Fatigue life estimation of similar and dissimilar single lap adhesive joints using a critical distance approach

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Introduction

The industrial demand for lightweight structures has significantly increased in past years, and thus composite materials are increasingly being used. Naturally, adhesive bonding figures as the most appropriate joining technology for this type of structures. Due to their multimaterial nature, the fatigue life of adhesive joints is highly influenced by the substrate material. Therefore, accurately predicting the fatigue life of similar and dissimilar adhesive joints, for different materials is of paramount importance [1].

Experimental methodology

Three different configurations of single lap joints, Figure 1, were tested under static and constant amplitude fatigue loading conditions. For these configurations, the dimensions were kept constant, and the substrate material was varied, from high strength steel to a composite with an epoxy matrix reinforced with glass fibers (GFRP) oriented at 0°/90°. All the substrates were bonded by a ductile methacryle adhesive. The fatigue tests were conducted with a frequency of 10 Hz and a load ratio (R) of 0.1.

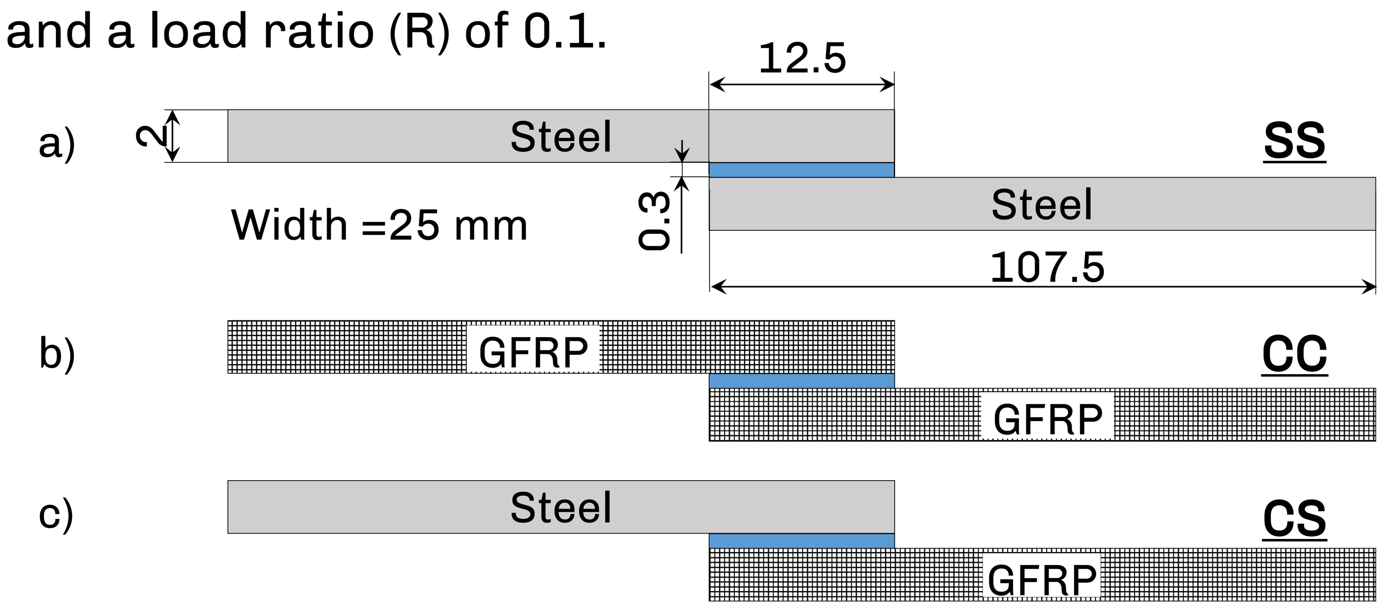

Figure 1 – Tested single lap joint configurations: a) steel-steel (SS); b) composite-steel (CS); c) composite-composite (CC) (dimensions in mm).

Experimental results

1. Static results

Figure 2 presents the static results for all the tested conditions.

