Improving the Fatigue Strength of Butt Welds in the As-Welded and Grit-Blasted Condition for Steel Towers of Wind Turbines

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Butt welds are one of the most common structural details in wind turbine steel towers. In this paper, results from fatigue tests on butt welds in the as-welded and grit-blasted conditions are presented. In addition, finite element analyses were performed using the effective notch stress and the crack propagation approaches. By using macroscopic measurements and three-dimensional scan, the notch effect of the weld seam was considered. These results were compared with results from fatigue tests. On the basis of a successful alignment between simulation and experiment, the possibility to discuss the fatigue resistance influencing variables from the seam geometry is presented.

INTRODUCTION

Electricity from on- and offshore wind farms plays an important part in achieving the goal of increasing the share of renewable energies. Consequently, there has been a rapid development of wind turbines. The growing nominal power of wind turbines necessitates an increase in rotor diameter and hub height, along with stricter requirements related to wear, material fatigue, and corrosion protection systems. Because of its impact on total costs, the optimization of the tower structure stands out as one of the most important design factors. Among the most common structural details in such tower structures are butt-welded joints with DV-weld geometry (see Fig. 1). For tubular steel towers, steel grade S355 with plate thicknesses ranging from 14 mm to 70 mm is used. Monopiles for offshore foundations currently contain plate thicknesses up to 170 mm. The butt welds are welded through the whole profile and are without a systematic linear misalignment. The submerged arc (SMA) welding process is used because of the plate thicknesses and the required melting deposition rates. This fully mechanized welding process and the high manufacturing standard enable consideration of the high execution quality in fatigue strength verification.

The seam geometry of SMA-welded joints, characterized by reduced weld height $h$ and smooth weld toe angles $\alpha$, results in a lower notch effect and, consequently, higher fatigue resistance (Drebenstedt et al., 2021). Therefore, the necessity to reevaluate the fatigue class (FAT) value of transversely loaded butt welds is obvious. The FAT value of butt-welded joints, according to Eurocode 3, is based on $n = 2,843$ fatigue tests, whereby the complete documentation of the geometric weld dimensions is only available for a few test specimens. In addition, most of these tests were performed for plate thicknesses smaller than $t = 25$ mm, and the maximum of tested plate thickness was $t = 40$ mm. Based