Low-cycle Fatigue of Post Weld Treated Butt Welds Made of High-strength Steels

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ABSTRACT

The low-cycle fatigue behaviour of butt welded plates made of S960QL, and S1100QL is presented in this paper. Specimens in as welded condition and post-weld treated specimens are considered as well as the influence of yield strength on the low-cycle fatigue behavior. Summarized evaluation and comparison with regard to different post weld treatment methods such as TIG-dressed, high frequency hammer peened and ground welds are worked out. The results are discussed referring to fatigue class classification of Eurocode 3 and the recent IIW guideline.

KEY WORDS: Low-cycle fatigue, butt welds, high-strength steel, post weld treatment

INTRODUCTION

High-strength steel is preferentially used for structures which are exposed to very high loading at minimized structural weight, such as crane structures. Although the number of load cycles is rather low compared to other fatigue loaded structures such as bridges and wind energy towers, fatigue is also the governing factor for design. But low-cycle fatigue that usually implies fatigue failure below 40,000 load cycles, is barely investigated, especially for welded high strength steels.

Common fatigue design guides apply for carbon steels with yield strengths up to 700 MPa. In most codes it is assumed that the material strength has no influence on the fatigue resistance of welded structures. But for very high local stresses, the yield limit cannot be disregarded. Although fatigue design curves start at 10,000 load cycles, fatigue test data are mainly based on tests with failures between 100,000 and 2 million load cycles. So the question is whether in reality the constant slope of the SN-curve is changing to a more horizontal slope, and where the lower bound of this curve is to be set.

Low-Cycle Fatigue

Low-cycle fatigue means usually a number of failure load cycles below 10,000 to 40,000, in which the transition to high-cycle fatigue is fluid and not clearly defined. Conventional standards and recommendations, such as EN 1993-1-9 (2010) and the International Institute of Welding (IIW, Hobbacher, 2008) provide linear fatigue design S-N-curves starting at 10,000 load cycles independent of material strength. In practice often the yield strength Re is considered to be the lower limit to low-cycle fatigue (Hrabowski, Herion and Ummenhofer, 2011). For more detailed analyses low-cycle fatigue of ductile materials can be separated from high-cycle fatigue by means of the deformation criterion (Gudehus and Zenner, 2000). Herein, also the influence of the stress range ratio is considered within the following formulae:

\[ R_e^* = R_e \cdot (1 - R) \]  \hspace{1cm} (1)

where \( R_e \) is the yield strength in MPa and R is the stress range ratio with

\[ R = \frac{\sigma_{\text{min}}}{\sigma_{\text{max}}} = \text{const.} \]  \hspace{1cm} (2)

For axial loading the maximum stress range to be reached is

\[ R_m^* = R_m \cdot (1 - R) \]  \hspace{1cm} (3)

where \( R_m \) is the tensile strength in MPa and R is the stress range ratio according to eq. (2).