Materials Science & Engineering A 564 (2013) 478–484

Contents lists available at SciVerse ScienceDirect

Materials Science & Engineering A

journal homepage: www.elsevier.com/locate/msea

Low cycle fatigue of welded joints with aging influence

H. Zaletelj*, G. Fajdiga, M. Nagode

University of Ljubljana, Faculty of Mechanical Engineering, Askerceva 6, 1000 Ljubljana, Slovenia

ARTICLE INFO

Article history:
Received 30 August 2012
Received in revised form
24 November 2012
Accepted 26 November 2012
Available online 3 December 2012

Keywords:
Mechanical characterization
Welding
Aging
Fatigue

ABSTRACT

The article is a continuation of welded joints research, which is intended to improve the fatigue life prediction of the exhaust system's welded parts. It is focused on the low cycle fatigue (LCF) range, where the influence of high loads on the material durability was analyzed. Sometimes the practice shows an unprofitable production of some intensively loaded parts evaluated in the range of high cycle fatigue or fatigue endurance limit. Numerous LCF tests of samples without weld, with weld and with aging influences were performed. Testing was performed on a servohydraulic test machine where the strain was controlled. The tables and graphs show the results of the monotonic tension tests, LCF tests and the results of the artificial aging influences on the welded joints. The article also includes the fatigue degradation regarding the weld influence and minor aging effect on fatigue properties at higher strains. The results present a contribution to the progression of knowledge and the research of new technologies, especially in the area of the fatigue of welded parts under high loads.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

High-efficient and reliable machine parts require an analysis and characterization of different influences on the material durability. Material durability depends on mechanical properties, geometric parameters, manufacture technologies, load manes, load intensity, etc. Applying different mechanical and thermal treatments can increase durability. This treatments perform decreased abrasion, increased mechanical properties, improved fatigue life, etc [1].

Some machine parts are subjected to unexpected loads that contribute to crack growth in critical places. Low cycle fatigue methods are used for the unexpected occurrences where load is usually very high. The strain is controlled as the load parameter for the LCF observation, where considerable progress was made especially with high-performance equipment.

The article describes the procedure and results of the LCF research being a continuation of an extensive research, the first part of which focused on high cycle fatigue analysis [2]. The research was made in collaboration with the company Bosal Emission Control Systems (ECS), who provided the material and test samples production. Ferritic stainless steel was used as the base material (BM), this being usually applied for exhaust system parts of a motor vehicle. The base material and weld influence were analyzed. The durability reduction of welded samples can be observed due to weld geometry, different microstructure in a weld zone and temperature effects during welding [1,3,4]. Special attention has to be paid during the preparation of test samples. Welding parameters, test samples production and the LCF test manner are introduced in the sections below. The chemical composition of the base material and welding wire is shown in the table.

An exhaust system is subjected to temperature influence over a period of time. This effect is known as aging [5,6] and its influence on low cycle fatigue properties is presented. With regard to different temperatures along an exhaust system, different aging parameters were chosen and analyzed. Different aging conditions do not always precede the increased fatigue properties. Sometimes negative results appear. Test samples were aged in a furnace at different temperatures for different periods of time. Experimental data are presented with durability ε–N curves, which are usually used to present LCF test results [7,8]. The tables also present the Weibull distribution and ε–N curve parameters. Finally, according to this investigation the life-time prediction of exhaust system components can be determined more accurately.

1.1. ε–N curves

Coffin and Manson [7,8] proposed a characterization of fatigue life based on plastic strain amplitude. They noted that when the logarithm of the plastic strain amplitude $\Delta\varepsilon_p/2$ was plotted against the logarithm of the number of load reversals to failure, $2N_f$, a linear relationship for metallic materials follows.

$$\frac{\Delta\varepsilon_p}{2} = \varepsilon_f'(2N_f)^c \quad (1)$$

ε_f' represents the fatigue ductility coefficient and c is the fatigue ductility exponent. In general, ε_f' is approximately equal to the fracture ductility ε_f in monotonic tension test ($N=1$) and c is the gradient of the straight line.

* Corresponding author. Fax: +386 142 14074.
E-mail address: henrik.zaletelj@fs.uni-lj.si (H. Zaletelj).

0921-5093/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.msea.2012.11.101

Total strain amplitude in a constant strain amplitude test, $\Delta\varepsilon/2$, is the sum of elastic strain amplitude $\Delta\varepsilon_e/2$ and plastic strain amplitude $\Delta\varepsilon_p/2$.

$$\frac{\Delta\varepsilon}{2} = \frac{\Delta\varepsilon_e}{2} + \frac{\Delta\varepsilon_p}{2} \tag{2}$$

The elastic term can be expressed as

$$\frac{\Delta\varepsilon_e}{2} = \left(\frac{\sigma_f'}{E}\right)(2N_f)^b \tag{3}$$

where σ_f' is a tensile strength, E is the Young's modulus and b is related to the strain-hardening exponent. Combining Eqs. (1)–(3) gives the basis for the strain-life approach to fatigue design:

$$\frac{\Delta\varepsilon}{2} = \left(\frac{\sigma_f'}{E}\right)(2N_f)^b + \varepsilon_f'(2N_f)^c, \tag{4}$$

where the first and the second term on the right side are the elastic and plastic components respectively.

