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Investigations on the Fatigue Behavior of Welded Details with Imperfections

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Abstract : The dimensioning of steel structures subject to fatigue loads, such as wind turbines, bridges, masts and towers, crane runways and weirs or components in crane construction, is often dominated by fatigue verification. The fatigue details defined by the welded connections, such as butt or cruciform joints, longitudinal welds, welded-on or welded-in stiffeners, etc., are decisive. In Europe, the verification is usually carried out according to EN 1993-1-9 on a nominal stress basis. The basis is the detailed catalog, which specifies the fatigue strength of the various weld and construction details according to fatigue classes. Until now, a relation between fatigue classes and weld imperfection sizes is not included. Quality levels for imperfections in fusion-welded joints in steel, nickel, titanium and their alloys are regulated in EN ISO 5817, which, however, doesn't contain direct correlations to fatigue resistances. The question arises whether some imperfections might be tolerable to a certain extent since they may be present in the test data used for detail classifications dating back decades ago. Although current standardization requires proof of satisfying limits of imperfection sizes, it would also be possible to tolerate welds with certain irregularities if these can be reliably quantified by non-destructive testing. Fabricators would be prepared to undertake carefully and sustained weld inspection in view of the significant economic consequences of such unfavorable fatigue classes. This paper presents investigations on the fatigue behavior of common welded details containing imperfections. In contrast to the common nominal stress concept, local fatigue concepts were used to consider the true stress increase, i.e., local stresses at the weld toe and root. The actual shape of a weld comprising imperfections, e.g., gaps or undercuts, can be incorporated into the fatigue evaluation, usually on a numerical basis. With the help of the effective notch stress concept, the fatigue resistance of detailed local weld shapes is assessed. Validated numerical models serve to investigate notch factors of fatigue details with different geometries. By utilizing parametrized ABAQUS routines, detailed numerical studies have been performed. Depending on the shape and size of different weld irregularities, fatigue classes can be defined. As well load-carrying welded details, such as the cruciform joint, as non-load carrying welded details, e.g., welded-on or welded-in stiffeners, are regarded. The investigated imperfections include, among others, undercuts, excessive convexity, incorrect weld toe, excessive asymmetry and insufficient or excessive throat thickness. Comparisons of the impact of different imperfections on the different types of fatigue details are made. Moreover, the influence of a combination of crucial weld imperfections on the fatigue resistance is analyzed. With regard to the trend of increasing efficiency in steel construction, the overall aim of the investigations is to include a more economical differentiation of fatigue details with regard to tolerance sizes. In the long term, the harmonization of design standards, execution standards and regulations of weld imperfections is intended.

Keywords : effective notch stress, fatigue, fatigue design, weld imperfections
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