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Assessment of fatigue strength of steel butt-welded joints in as-welded condition – Alternative approaches for curve fitting and mean stress effect analysis

Timo Nykänen*, Timo Björk

Lappeenranta University of Technology, Laboratory of Steel Structures, P.O. Box 20, FIN-53851 Lappeenranta, Finland

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ABSTRACT

Experimental fatigue data for butt-welded joints in as-welded condition and under constant amplitude tensile loading (secondary bending included) were analyzed using the nominal stress system and the notch stress system. Two approaches were used; a standard fitting procedure and minimization of the sum of squared perpendicular distances from a line with a fixed and free slope. In all cases, the latter method gave better agreement between the experimental and predicted fatigue life and fatigue strength. The analyses showed both with all broken specimen data included and with reduced data that the FAT225 curve, as recommended by IIW, might be too optimistic for the notch stress approach in the case of butt-welded joints in as-welded condition. It was also found that use of the local stress ratio instead of the applied stress ratio might explain many issues concerning current observations and apparent inconsistencies in reported literature.

* Corresponding author. Tel.: +358 0294 463419; fax: +358 (05) 621 2499.
E-mail addresses: timo.nykanen@lut.fi (T. Nykänen), timo.bjork@lut.fi (T. Björk).

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Nomenclature

ASW	as-welded condition
FAT	IIW fatigue class, fatigue strength corresponding to two million cycles
FEM	finite element method
GMAW	gas metal arc welding
GMAW-P	pulsed gas metal arc welding
GTAW	gas tungsten arc welding
HFMI	high frequency mechanical impact treatment (generic term)
Hybrid LF	CO_2-laser combined MAG welding, laser travels first
Hybrid MF	CO_2-laser combined MAG welding, MAG travels first
IIW	International Institute of Welding
MAG	metal active gas welding
MSSPD	minimization of the sum of squared perpendicular distances from a line
NIMS	National Institute for Materials Science (Japan)
SAW	submerged arc welding
SLM	structured light method
SMAW	shielded metal arc welding
SWT	Smith-Watson-Topper approach
UHSS	ultra-high-strength steel
UP	ultrasonic peening (device name)
C	fatigue capacity
E	Young's modulus
e	axial misalignment
H	cyclic strain hardening coefficient
K_f	fatigue effective stress concentration factor between notch stress and nominal stress
K_m	structural stress concentration factor
K_t	stress concentration factor
K_w	fatigue effective stress concentration factor between notch stress and structural stress
k_1	factor for the calculation of characteristic values
l	half distance between clamps
m	slope of the line for stress cycles
N_f	cycles to failure
n	cyclic strain hardening exponent, number of specimen
P	damage parameter
R	applied stress ratio
$R_\perp$	perpendicular distance from a line
R_m	ultimate strength
r	correlation coefficient
Stdv	standard deviation
S_y	yield strength
s	relative residual stress, $\sigma_{\mathrm{res}}/R_m$
t	plate thickness of the specimen
α	angular misalignment
Δ	range
ε	strain
θ	weld toe notch angle
ρ	radius
ρ_f	fictitious radius
σ	stress
σ_k	effective notch stress