Is the Difference Significant?
Compare Data Sets	Untreated	5	-5.129	2.571	Yes
	Treated	6			
Compare Data Sets To Fatigue Categories	Untreated	5	2.021	2.776	No
	Category C'	135			
	Untreated	5	4.191	2.776	Yes
	Category B	55			
	Treated	6	-0.111	2.571	No
	Category B	55			
	Treated	6	-2.707	2.571	Yes
	Category C'	135			

INTERPRETATION

Because of the following limitations, it cannot be concluded that all details receiving ultrasonic treatment will show the same improvement:

- This study does not address the effect of weld treatment on the fatigue limit for the category C' details.

- Because only one stress range was tested, it is unknown whether or not the slope of the resistance line for the treated detail will be about 3 as would be expected for the untreated detail. The same improvement may not occur at other stress ranges or R-ratios.

- The welds treated in this demonstration received what was probably a higher degree of treatment than would be expected in actual practice. More testing is required to determine the optimum treatment time and procedures need to be developed to ensure the correct degree of treatment is attained in all cases.

- This study looks at only one type of detail welded with the semi-automatic SAW process. Other weld processes may show different effects when treated.

CONCLUSIONS

- ✍✍There was a definite increase in the fatigue life of the treated weldment versus the untreated weldment in these tests. This made what was normally a category C' detail behave like a category B.

- ✍✍These tests show that ultrasonic peening increased the fatigue life an average of 8-times over the untreated weld at the stress range of 130 Mpa (19 ksi). The effect on fatigue resistance was not evaluated because only one stress range was used for testing.

- ✍✍More research is needed to define treatment speed and quality control guidelines for this process before it can be counted on to provide fatigue improvement for new designs.

- ✍✍More research is needed to look at different types of weldments, different stress ranges, and the effect of ultrasonic peening on the fatigue limit for typical bridge details.

REFERENCES

1) Albrecht, P., and Rubeiz, C.G., "'Variable Amplitude Load Fatigue Task A - Literature Review, Volume III - Variable Amplitude Fatigue Behavior," Publication No. FHWA-RD87-061, Federal Highway Administration, April, 1990.