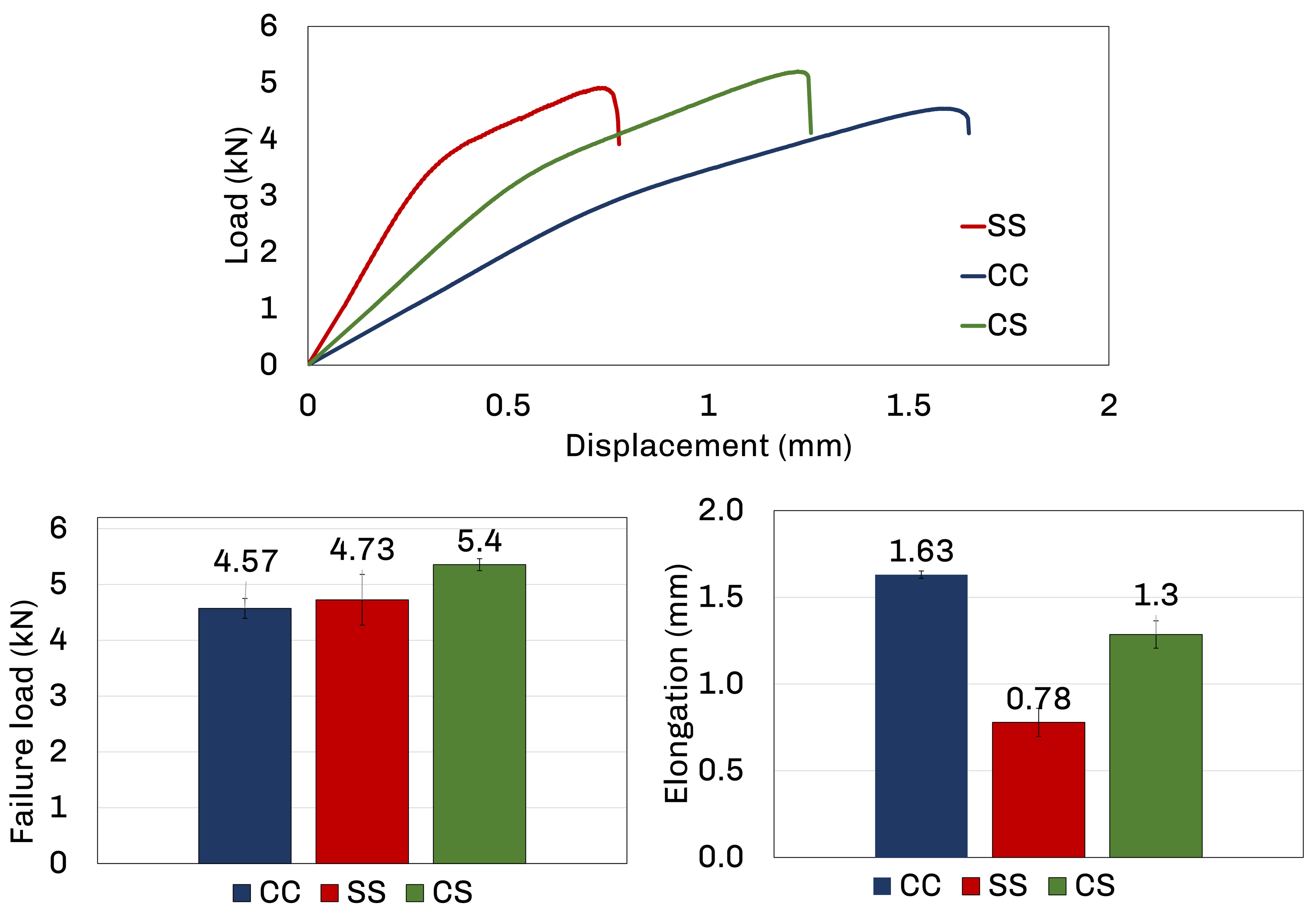

Figure 2 – Static results for all the tested conditions.

2. Fatigue life results

Figure 3 presents the fatigue results for the tested conditions.

