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Eurocode 9 to estimate the fatigue life of friction stir welded aluminium panels

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ABSTRACT

Eurocode 9 is a standard that covers the design of building and engineering structures made from wrought and cast aluminium alloys. A part of the Eurocode 9 handles the design of aluminium structures susceptible to fatigue. Eurocode 9 has data for aluminium alloys and welded structures for conventional welding methods (fusion welding) except for friction stir welding processes. The present study compares fatigue test results from friction stir welded joints with fatigue curves of traditional fusion welded joints which are presented in Eurocode 9. The results are in reasonable agreement with experimental data and FEM predictions. This suggests that Eurocode 9 can be used for estimating the fatigue strength of friction stir welded joints.

1. Introduction

Friction stir welding (FSW) is a low heat input solid state welding technology especially suitable to low melting point metals, such as Al and Cu [1]. The application of the FSW technology in aerospace, automotive and shipbuilding industry is seen to provide superior joint integrity. As the temperature remains below the melting point, residual stresses are low. In addition, the absence of filler material in the weld gives limited risk of porosity formation and a smooth surface of the weld resulting in good fatigue properties [2,3]. Conventional fusion welding of aluminium alloys results in solidification cracking and higher residual stresses compared to FSW. Using filler material and shielding gas results in rather different fatigue properties of fusion welding components compared to FSW ones.

Several studies have been conducted on friction stir welded butt joints, demonstrating that they have fatigue strength close to that of the base material, and generally higher than the strength of the joints obtained with traditional welding techniques [4–9].

Nowadays FSW is widely used. Often, aluminium profiles are welded together to form large panels used in engineering structures where fatigue is an important design criteria. Eurocode 9 [10] is a standard for fatigue assessment of aluminium structures and weldment based on nominal stresses. Eurocode 9 includes data for aluminium alloys and welded structures for conventional welding methods but not for the FSW procedure. In the present paper the capability of Eurocode 9 for estimating the fatigue life time of FS welded extruded aluminium profiles is investigated. The present study compares experimental fatigue data of friction stir welded joints with fatigue curves of fusion welded joints in Al 6005.

In previously published papers by the present authors [11,12] fatigue assessment of FS welded hollow panels has been performed using finite element method (FEM) stress analysis and the theory of critical distance method (TCD). The critical distance method has been proposed for fatigue assessment of a notch component or a body containing a crack. The method is associated with averaging stress around a notch or taking stress at a distance from the notch root and the average stress is used for fatigue life prediction. The procedure of using TCD method is explained in aforementioned references by author.

In the present study Eurocode 9 is used for prediction of fatigue life at the failure locations (both for base metal and weld material). These predictions are compared with FEM computation in this study.

2. Experimental

2.1. Materials and welding

The profiles used in fatigue tests were made of extruded aluminium 6005A in the T6 (artificially aged) condition. Chemical composition and mechanical properties of the alloy are shown in Tables 1 and 2. The tensile properties were measured on samples from the studied profile according to the standard EN 10002-1:2001. These profiles are used as floors in trains and deck panels in shipbuilding, as well as some application as military bridges.

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Table 1
Chemical composition (in wt.%).

	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
6005A actual	0.61	0.21	0.07	0.15	0.54	<0.01	<0.01	0.02	Bal
6005A nominal	0.5–0.9	<0.35	<0.30	<0.50	0.4–0.7	<0.30	<0.20	0.10	Bal

Table 2
Mechanical properties of 6005A.

	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Young's modulus (GPa)
6005A T6 actual	253	280	10	69.5
6005A T6 typical (AluSelect)	260	285	13	69.5
6005A T6 nominal	min 225	min 270	8	

Friction stir welding technique was used to join these profiles at the facilities of Sapa Technology in Sweden. The studied profiles are shown in Fig. 1 before and after friction stir welding. Two main profiles with different weld geometries (geometry of extruded profiles around the weld location) are investigated. The two weld geometries are:

1. hourglass shape,
2. half overlap (truss, diagonal ribs).

Two series of hourglass shape were produced (we call these series A and B). Two series of half over lap was also produced (series C and D).

