Estimation of the Fatigue Limit on the Basis of Infrared and Potential Drop Methods

Nahuel Micone, Wim De Waele
Department of Electrical Energy, Systems and Automation, Ghent University
Zwijnaarde, Gent, Belgium

ABSTRACT

An accurate knowledge of the fatigue limit plays an important role in the fatigue structural design. Traditional experimental methods to estimate this stress level are highly time consuming. In recent years the application of Infrared (IR) technology for accelerated fatigue damage evaluation has increased. However, this technology is not always deployable, e.g. due to lack of space or accessibility, in aqueous environments. Under such circumstances, the Potential Drop (PD) technique has shown to be applicable for crack initiation and crack growth assessment. This paper focuses on the description and comparison of the established IR and a novel PD method to find the fatigue limit of an HSLA steel in an efficient manner. Based on preliminary tests, the results of both methods show good correlation.

KEY WORDS: Fatigue limit; Infrared thermography; Potential drop; Energetic approach.

NOMENCLATURE

- \( f \) loading frequency (Hz)
- \( N \) number of cycles (-)
- \( N_t \) number of cycles corresponding to the fatigue limit (-)
- \( N_i \) fatigue life at ith stress range (-)
- \( P_s \) survival probability (%)
- \( R \) stress ratio (-)
- \( \Delta T_s \) stationary temperature increment (°C)
- \( \Delta T_{si} \) stationary temperature at ith stress range (°C)
- \( \Delta V_s \) stationary voltage increment (V)
- \( \sigma_f \) fatigue limit obtained by the traditional method (MPa)
- \( \sigma_{PD} \) fatigue limit obtained by the Potential Drop method (MPa)
- \( \sigma_{TM} \) fatigue limit obtained by the Infrared method (MPa)
- \( \sigma_i \) stress range (MPa)

INTRODUCTION

The definition of the fatigue limit (\( \sigma_0 \)) is an important step during the design stage of a component subjected to cyclic loads. For some materials (steel e.g.), and constant amplitude cyclic loads, it is accepted that a steady fatigue limit is achieved after approximately \( 5 \times 10^6 \) cycles. The stresses below this limit (see Fig. 1) are defined as not damaging and it might therefore be taken as a stress reference for “safe life” structural design.

Traditionally, the fatigue limit is estimated from a series of (constant amplitude) fatigue tests conducted to determine the entire S-N curve of the material. For design purposes, the fatigue limit is generally taken equal to the endurance level at \( 5 \times 10^6 \) cycles. In any case, the S-N curve has to be partially or totally determined in order to establish this parameter. Such experimental analysis is highly time consuming.

In the last two decades the use of infrared thermography for the rapid determination of the fatigue limit has increased. Several authors have published (slightly) different methodologies to quickly estimate it in an accurate manner (Luong MP, 1998; La Rosa G, 2000; Crupi, 2008). Notwithstanding this technique is a powerful tool to estimate the fatigue limit, its application might be hindered by different factors such as accessibility of the interesting region, composition of the surrounding environment and its temperature, among others.

Based on own preliminary tests, it was evidenced that some electrical properties change in a similar way as temperature upon fatigue loading. Therefore it was hypothesized that the potential drop technique might