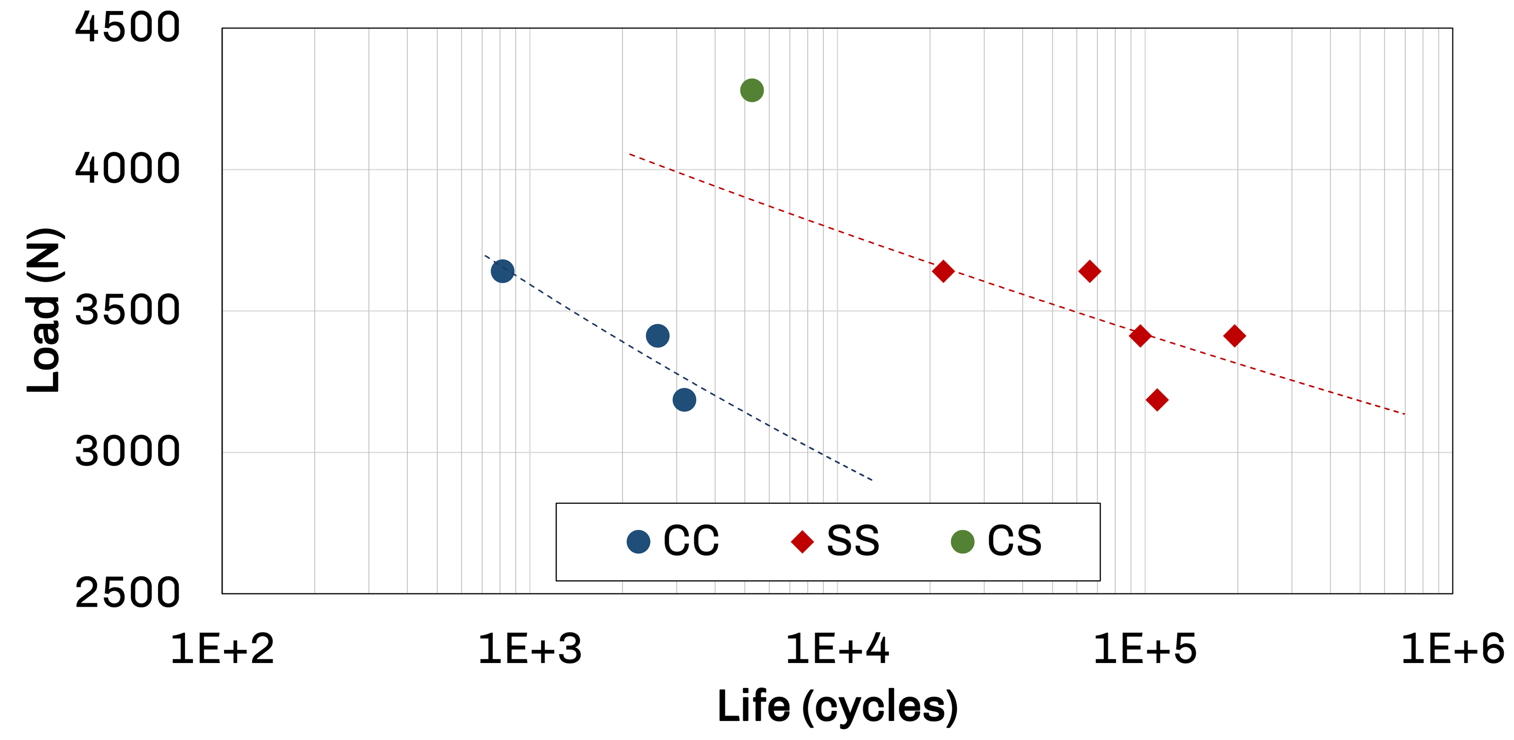

Figure 3 – Fatigue life results for all the tested configurations.

Fatigue life estimation

To estimate the fatigue life of the joints under study, a critical distance based fatigue life estimation procedure, developed in a previous study [2], was used. A schematic representation of the fatigue life estimation procedure is shown in Figure 4.

