Available online at www.sciencedirect.com
SCIENCE DIRECT
International Journal of Fatigue 27 (2005) 95–101
International Journal of Fatigue
www.elsevier.com/locate/ijfatigue

Technical Note

Investigation of the fatigue behaviour of the welded joints treated by TIG dressing and ultrasonic peening under variable-amplitude load

Lixing Huo *, Dongpo Wang, Yufeng Zhang

Welding Division, College of Material Science and Engineering, Tianjin University, Tianjin 300072, China

Received 24 March 2003; received in revised form 4 May 2004; accepted 17 May 2004

Abstract

Weld toe treatment by ultrasonic peening (IIW.Doc.XIII-1817-00; J. Mech. Strength 21(1999)289; Welding World (3/4)(2001); Welding World (37)(1996)72) or TIG dressing (Trans. Jpn. Welded Soc. 17(2)(1986)3; Int. J. Fatigue 21(6)(1999)587; Metal Construction 19(2)(1984)143; Int. J. Fatigue 20(9)(1998)677) improves the fatigue performance of welded joints and structures significantly. This has been verified by many constant amplitude fatigue tests. However, there is the need to check their benefits for structures subjected to variable-amplitude loading. Therefore, fatigue tests were performed on fillet welded joints in 16Mn steel for three different conditions: as-welded, TIG dressed and after treatment by ultrasonic peening.

The beneficial effects of both TIG dressing and ultrasonic peening were found to be less under variable amplitude than under constant amplitude loading. In particular, under constant amplitude loading TIG dressing increased the fatigue strength by 37% and the fatigue life by 2.5 times. In contrast, under variable-amplitude loading the corresponding benefits were 34% increase in fatigue strength and 1.7–1.9 times increase in fatigue life. The improvement in fatigue performance due to ultrasonic peeing depended on the applied stress, being negligible at stresses approaching yield, but greater than that due to TIG dressing in the low stress/high-cycle regime. Under constant amplitude loading, ultrasonic peening increased the fatigue strength by up to 84% and the fatigue life by 3.5–27 times. In contrast, under variable-amplitude loading the corresponding benefits were 80% increase in fatigue strength and 2.5–17 times increase in fatigue life.

For either constant or variable-amplitude loading, the improvement in fatigue strength of the welded joints due to ultrasonic peening was greater than that due to TIG dressing, but only in the low stress/high-cycle regime.

Keywords: Variable-amplitude loading; Ultrasonic peening; TIG dressing; Fatigue performance; Welded joints; Steel

1. Introduction

Weld toe treatment by ultrasonic peening [1–4] or TIG dressing[5–9] have, on the basis of constant amplitude fatigue tests, been shown to improve the fatigue properties of welded joints and structures significantly. However, actual structures are generally subjected to variable-amplitude loading, in which the stress amplitude and the mean stress may vary at any time. It is evident that this will cause some effect on the fatigue properties of welded joints and structures and the beneficial effect of weld toe improvement techniques. In order to check the effectiveness of ultrasonic peening and TIG dressing, comparative fatigue tests were performed under both constant and variable-amplitude loading on fillet welded joints in a structural steel in three different conditions: as-welded, joints treated by ultrasonic peening and joints treated by TIG dressing.

This paper details the tests and presents the results obtained.

2. Test materials and test method

2.1. Test materials and preparation of the specimen

The test specimens consisted of 8 mm thick plates with longitudinal fillet welded attachments, as shown in Fig. 1. They were made from 16Mn steel plate with the mechanical properties shown in Table 1. The specimens

* Corresponding author. Tel.: +86-2227405889; fax: +86-2227407022.

E-mail address: lxhuo@tju.edu.cn (L. Huo).

0142-1123/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijfatigue.2004.05.009

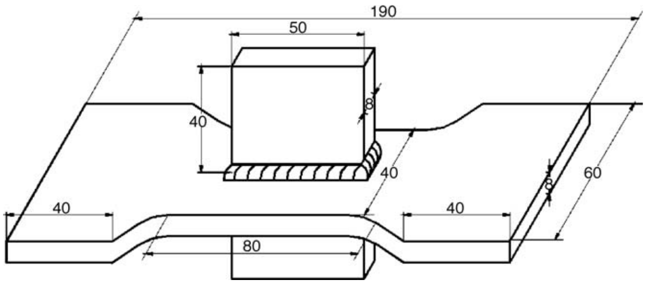

Fig. 1. Geometrical characteristics of specimen.

were welded by the manual metal arc process using J507 electrodes and the welding parameters given in Table 2.

2.2. The method of ultrasonic peening

Ultrasonic peening was performed by directing the gun at the weld toe and perpendicular to it. The peening needles were arranged along the weld. Slight pressure was applied to the peening gun in order to direct the peening treatment.

A two-pass treatment was applied at a speed of 1.2 m/min, using an excitation current of 1.3 A.

2.3. Method and parameters of TIG dressing

TIG dressing was performed according to related documents [5–9] with the TIG re-melting parameters recommended by IIW. Preheating treatment was not required for the steel used. TIG dressing was performed with the specimen in horizontal level. There was no arc restarting occurrence during the period of operation. The TIG dressing parameters are shown in Table 3.

Table 1
Mechanical properties of 16Mn

Material	Yield strength (MPa)	Tensile strength (MPa)	Elongation rate (%)
16Mn	390	590	24

Table 2
Welding parameters

Diameter of electrode (mm)	Welding speed (mm/min)	Welding current (A)	Welding voltage (V)
4.0	130	160	24–26

Table 3
Parameters of TIG dressing

Current type	Diameter of wire (mm)	Current (A)	Voltage (V)	Speed of travel (m/min)	Heat input (kJ/cm)	Shielding gas
Direct current	3.2	140–160	15–20	0.1	13–20	Argon

2.4. Method of fatigue test

The tests were carried out in a 100 kN HF fatigue testing machine.The static load accuracy for the full range of the testing machine was 0.2%, while the accuracy of the dynamic load amplitude of vibration was 2%.

*Testing method***:** The specimens were divided into three groups: as-welded, specimens treated by ultrasonic peening and specimens treated by TIG dressing. All three groups of specimens were tested under both constant and variable-amplitude loading.

Load application: The specimens were fatigue tested axially under tensile loading. The stress ratio (R) was 0.1 for the constant amplitude tests.

2.5. Load spectrum for the variable-amplitude fatigue tests

A block program loading sequence was used in the variable-amplitude fatigue tests. This consisted of three blocks of constant amplitude stress, referred to as the minimum (i.e. smallest), medium (i.e. intermediate) and maximum (i.e. largest), applied in the sequence shown in Fig. 2. The mean stress was maintained constant for all blocks, at $0.55 \times$ maximum stress. The difference between the maximum and medium stress levels was 27 MPa and the difference between the minimum and medium levels was about 18 MPa. Consequently, the stress ratio was close to 0.1 for all stress cycles. The actual stress levels applied in the tests are detailed in Table 4.

3. Analysis and results of constant amplitude fatigue tests

The test results obtained from the as-welded specimens under constant amplitude loading are presented in Table 5. Those for specimens treated by ultrasonic peening (UPT) or TIG dressing (TD) are given in the Tables 6 and 7, respectively.

The results are plotted in Fig. 3, together with S–N curves of the form $S^m N = C$. These were fitted to each set of results, as detailed in Table 8.