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## INVESTIGATION OF THE FATIGUE BEHAVIOUR OF LASER STAKE-WELDED T-JOINTS

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**Abstract:** Research, development and production of laser stake welded joints have been pushed and supported by the demand of light and safe structures in different fields. Recent experimental testing on laser stake-welded T-joints showed an unexplained difference in fatigue behaviour (slope of the fatigue curve) when the loading condition (tension VS bending) and the thickness of the plates connected (thin VS thick structures) are varied. The present work investigates the crack tip plasticity evolution ahead of the crack like notches with varying the loading condition. From the obtained results, an easy and fast procedure is proposed for the fatigue assessment of laser stake-welded T-joints under bending load based on the strength curve defined in tension. The correction is derived based on the driving force at the notch tip. The method is validated, in the end, with a case study.

### 1. Introduction

Marine technology has focused on the investigation and applicability of new lightweight solutions for load-carrying structures, leading to the employment of increasingly thin welded components and more complex structures such as laser-stake-welded sandwich plate system (see Fig. 1-a). The fatigue behaviour of these joints, made essentially of thin plates, is not well understood. Recent contributions on the topic are given by Frank and collaborators in different works [1–3] related to laser stake-welded T-joints. The present paper concentrates on the influence of crack tip plasticity on the slope of fatigue curve for laser stake-welded T-joints. It proposes a new fatigue model that permits to derive the bending number of cycles to failure directly from the tension fatigue curve with the use of crack driving force ratio.

### 2. Results

Linear elastic stress analysis of cracks provides the stresses tend toward infinity at the crack tip. In real materials and applications, the stresses at the crack tip must be finite because of crack tip localized plasticity, which effects on the stresses distribution.

On the base of the Irwin's approach [4] for the evaluation of the crack tip plastic zone, the following crack driving force ratio,  $F_R$ , is assumed as a correction factor to evaluate an effective J-integral for laser stake-welded T-joints when subjected to bending load:

$$\sqrt{J}_{eff} = \sqrt{J} \cdot F_R \quad (1.1)$$

Where  $\sqrt{J}$  is the generic J-integral value which the number of cycles to failure must be evaluated of. The  $F_R$  ratio permits to take into account different stress gradient at the crack tip for the bending and the tension load. The crack driving force ratio presents the trend shown in Fig. 1-b as the external load of the welded joint increases (number of cycles to failure decreases), and it is numerically evaluated through Finite Element analysis.

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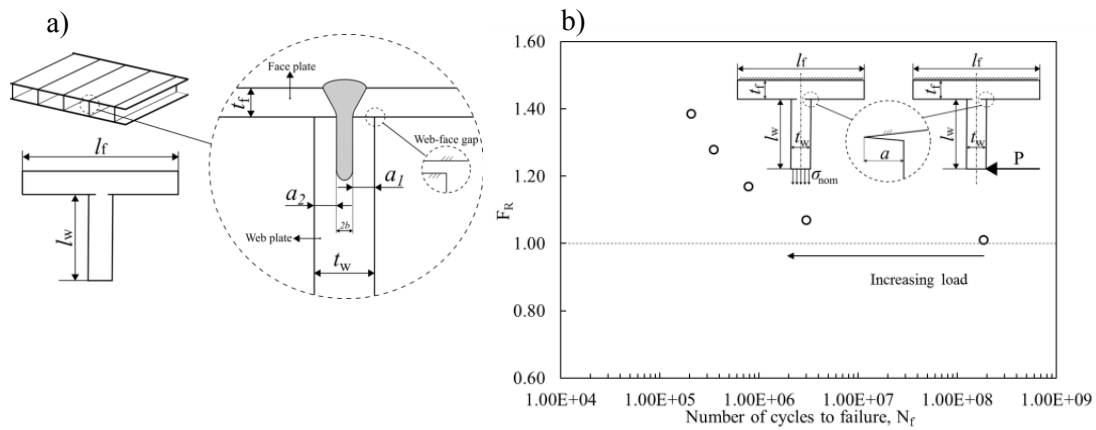


Figure 1. (a) Schematic web-core steel sandwich panel and (b)  $F_R$  trend VS number of cycles to failure

The method is verified on a case study taken from Ref. [1] and the results are reported in Table 1 considering the number of cycles to failure obtained through the proposed method, and the one reported experimentally [1].

Table 1. Comparison within the estimated and expected number of cycles to failure for bending load

Load Level	$F_R$	$\sqrt{J}$	$\sqrt{J_{eff}}$	$N_{f\text{bending}}$	$N_{f\text{bending}}$	$\Delta$
		$[\text{kJ}^{0.5}/\text{m}]$	$[\text{kJ}^{0.5}/\text{m}]$	Estimated	Exp.	
1	1	0.1263	0.1263	$>2.00E+06$	$>2.00E+06$	-
2	1	0.3365	0.3365	$>2.00E+06$	$>2.00E+06$	-
3	1.17	0.4627	0.5417	$4.04E+05$	$4.18E+05$	-3
4	1.28	0.5609	0.7179	$1.24E+05$	$1.09E+05$	14
5	1.39	0.6366	0.8827	$5.19E+04$	$4.48E+04$	16

### 3. Conclusions

For high loading levels, the bending presents a higher crack driving force. The difference and so  $F_R$  increases as the load does. The fatigue curves do not consider a priori this aspect and as a result it takes shape in a lower number of cycles and so a higher slope for the bending. The obtained  $F_R$ , permits to consider the more critical condition of the bending load type defining a so-called effective J-integral  $\sqrt{J_{eff}}$ . The effective J-integral is later employed in the tension fatigue curve, in order to obtain the number of cycles to failure of the bending case corresponding to the desired load  $\sqrt{J}$ . The results agree with the experimental test, with very small percentage error  $\Delta$  if the common scatter of fatigue data is considered.

### References

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