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FATIGUE ANALYSIS OF WELDED ALUMINIUM JOINTS WITH LONGITUDINAL AND ROUND STIFFENER SUBJECTED TO BENDING LOADS BY NOMINAL, STRUCTURAL AND NOTCH STRESS RANGE APPROACHES

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1. Introduction

The fatigue strength of welded aluminium structures depends largely upon the global and local geometrical parameters causing stress concentrations. For welded structures there are two main stress-raising effects: the effect of the structural discontinuities (influence of global geometry) and the effect of the local notch at the weld toe (influence of local geometry). The actual stress that causes the fatigue cracking can be categorized as: nominal stress σ_n, structural stress σ_s and notch stress σ_{kt}. Depending which stress is chosen as input parameter the procedures for the assessment of fatigue life are distinguished. Fatigue behaviour of welded aluminium joints with longitudinal and round stiffener subjected to bending loads are systematically investigated in this study. Fatigue analysis based on nominal stress range approach, two local approaches based on structural (hot spot) as well as notch stress respectively are applied.
A possibility of using existing design σ-N curves, usually assuming joints subjected to axial load, for the joints subjected to bending loads, was investigated in this work. Fatigue test results of specimens with longitudinal stiffener (60 test specimens) and round stiffener (50 test specimens) subjected to bending loads have been assessed using a nominal, structural, and notch stress range approach, and compared with appropriate design σ-N curves: nominal stress σ-N design curve, **FAT 28** (International Institute of Welding – IIW 1996), structural stress σ-N design curve, **FAT 40** (Niemi 2000) and notch stress σ-N design curve, **FAT 55** (Det Norske Veritas – DNV 1997).

2. Test specimens

Test specimens with longitudinal as well as with round stiffener were cut out from 4 mm thick plate in rolling direction and welded, figures 1 and 2. Welding parameters were as follows:

- Welding procedure	TIG
- Welding current	I=80-140 A
- Welding voltage	U=22 V
- Parent metal	AlMg4.5Mn and AlMg2.5
- Adding metal	AlMg5 and AlMg3

