Available online at www.sciencedirect.com

ScienceDirect

Procedia Structural Integrity 7 (2017) 315–320

Structural Integrity Procedia

www.elsevier.com/locate/procedia

3rd International Symposium on Fatigue Design and Material Defects, FDMD 2017, 19-22 September 2017, Lecco, Italy

Fatigue limit evaluation of structure materials based on thermographic analysis

R. Prochazka*, J. Dzugan, P. Konopik

COMTES FHT, Department of mechanical testing and thermophysical measurement, Prumyslova 995, Dobrany 33441, Czech Republic

Abstract

The work presented here is dealing with implementation of new approach to fatigue limit determination. The approach is based on application of thermography on specimen that is step-by-step increasingly loaded. Detected temperature changes at different stress levels are evaluated and final fatigue limit level is determined.. Thermography analysis seems to have a great potential to reduce the material demand and to achieve the minimum testing time while the quality of test results remains comparable to standard approach. This is extremely useful in cases where the experimental material is strictly limited, such as new materials development, residual service life of in-service components determination or also, nowadays, for additive manufacturing components, where specimens preparation is expensive.
Each specimen was tested at different stress amplitudes, where the test procedure consists of at least 8 loading steps. Results obtained with the thermography technique were compared with those obtained from standard high-cycle force-controlled fatigue tests under constant loading until failure in accordance with the ASTM E466-07 standard. All tests were done at room temperature with the cycle asymmetry coefficient R = -1.

Keywords: Fatigue limit; thermographic methodology; degradation

* Corresponding author. Tel.: +420 377 197 358; fax: +420 377 197 310
E-mail address: radek.prochazka@comtesfht.cz

10.1016/j.prostr.2017.11.094

1. Introduction

The use of infrared thermography methodology, as a tool for investigation of fatigue processes, is well known for two decades in the research field and for last decade the technology is widely used as a commercial tool in many applications. For every application, the suitability of chosen cameras depends on its sensitivity, image resolution and recording speed. Fortunately, for the purpose of using thermal camera to obtain a fatigue limit, it is possible to use a relatively slow recording speed with a low resolution of the images as used in works by Luong (1992, 1993, 1995, 1988), La Rosa (2000), De Finis (2015), Cura (2005) and Shiozawa (2016).

In one of the early studies, K. L. Reifsnider (1974) showed possibilities of heat increment measurement during the cyclic loading of composite materials. The following years, there have been many attempts to describe fatigue processes using an infrared camera. Among those researchers, Luong (1992) investigated a small temperature increase in material during the cyclic loading even bellow the fatigue limit. Based on this investigation, he established two lines to interpolate the thermal data. First, he split the data into two groups: one for stresses under the fatigue limit and one for stresses above it. This estimation is named graphical method.

In the scope of this work, this graphical method was used for fatigue limit evaluation of a duplex steel to investigate the fatigue limit of a degraded material due to a thermal material degradation which is represented by the butt welded joint.

2. Experimental study

Rapid investigation of material properties is very difficult in case of fatigue testing, especially in area of high cycle fatigue tests, where the specimen is expected to survive up to 10 million loading cycles. Staircase method is the one of the most common procedures for estimating the fatigue limit, which brings many difficulties in the speed of testing and self-heating of loaded specimens due to high loading rate, e.g. in duplex stainless steels. To reduce the time for fatigue limit determination, the self-heating test procedure employing an IR camera is used.

2.1. Material and specimens

A duplex stainless steel plates are intended for welded structural applications. Therefore, there is a need for knowledge of how significant the degradation is in fatigue limit and lifetime. The test simulates a thermal degradation of material properties in operation time and helps calibrate this proposed method. The results can be also used for subsequent experiments, where the change in material properties of a component can be monitored using non-invasive methods to provide data for a lifetime assessment.

Flat specimen geometry was designed in accordance with ASTM E466-07 standard (2007). The thickness of all specimens reflects the future thickness of the sheet for welds (see Fig. 1 and Fig. 2). To avoid the specimen slipping in grips and thus its additional heating due to the low gripping force, the hydraulic grips MTS with capacity of ± 250 kN were employed.

As a first step, the reference fatigue limits of base material and degraded material were measured in accordance with CSN 420363 standard; the fatigue limit values were confirmed by testing at least 5 specimens for each material. Degraded material was represented by butt welded joint across the cross section area of dog bone specimens as illustrated in Fig. 1.

a b

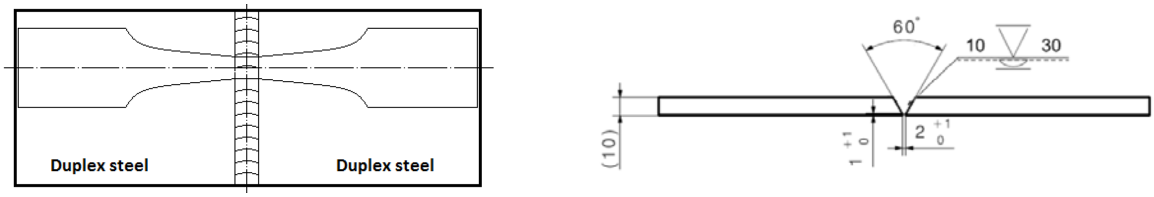

Fig. 1 (a) Specimen orientation at the weld joint; (b) dimensions of the weld type