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# Mechanical behavior of hot-dip galvanized welded steel under cyclic loading

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**Abstract**

This paper investigates the effect of a galvanizing coating on the fatigue strength of S355 structural steel. While in the literature some results from fatigue tests made on unnotched specimens can be found, very few results are available dealing with notched components and, at the best of authors' knowledge, no results are available dealing with welded joints. The aim of the present paper is to partially fill this lack of knowledge. A comparison is carried out, between hot dip galvanized fillet welded cruciform joints made by S355 structural steel and not treated welded joints characterized by the same geometry, subjected to a load cycle $R = 0$. 34 new experimental data are summarized in the present contribution, in terms of stress range $\Delta\sigma$ and averaged strain energy density range $\Delta\overline{W}$ in a control volume of radius $R_0 = 0.28$ mm.



*Keywords:* galvanized steel; high cycle fatigue; fillet welded cruciform joint; SED.

## 1. Introduction

Hot-dip galvanizing is a surface treatment that allows protecting components from corrosion. Galvanizing is found in several industrial applications, in particular when iron or steel are used. Hot-dip galvanizing has a proven and growing history of success in a large number of applications worldwide.

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**Nomenclature**

| | |
|---|---|
| $2\alpha$ | notch opening angle |
| $\gamma$ | supplementary angle of α: $\gamma = \pi - \alpha$ |
| $\nu$ | Poisson's ratio |
| $\Delta\sigma$ | stress range |
| $\Delta\sigma_A$ | fatigue strength in terms of stress range at $N_A$ cycles |
| $\Delta K_{1,2,3}$ | mode 1, 2 and 3 notch stress intensity factor range |
| $\Delta K_{1A}$ | fatigue strength in terms of notch stress intensity factor range at $N_A$ cycles |
| $\Delta\bar{W}$ | averaged strain energy density (SED) |
| $\Delta\bar{W}_C$ | critical value of the SED range |
| $\lambda_{1,2,3}$ | mode 1, 2 and 3 Williams' eigenvalues |
| $E$ | Young's modulus |
| $e_{1,2,3}$ | mode 1, 2 and 3 functions in the SED expression |
| $f$ | frequency |
| $K_{1,2,3}$ | mode 1, 2 and 3 notch stress intensity factor (NSIF) |
| $k$ | inverse slope of the Wöhler curve |
| $N$ | number of cycles |
| $Ps$ | survival probability |
| $R$ | load cycle ratio |
| $R_0$ | radius of the control volume for the calculation of the averaged SED value |
| $T_\sigma$ | scatter index referred to the stress range |
| $T_W$ | scatter index referred to the SED range |

While the monotonic behaviour of steel is not greatly affected by the presence of the zinc layer, except for the yield stress, under cyclic stress the fatigue strength is usually reduced. This point has been discussed by Bergengren and Melander (Bergengren and Melander, 1992) dealing with high-strength steels without any stress concentration effect or geometrical discontinuity. In (Bergengren and Melander, 1992) it was found that there is a reduction of the fatigue life increasing with the thickness of the zinc layer. On the other hand other authors did not find any correlation in terms of loss of the fatigue strength due to the coating thickness (Browne et al., 1975; Nilsson et al., 1989). The effect of a galvanizing coating on the fatigue strength of unnotched ferritic steel has been extensively investigated in (Vogt et al., 2001) and a tool based on the Kitagawa–Takahashi diagram has been employed for the prediction of the fatigue resistance of hot-dip galvanized steel. It was proven that the fatigue strength of a ferritic steel is not affected by the zinc layer if the thickness does not exceed the threshold value of 60 μm.

Some recent studies have been recently performed, dealing with galvanized steel wires for bridge construction (Jiang et al., 2009; Yang et al., 2012), the fatigue behaviour of two hot-dip galvanized steel with similar static load-bearing capability (Berchem and Hocking, 2007) and of galvanized rear axles made of micro-alloyed steel (Dimatteo et al., 2011). Other aspects tied to the galvanizing process are discussed in (Maaß and Peißker, 2011).

While in the literature some results from fatigue tests made on unnotched specimens are nowadays available, very few results are available dealing with notched components. At the best of authors' knowledge the only complete set of data from notched specimens is due to Huhn and Valtinat (Valtinat and Huhn, 2004). Low-cycle and high-cycle fatigue tests were carried out on S 235 JR G2 specimens. Plates with holes and bearing-type connections with punched and drilled holes were examined. Plates with holes were able to withstand a higher stress range $\Delta\sigma$ at the same number of cycles $N$ up to failure than the joints. A comparison between specimens with punched holes and the ones with drilled holes has showed the negative influence of punching on the fatigue strength. However, a direct comparison between uncoated and hot-dip galvanized notched steel is not available in (Valtinat and Huhn, 2004) and it is not possible to quantify the fatigue strength reduction due to the galvanizing process. Finally, no results about the effect of hot-dip galvanization on the behaviour of welded structural steel are available. The main aim of the present paper is to partially fill this lack considering uncoated and hot-dip galvanized fillet welded cruciform joints made of structural steel S355. Two new fatigue sets of data are summarized in the present paper. The reduction of