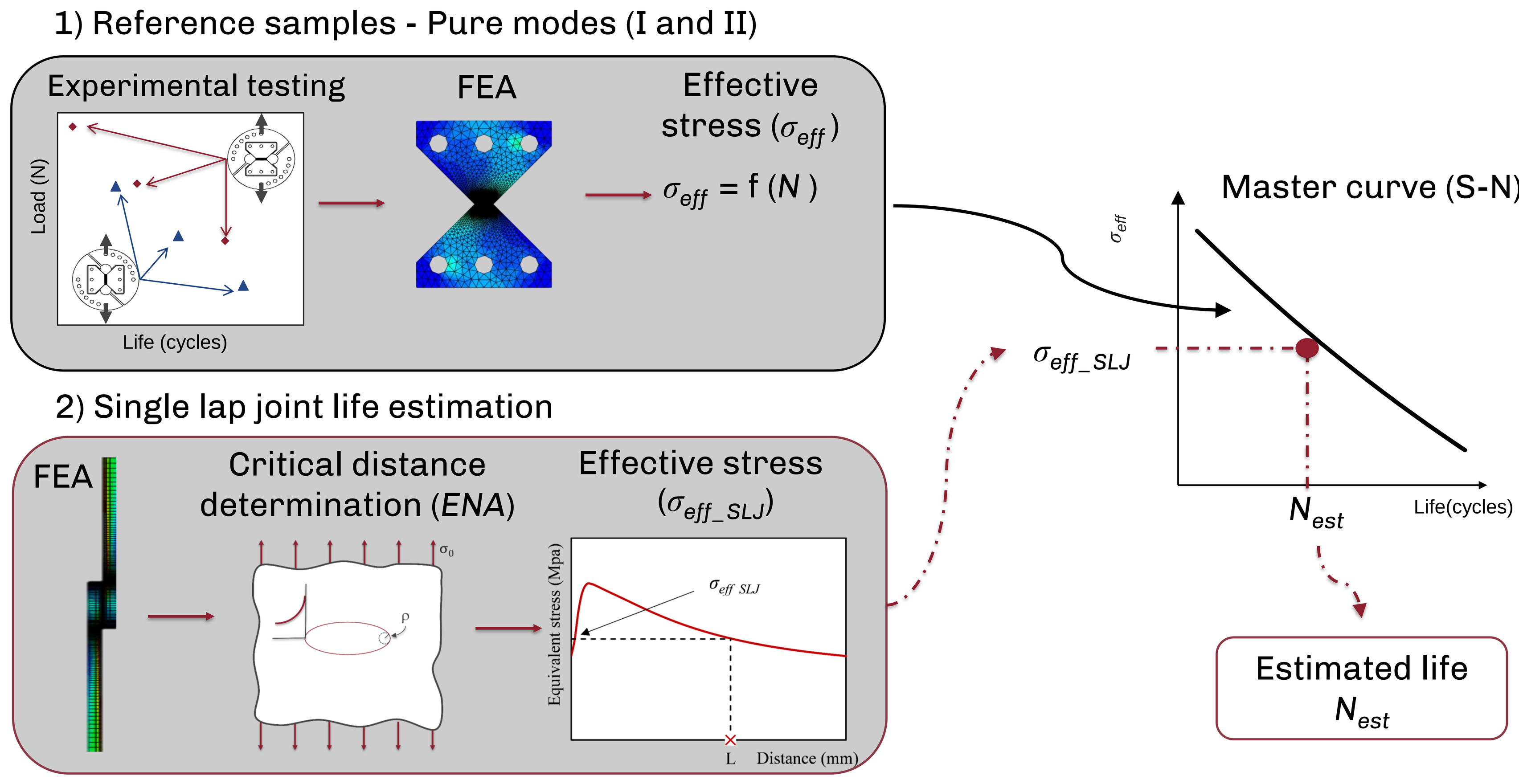

Figure 4 – Schematic representation of the fatigue life estimation procedure.

Figure 5 shows a comparison between the estimated and the experimental fatigue life of the SS and CS configurations. It can be seen that the almost all results lie within the factor of 2 boundaries.