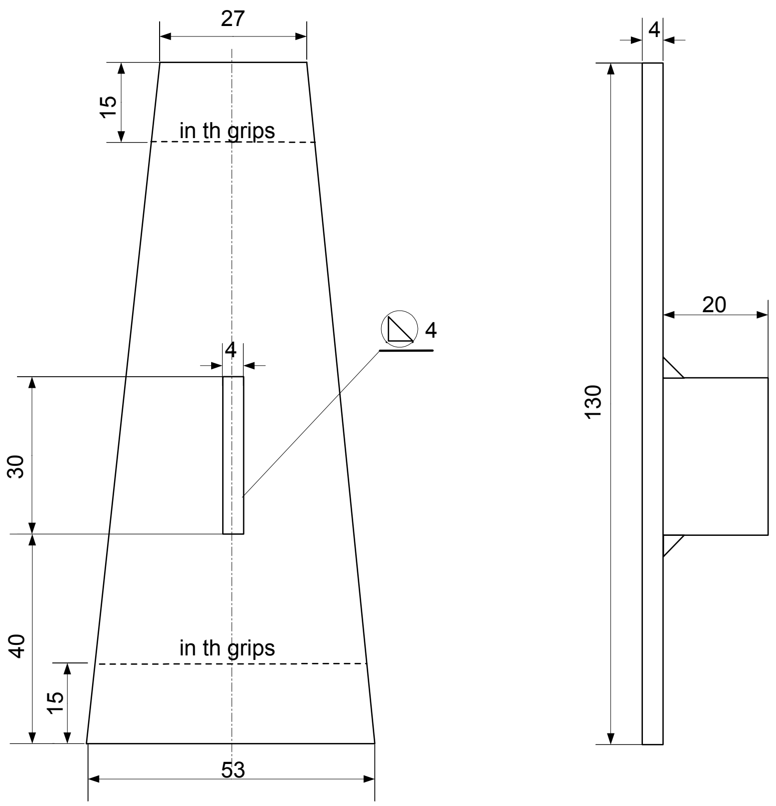

Figure 1. Test specimen with longitudinal stiffener

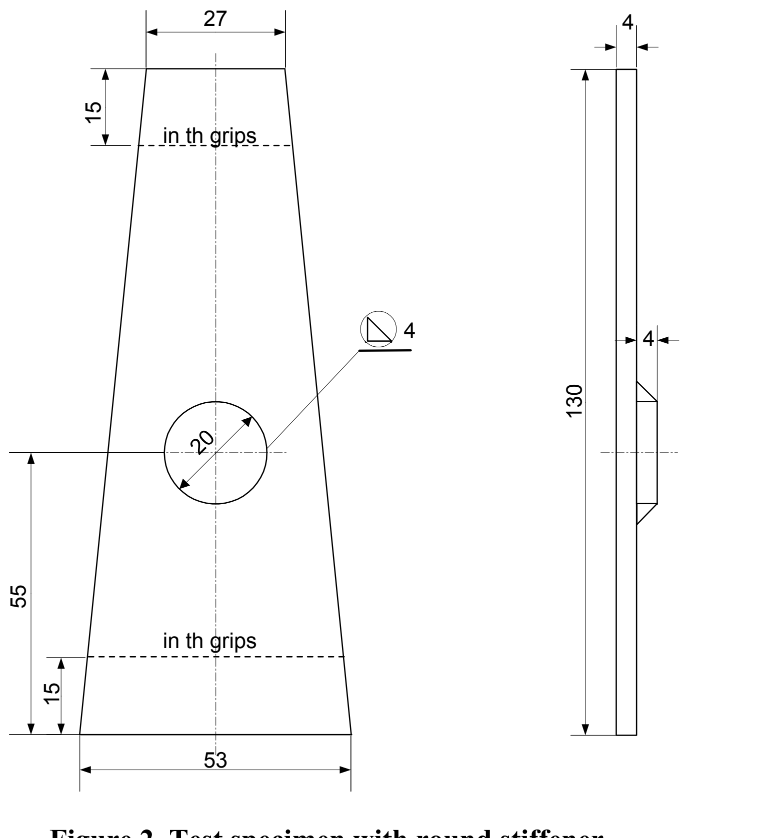

Figure 2. Test specimen with round stiffener

3. Experimental procedure

Fatigue tests were performed on mechanically driven bending test machine under constant amplitude of pulsating loads and stress ratio R=0. This machine, designed and built at FESB - University of Split, Department of Mechanical Engineering, enables fatigue tests of four specimens in the same time, figure 3. Stress analyses are performed by the strain gages measurements (figure 4) and finite element method.

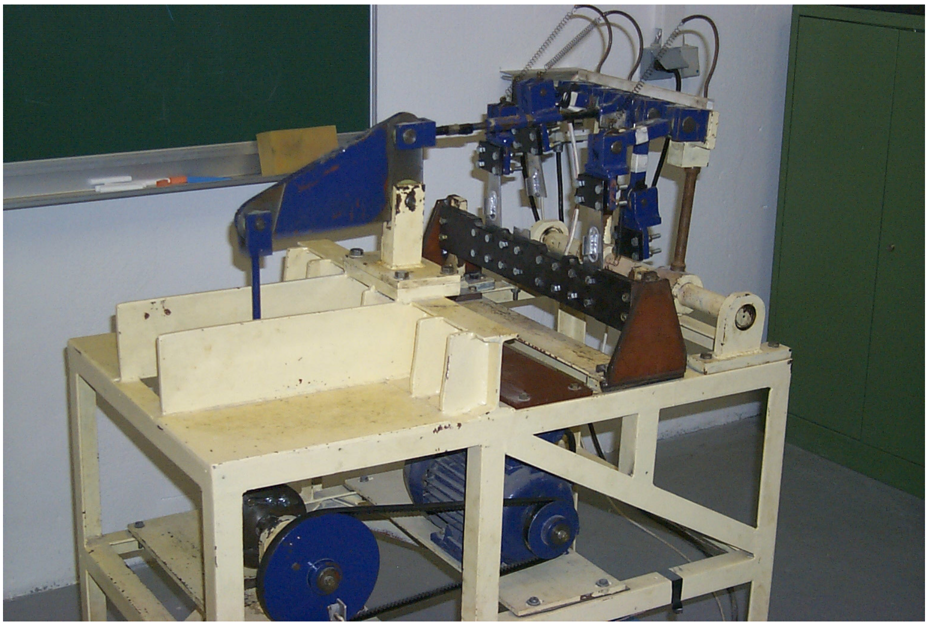

Figure 3. Fatigue test machine

Figure 4. Test specimens with strain gauges

The different levels of stress calculation were carried out to obtain the nominal stress, structural stress and notch stress. In this study the structural stress concentration factors are obtained by linear extrapolation method using single layer finite element models with 20-node solid elements with reduced 2-point integration in thickness direction, figure 5. Mesh size in a direction perpendicular to the weld was: first row of elements 0,4t, and second row of elements 0,6t. The loading mode was bending. The notch stress concentration factors are obtained according the Det Norske Veritas recommendations (1997) for determination of notch stresses modelling real weld geometry of investigated joints, figure 6.

