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ARTICLE

FATIGUE LIFE EXTENSION PEENING OF WELDS IN HOLLOW SECTION CONNECTIONS

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It is well-known, both internationally and in North America, that peening of welded joints produces an extension of the fatigue life of welded connections. The position of American and Canadian codes/standards on this topic is reviewed below, along with further international research evidence, with particular emphasis on material pertaining to welded tubular structures.

The writer is a member of both the AWS D1.1 code technical committee and the CSA W59 standard technical committee, which are cited below.

1. USA

The current U.S. national welding standard produced by the American Welding Society (AWS 2010) contains a Section 8.4 on "Fatigue Life Enhancement" in which five methods for reconditioning weld details are listed: Profile Improvement; Toe Grinding; Peening ("Shot peening of weld surface, or hammer peening of weld toes"); TIG Dressing; Toe Grinding plus Hammer Peening. This section concludes with the general statement that ... "The Engineer shall establish the appropriate increase in the allowable stress range".

Elsewhere in this code, however, in Chapter 2 Part D – "Specific Requirements for Design of Tubular Connections (Statically or Cyclically Loaded)", Clause 2.21.6.6 deals specifically with "Fatigue Behavior Improvement" of welded tubular connections. Herein, it states that ... "For the purpose of enhanced fatigue behavior, and where specified in contract documents, the following profile improvements may be undertaken for welds in tubular T-, Y-, or K-connections:

(3) The toe of the weld may be peened with a blunt instrument, so as to produce local plastic deformation which smooths the transition between weld and base metal, while inducing a compressive residual stress." For regular welded tubular connections, with a diameter-to-thickness (D/t) ratio of the chord member not exceeding 48 and where appropriate inspection has been performed, Clause 2.21.6.6(3) supports a fatigue category improvement from X_2 to X_1 (if actual stress concentration factors are known), or from K_2 to K_1 . These stress categories are described in Table 2.7 and refer to the S–N curves in Figure 2.13. Quantitatively, at 2 x 10⁷ cycles for example, this implies an increase in permissible stress range by a factor of about 1.25 (or conversely, about 2.0 on cycle life).

2. CANADA

The current Canadian national welding standard produced by the Canadian Standards Association (CSA 2003) contains a Clause 9.5–Fatigue Life Enhancement in which four methods for reconditioning welded details are listed: Toe Grinding; Peening ("Shot peening of weld surface, or hammer peening of weld toes"); TIG Dressing; Toe Grinding plus Hammer Peening. Thus, the mandatory part of CSA W59 endorses hammer peening for fatigue life extension.

CSA W59 also contains a non-mandatory Appendix R, in which Section R3.5–Hammer Peening gives detailed requirements for peening procedures and an applicable range of application (such as yield strengths \leq 800 MPa [116 ksi], and thicknesses \geq 10 mm). In CSA W59 Section R3.8–Stress Range Increase the standard states ... "The allowable stress range for cyclically loaded connections may be increased by a factor of 1.3 along the S–N design curve, which is equivalent to a factor of 2.2 on cycle life, for an S–N curve slope of approximately 1/3, when toe grinding, hammer peening, or TIG dressing is used". Thus, although in an "informative" rather than "normative" Appendix of the code, the permissible increase in fatigue life for such treatment is even conservatively quantified. Appendix R is supported by 12 references, many of which are documents from the International Institute of Welding (IIW) and The Welding Institute, U.K.

3. INTERNATIONAL STUDIES

A review of relatively recent research literature on peening treatments reveals that several modern methods of high frequency peening, all of which have European origins, are in current use:

- (i) PIT Pneumatic Impact Treatment
- (ii) HiFIT High Frequency Impact Treatment (also pneumatic)
- (iii) UIT Ultrasonic Impact Treatment
- (iv) UP Ultrasonic Peening
- (v) UNP Ultrasonic Needle Peening.

These all operate in a similar manner to ordinary hammer peening equipment, only at considerably higher frequency, which reduces vibration and noise and gives a high improvement in fatigue strength. Although they are different processes, their properties and resulting improvement in fatigue strength appear to be similar (Pedersen et al., 2009). Weich et al. (2008) have shown that even fatigue-damaged welds can be treated with the same success as new welds. The correct execution technique, operator training and quality control for such weld treatment has also been emphasized (e.g. Günther and Kuhlmann, 2009; Walbridge and Nussbaumer, 2008).

In the most recent comprehensive fatigue design guidance by the International Institute of Welding (Hobbacher, 2008), hammer peening is covered in Section 3.5.3.5. This document limits the application to steels with a yield strength \leq 900 MPa [130.6 ksi], to 50 mm \geq thickness \geq 10 mm, and notes the influence of the applied stress ratio (R) on the fatigue life benefit. (For example, if R > 0.4 there is no benefit). The maximum stress-range benefit that can be claimed from hammer peening, for use with the nominal stress approach, is given by the Table below.



Use of Pneumatic Impact Treatment (PIT) equipment for weld peening 3

4. CONCLUSION

Hammer peening – and high frequency hammer peening – of weld toes in welded joints is an internationally accepted method for fatigue life enhancement. The technique is recognized in Canadian and American codes/standards and has been used on railway and highway bridges in North America. When performed by properly trained operators, a fatigue stress range improvement factor of 1.3 (or alternatively a factor of 2.2 on fatigue life) can, in general, be conservatively assumed for welded tubular steel connections.

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