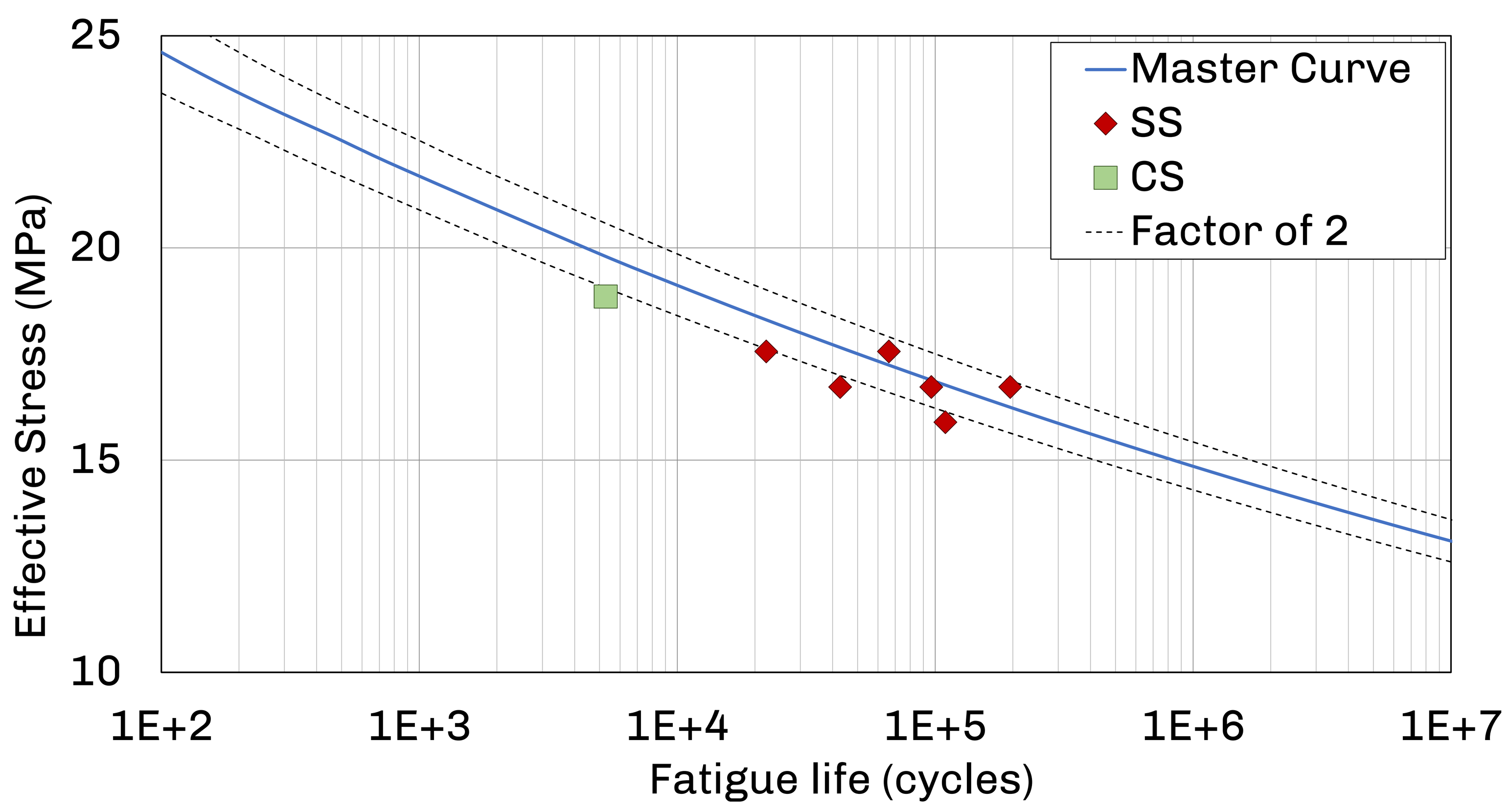

Figure 5 – Estimated vs experimental fatigue results.

Conclusions

The static results show that the CS configuration presents the highest static strength, followed by SS that shows higher stiffness. Contrarily, CC joints presented the lowest strength but highest elongation at failure.

A critical distance based fatigue life prediction approach was applied to the configurations under study and the estimated fatigue life approach shows a good agreement with the available experimental results.

References

[1] Cruz-G C.E., Akhavan-Safar A., da Silva L.F.M., Ayatollahi M.R. On the evaluation of a critical distance approach for failure load prediction of adhesively bonded dissimilar materials. Contin Mech Thermodyn 2020.

[2] Castro Sousa F, Akhavan-Safar A, Goyal R, da Silva LFM. Fatigue life estimation of single lap adhesive joints using a critical distance criterion: An equivalent notch approach. Mech Mater 2021;153:103670

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