New developments in the fatigue design of circular hollow section K-joints

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ABSTRACT

To enable lightweight design, also fatigue loaded structures are more and more made of high strength steels. Herein, the K-joint with gap is the favored joint configuration for lattice girders. Existing design rules are based on joints with small wall thickness and made of mild steels. Fatigue tests as well as numerical parameter studies are carried out to extend the application range of common design rules to larger wall thicknesses and high strength steel grades. The nominal stress method as well as the structural stress (hot spot) method is considered. Further instructions for fatigue resistant constructions are given to allow a safe and economic design of such joints and girders.

KEY WORDS: Fatigue; K-joints; circular hollow sections; high strength steels; nominal stress, structural stress.

INTRODUCTION

The typically used joint type in lattice girder design is a K-joint with gap made of circular hollow sections (CHS). To reduce weight and welding costs, also fatigue loaded structures are more and more made of high strength steels. However, for high strength steels as well as for sections with large thickness only little information about the fatigue behavior is available. The existing and approved design rules have origin in experimental investigations on joints with small wall thickness made of steel with yield strengths of 235 or 355 MPa. It is questionable whether these design recommendations are valid for the described applications. Preliminary investigations have shown, that in several cases this could lead to very conservative and uneconomic design on the one hand, or to unsafe constructions on the other hand (Herion et al, 2014).

Thick-walled sections with low slenderness and high strength steel grades are not covered by recent design recommendations sufficiently. In addition, today’s software and hardware solutions offer a much wider range of possibilities. For these connections the existing design rules are to be verified and extended by larger wall thicknesses and high strength steel grades.

STATE OF THE ART

Until the nineties the fatigue behavior of hollow section joints has been widely investigated. The results of the research were summarized in the CIDECT Design Guide 8 (Zhao et al., 2001), which is also the basis for recent standardization. In 2008 the ISO 14347 emanated from the CIDECT Design Guide. About the same time in the development of the Eurocode 3 Part 1-9 (2010) the recent international research results are considered. Since then, only little further research on the fatigue behavior of K-joints with gap has been published (Schumacher et al., 2001; Kühlmann et al., 2015). No further systematic efforts have been made to develop new formulae or to extend the validity range of the application of the design graphs and parametric formulae (Herion, 2018).

Nominal Stress Approach

CIDECT DG 8 (Zhao et al., 2001) as well as EN 1993-1-9 (2010) give detail categories for lattice girder joints made of hollow sections. Since the recommendation for EN 1993-1-9 (2010) are taken form CIDECT DG 8 (Zhao et al., 2001), the content is the same. The classification is depending on the wall thickness ratio t, which is given by the reciprocal value 1/t = t0/t1 with the wall thickness of the chord profile t0 and the wall thickness of the brace profile t1. For larger values of 1/t the fatigue resistance increases. Between the absolute limits of 1.0 ≤ 1/t ≤ 2.0, the values for the detail class can be interpolated. For CHS K-joints the detail class lies between 45 for t0 = t1 and 90 for t0 = 2.0 t1. Against the assumption of an inverse slope of the fatigue strength curve m = 3 as used for all other structural details in the fatigue strength diagrams, for hollow section joints an inverse slope of m = 5 is valid (Wardenier, 1982).

For the nominal stress approach, which is based on fatigue tests, the parameter range is very narrow and e.g. wall thicknesses up to 8 mm and outer chord diameters up to 300 mm are included. The detail categories for hollow section K-joints apply for the load case “Balanced axial load of the braces” and resulting axial load in the chord. Although very few tests were carried out on high-strength steel grades, EN 1993-1-9 (2010) applies up to S700.