Profiles were welded with two welding heads operating from top and bottom sides of the panels. Therefore each panel contains weld nuggets both on the top and the bottom side at the centre part of the panel. Two welding procedures were used. In the first one, simultaneous welding of the top and the bottom side (series B, C, D were welded in this way) was performed. The second procedure involved welding first on the bottom and then on the top side (series A). A Summary of the welding procedure for each series is shown in Table 3. Welding parameters such as rotation speed, traverse speed, tilt angle were similar for all series. In a previously published paper [11], welding procedure and clamping conditions are explained.

2.2. Fatigue testing

Sections of 100 mm width were prepared for fatigue testing. 3-Point bending was used in the fatigue tests. This method is employed since it produces more stress at the centre part of the panels where the weldment is located. Constant amplitude fatigue

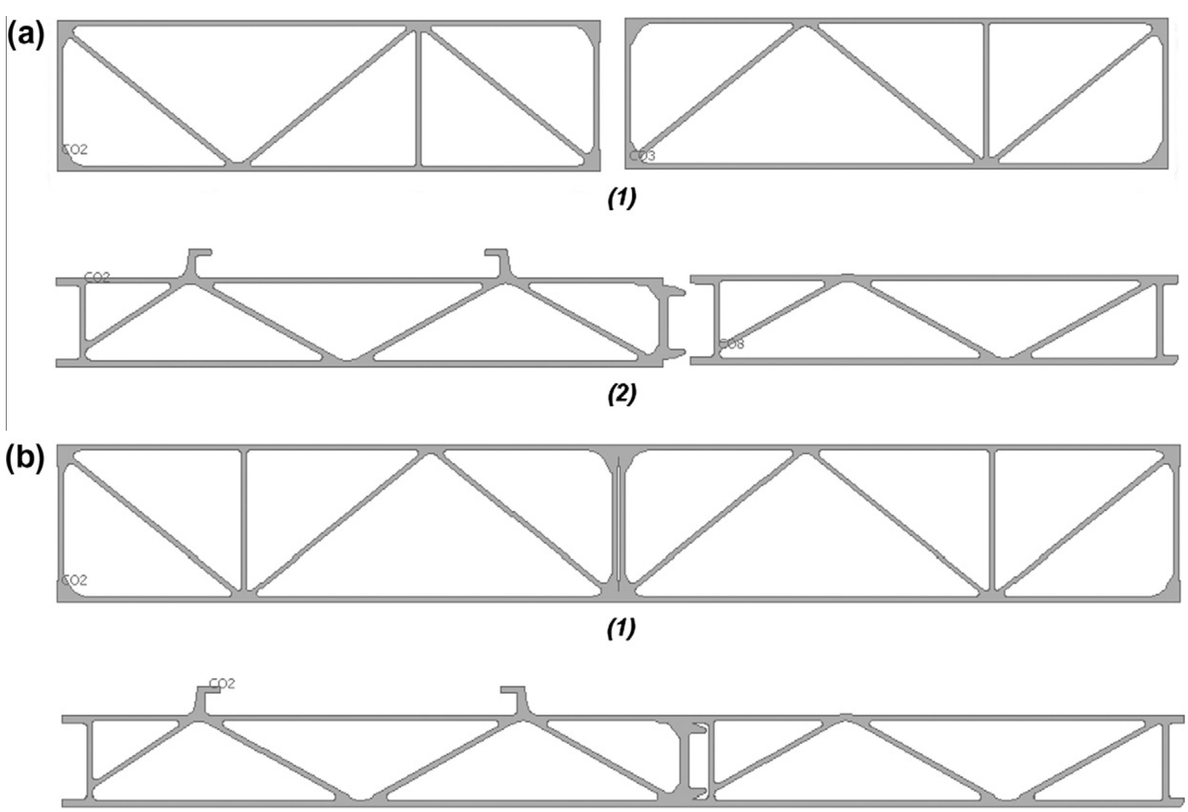

Fig. 1. Extruded aluminium profiles. Profiles are welded from top and bottom side; (a) before welding; (b) after welding; (1) is hourglass shape profile and (2) is halfoverlap (truss, diagonal ribs).