FATIGUE CRACK PROPAGATION IN HSS S690QL WELDED CONNECTIONS IN BRIDGES

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Abstract: The fatigue and crack study of HSS S690QL steel welded pieces is first experimentally analyzed by fatigue tests on small samples of Base Material (BM), Heat Affected Zone (HAZ) and Weld Metal (WM) separately for several stress ratios, stress levels, on smooth and notched samples. The Lemaître-Chaboche fatigue model combined with the stress gradient method and the three sets of parameters are found to accurately describe the behavior of each material. Another experimental campaign with larger pieces (closer to the scale of the bridge connections) called "small scale samples", with/without welded stiffeners, with several geometries and with/without post-treatment has shown each effect separately: the scale and machining effects, residual stresses due to the welding, geometrical and post-treatments effects. Numerical simulations of these experiments are used to improve and validate the material data, with a study in real context and size. Then, the characterized fatigue damage model is coupled with the element deletion method to model the propagation of cracks along the welded samples and the numerical predictions are compared with experimental results in order to validate the approach.

1. Introduction

The project aims to analyse the fatigue resistance of welded connections of HSS S690QL steel improved by post-treatments, as these connections are critical details in fatigue life due to residual stresses and stress concentration. The study covers a lack of knowledge of this steel grade and its welded connections. The effect of weld post-treatments on the performance of this steel under real working conditions is investigated by means of an extensive study combining both experiments and numerical simulations.

2. Results

For the first experimental campaign, numerous mechanical (monotonic) and fatigue tests are performed on BM (HSS S690QL), HAZ and WM separately to describe their mechanical and fatigue behavior. For each material, the material behavior is assumed to be defined by the parameters of the mechanical laws (i.e. Hooke, Hill yield locus, Voce and Armstrong-Frederick) and the fatigue law (i.e. Lemaître-Chaboche model coupled with the gradient method) [1]. Then, the "small case samples" (Figure 1a) are produced and tested in fatigue up to rupture (Figure 1b) considering several geometries with or without post-treatment (PIT or TIG remelting) and tested for several stress ratios and levels. Each material state generate a different curve (Figure 2a). The description of the fatigue behavior of these materials are then improved when taking into account the scale and surface state effects, the residual stresses (already present in the plate and induced during welding) and the effect of the post-treatment. The impact of each aspect was analyzed by means of numerical simulations of the tests performed on the connections (Figure 2b) and the use of fatigue analysis.

Finally, the characterized fatigue damage model is coupled with the element deletion method [2] in order to track the evolving geometry of the cracks during propagation along the

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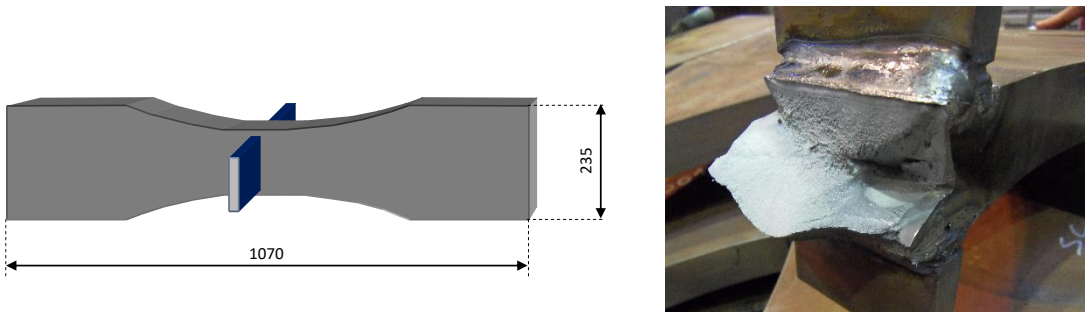
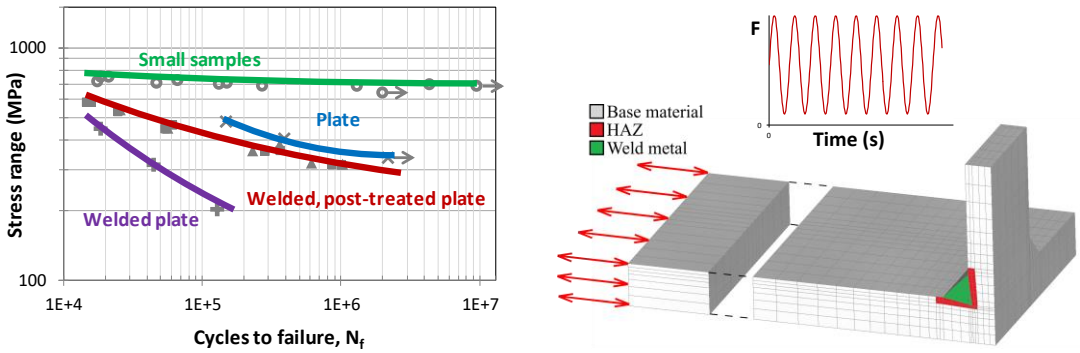
samples. Then, the predicted shape of the fracture process zone is compared with the experimental results for different configurations. As expected, the final shape of the fractured edge is highly influenced by the geometry of the welded samples, the material behavior of the Base Material and the testing conditions (e.g. stress ratio).



(a) (b)

Figure 1. (a) Geometry of a small case sample (in mm) (b) Failure surface at the end of a fatigue test.



(a) (b)

Figure 2. (a) Results of experimental fatigue campaign on "small case samples" (b) Mesh used for the simulations of a fatigue test on a welded plate (1/4 of small case sample by symmetry).

3. Conclusions

In this work, the mechanical and fatigue behavior of HSS S690QL steel welded pieces was studied, where the effect of different critical aspects (e.g. residual stresses, surface state, post-treatment) was evaluated. The characterization of the considered material models was performed by means of mechanical tests under different conditions for each of the involved materials (BM, HAZ and WM). Lastly, the propagation of cracks along the welded samples was analyzed by means of numerical simulations. Fatigue tests on beams of 4 m long with transversal stiffeners allows to link the results with the actual scale as it is representative of a bridge.

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