Fig. 1 is a plot of the elastic, plastic and total strain variations versus the number of load reversals to failure $2N_f$. Although $\ln(\Delta\varepsilon_e/2)$ and $\ln(\Delta\varepsilon_p/2)$ vary linearly with $\ln(2N_f)$, $\ln(\Delta\varepsilon/2) = \ln(\Delta\varepsilon_e/2 + \Delta\varepsilon_p/2)$ does not [7,8].

1.2. ε–N curves for different probabilities of rupture

The number of load cycles to failure for different probabilities of rupture can be determined by a known probability density function at different load levels. Practically speaking, when determining the fatigue life of structures, we are often limited to a low number of test samples, Fig. 2. Experiments are often performed at more than two load levels without repetition at each level. To estimate the scatter of the corresponding durability curves, the integral procedure was developed and presented in the literature [9].

The mathematical form of the two-parametric Weibull distribution probability density function of the number of load cycles to failure, N, is written down in the form of the following equation:

$$f(N) = \frac{\beta}{\eta}\left(\frac{N}{\eta}\right)^{\beta-1}\exp\left[-\left(\frac{N}{\eta}\right)^{\beta}\right]; \quad N, \beta, \eta > 0 \tag{5}$$

where β defines the shape of the Weibull function and η is its spread along the number of load cycles to failure axis.

$$\eta = \eta(\varepsilon) = 10^{a_0 + a_1 \log(\varepsilon)}; \quad a_0 > 0, \quad a_1 < 0 \tag{6}$$

$$\beta = \text{const.}; \quad \beta > 0 \tag{7}$$

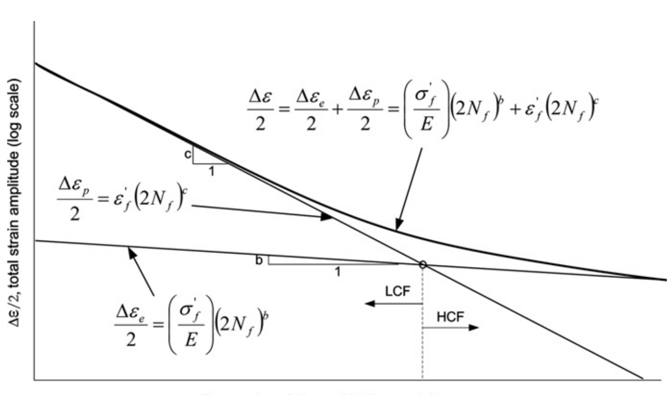

Fig. 1. The fatigue life as a function of total strain per cycles.

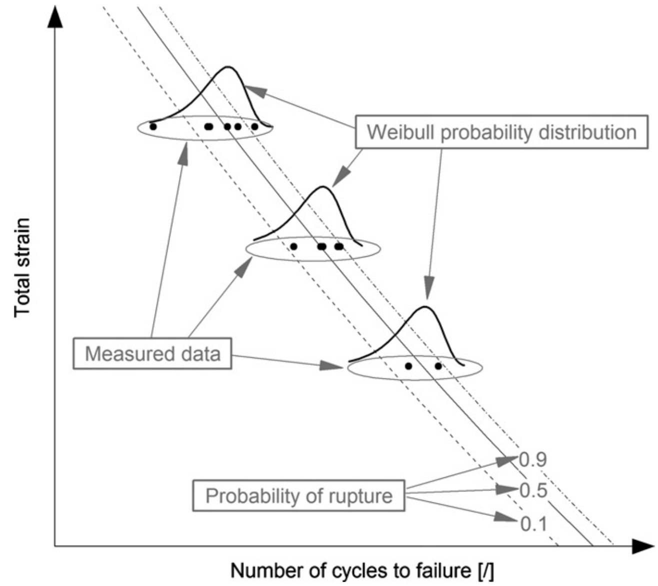

Fig. 2. ε–N curves and their scatter.

To estimate the parameters of the Weibull distribution, a program code, developed and proposed by Klemenc in [9], was used.

2. Experimental details

Testing was performed in order to analyze the low cycle fatigue and different aging conditions influences on the material durability. Welded test samples were proposed. Initially, the influence of the weld joint to the base material at low cycle fatigue was determined. The second goal was to find the differences in durability between the aged and non-aged specimens. Different aging parameters were used in order to validate the higher range of thermal influence on the material for different periods of time. The temperature of aging corresponds to the conditions appearing during the usage of an exhaust system.

Tests were separated in six parts. The specimens presenting the base material (BM) 1.4512 were tested first and do not include weld or additional heat treatment. The BM+W sign stands for the test specimens where both the base material and the weld were observed. The test specimens exposed to different aging processes are BM+W+A*X* (*X*=1, 2, 3, 4). The sections to follow present the test specimen preparation, testing description, aging conditions and results.

2.1. Test specimen and materials

The shape and dimensions of the test specimen correspond to the standard ASTM E606-04, which defines the procedure of strain controlled fatigue testing [10]. The dimensions of the specimen relate to the thickness of the sheet from which it is cut from. The thickness of the specimens was 2 mm. Moreover, the shape and dimensions correspond to the parameters defined for uniaxial testing. Some test specimens also contained a weld located at the middle of the length in the specimen test area. With this reason, the middle part of a test sample was stretched from 6 to 9 mm and it was performed at all samples, welded and non-welded. An extended middle part ensured that the weld toe would not be located in the arc transition area between the middle and the fixation part of a test sample. The length of the

Download English Version:

https://daneshyari.com/en/article/7983553

Download Persian Version:

https://daneshyari.com/article/7983553

Daneshyari.com