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Numerical analyses of corroded bolted connections

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Abstract

The interaction between fatigue and corrosion is the phenomena that is called Corrosion Fatigue (CF) and regarding steel structures subjected to cyclic loads. The S-N curves proposed by the main International Standards for fatigue life assessment do not take into account the state of degradation of the detail. For this reason, in this paper, a local approach is used to determine the fatigue life of corroded bolted joint with preload high strength bolts. In particular, fatigue life estimates are presented using the strain life method based on numerical analysis conducted on the joint, assuming that the crack nucleation phase is predominant in the whole fatigue life. The models used to simulate bolted joint are implemented using solid and contact elements and the geometry is realized taking into account the geometric imperfections produced by pitting corrosion. These imperfections were measured by surface surveys with a 3D profilometer. In conclusion, the results of the numerical analysis conducted on corroded joint model were compared with the experimental results obtained from cyclical tests.

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Keywords: bolted connections, fatigue analysis, steel bridges, corrosion fatigue

1. Introduction

An important number of bolted bridges in the world require fatigue life assessment to allow their maintenance and retrofitting. In particular, steel structures exposed to atmospheric corrosion for long periods often exhibit high levels of surface corrosion, even if they are protected with superficial coating. Steel corrosion-related deteriorations,

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including corrosion fatigue (CF), are the main contributors to the reductions of the structural integrity of metal bridges. Fatigue resistance can be significantly reduced by the presence of corrosion pitting because it facilitates the nucleation of the fatigue cracks at the pits propagating under cyclic loads.

The influence of corrosion is not only to be considered in terms of mass losses and corresponding reduction of the resistive area that are often negligible, but in the presence of superficial imperfections that generate stress concentrations defined notch factor effect (Rahgozar and Sharifi 2011). Also Zahrai (2003), Turnubull (2012) and Turnbull et al. (2010) concluded that fatigue life reduction is due to the irregularities that facilitate stress and strain concentrations and consequently cracks nucleation.

To assess the fatigue life taking into account the effect of surface imperfections one of the methodologies used is to model the geometry of the pits that are detected by a 3D measurements.

Sankaran et al.(2001) have conducted a research on the fatigue life of pre-corroded specimens using the shape of the pits to simulate elliptical cracks. Medved et al. (2004) modelled the pits through semi-elliptical geometry with shapes similar to the real ones. In the light of the results obtained by Shan-hua Xu and You-de Wang (2015), Xin-Yan Zhang et al. (2013) and M. Cerit et al. (2009) on unnotched specimens, the present study aim to obtain a fatigue life assessment of a fastened bolted connection subjected to accelerated corrosion through a finite element model based on surface detection of pits by means of a 3D profilometer. In this way, it was possible to analyse the fatigue behaviour taking into account surface pits effect. This methodology was pursued also by Athanasios Kolios et al. (2014) to study the effect of various typologies and numbers of pits.

The S-N curve obtained by numerical analysis were compared with the experimental data available for the case of study.

Nomenclature

f_y	Yield strength
f_u	Ultimate strength
N_f	Number of cycles to failure
N_i	Number of cycles for crack nucleation
N_p	Number of cycles for crack propagation
$\Delta\sigma$	Elastoplastic stress range
$\Delta\varepsilon$	Elastoplastic strain range
ΔS	Applied load range
E	Young module
K_t	Stress concentration factor
K'	Cyclic strength coefficient
n'	Cyclic hardening exponent
σ_f'	Fatigue strength coefficient
ε_f'	Strain ductility coefficient
b	Fatigue strength exponent
c	Strain ductility exponent
$F_{p,Cd}$	Bolt force pretension
f_{ub}	Bolt ultimate strength
A_s	Bolt net area
F_{normal}	Contact normal reaction force
K_{normal}	Contact stiffness
$x_{p.}$	Penetration
$F_{S,Rd}$	Joint force resistance
n	Number of friction resistant surfaces
n_b	Number of prel bolts
μ	Slip coefficient