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Fatigue Tests of Bimetal Zirconium-Steel Made by Explosive Welding

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Abstract

The paper presents the fatigue test results including the cracks growth in the composite zirconium-steel subjected to oscillatory bending. Specimens of square cross-section without remelted layer and with a remelted layer were tested. In the specimens the net ratio of thickness of zirconium and steel layers was $h_1 : h_2 = 2.5 : 1$. The tests were conducted under controlled force with frequency 28.4 Hz. It was observed that a higher fraction of the intermetallic inclusions near the interface increase the fatigue life.

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Keywords: explosive welding, bending, fatigue crack growth, joint

1. Introduction

At present, the materials cladded by means of the explosive method are more often applied in various fields of industry. Application of zirconium for constructional steel coating decreases the costs of apparatus requiring high corrosion resistance or temperature resistance. This material is widely applied for construction of processing apparatus in chemical industry, or for heat exchangers in power industry [1, 2].

The aim of this paper is to analyze the effect of stress on the fatigue life in explosively welded bimetallic zirconium-steel systems.

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Nomenclature

A_5	elongation
E	Young's modulus
K_t	theoretical stress concentration factor
M_a	amplitude of bending moments
N_f	number of cycles to failure ($N_f = N_i + N_p$)
N_i	number of cycles to initiation of crack
N_p	number of cycles crack growth
R	load ratio
α	significance level
ν	Poisson's ratio
σ_a	amplitude of nominal stress
σ_u	ultimate tensile stress
σ_y	yield stress

2. Experimental procedure

2.1. Material and specimen

The zirconium-steel bimetal made with explosive welding was tested. P265GH normalized carbon steel plate of 20 mm thickness was the base material [3, 4] and Zr 700 zirconium plate of 3.175 mm thickness was a clad material. Basic mechanical properties of both materials before joining (according to the certificate of the manufacturer) are presented in Table 1.

Table 1. Mechanical properties of Zr 700 and P265GH steel.

Materials	σ_y (MPa)	σ_u (MPa)	E (GPa)	ν	A_5 (%)
Zr 700	143	300	100	0.35	31
P265GH	311	467	210	0.30	33

Specimens with net square cross-sections of 7 mm thickness, 7 mm width and length 90 mm were tested (Fig. 1). Those were cut off the sheet with a thickness of 23 mm parallel to the detonation direction. Each specimen had an external notches with a root radius R = 22.5 mm. The specimen surfaces have been obtained by milling followed using polishing with progressively finer emery papers. A final average roughness 0.16 μm has been obtained. In the specimens the net thickness ratio of zirconium and steel layers was $h_1 : h_2 = 2.5 : 1$ [5].

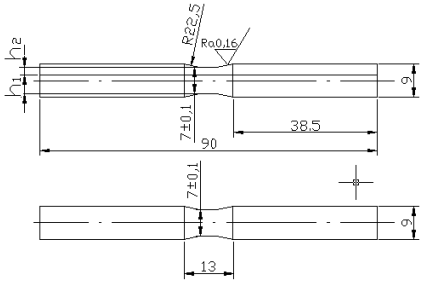

Fig. 1. Shape and dimensions of specimen, dimensions in mm.