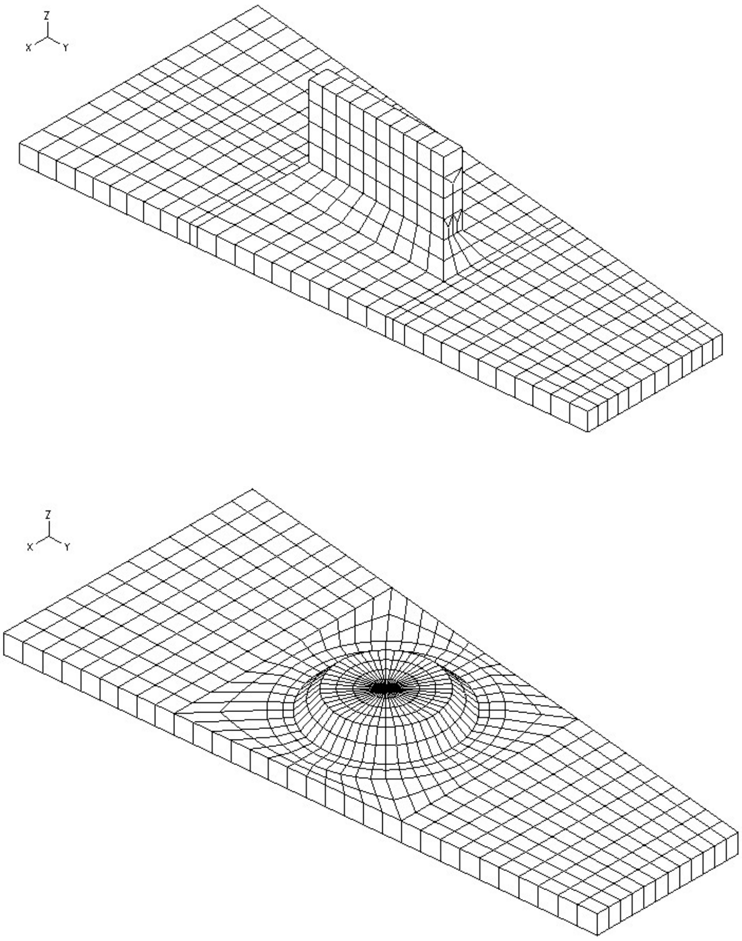

Figure 5. The finite element model for specimen with longitudinal and round stiffener (determination of structural stress concentration factor)

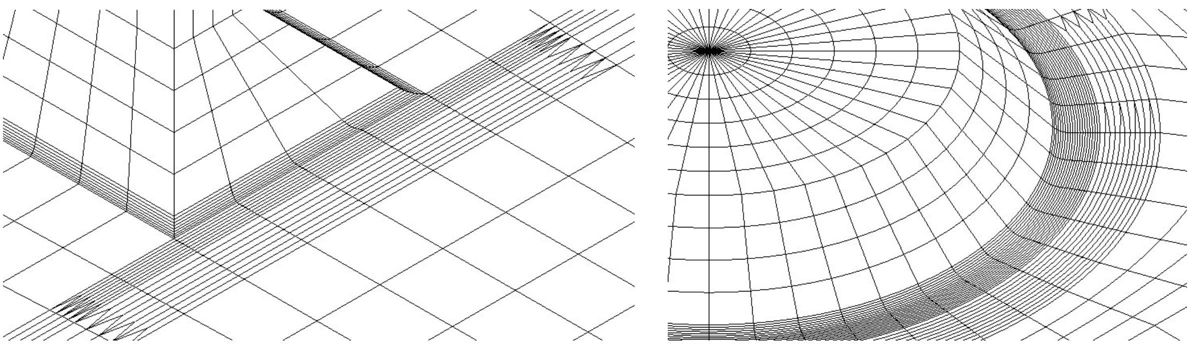

Figure 6. The finite element model for specimen with longitudinal and round stiffener (determination of notch stress concentration factor)

4. Test results

Results of stress calculations are summarised in table 1. Sixty specimens with longitudinal stiffener and fifty specimens with round stiffener were subjected to bending load to verify the fatigue capacity of these welded joints. The fatigue strength of joints have been assessed using a nominal, a structural, and a notch stress range approach, and compared with appropriate design curves, figure 7 and 8.

In order to compare the fatigue test results with appropriate design σ-N curves a factor of safety of design, δ, was defined as stress range obtained at the "stress mean line-2Stdev" at a reference fatigue life, $N_{ref}=2\cdot10^6$ cycles, obtained by test results (Matic 2003), divided by the characteristic design stress range given by fatigue design codes and recommendations at the same reference fatigue life, table 2.

Table 1. Stress calculation results (stress values at weld toe)

Type of specimen	Nominal stress [MPa]	Structural stress [MPa]	Notch stress [MPa]	Structural stress concentration factor, K_g	Notch stress concentration factor, K_{kt}
Specimen with longitudinal stiffener	20,12	32,95	46,698	1,637	2,321
Specimen with round stiffener	20,24	30,60	43,718	1,512	2,160

Table 2. Factor of safety of design, δ

Specimen	Factor of safety of design, δ_n (nominal stress)	Factor of safety of design, δ_s (structural stress)	Factor of safety of design, δ_{kt} (notch stress)
Longitudinal stiffener	1,072	1,222	1,210
Round stiffener	1,127	1,197	1,191

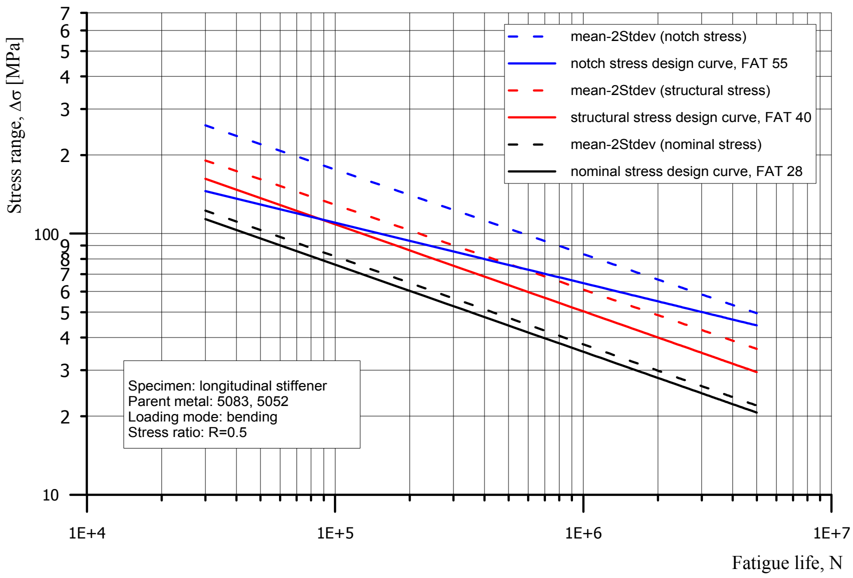

Figure 7. Fatigue test results of specimens with longitudinal stiffener subjected to bending loads compared with appropriate design curves

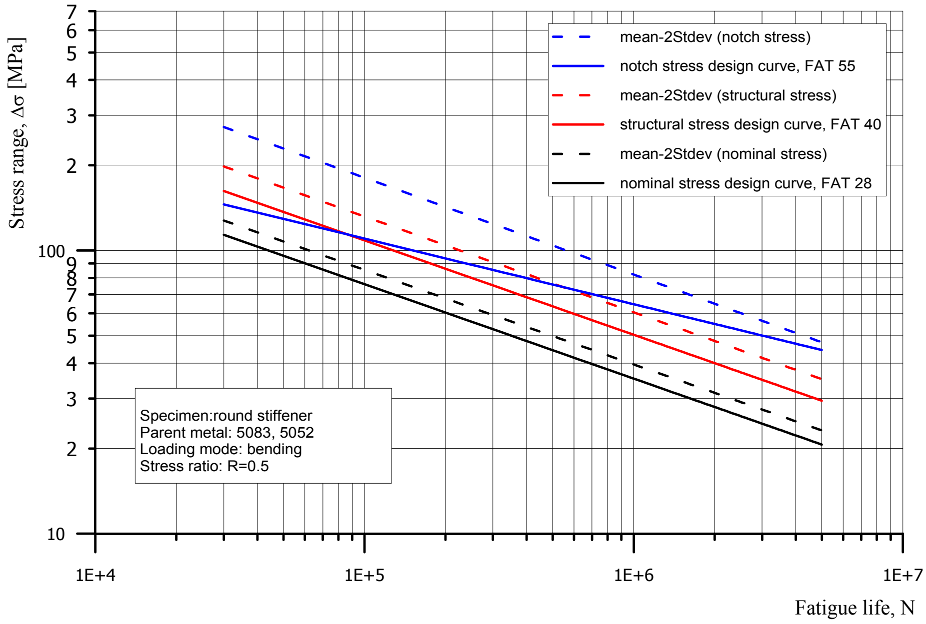

Figure 8. Fatigue test results of specimens with round stiffener subjected to bending loads compared with appropriate design curves

5. Conclusions

As a result of the investigation following conclusions are obtained:

- nominal stress design curve (IIW) can be used in design of joints with longitudinal and round stiffener subjected to bending,
- structural stress design curve **FAT 45** has been proposed for the design of joints with longitudinal and round stiffener subjected to bending,
- the predicted fatigue life of joints with longitudinal and round stiffener subjected to bending using notch stress design curve **FAT 55** is insufficiently accurate.

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