Fatigue experiments on connections made of very high strength steels

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Summary

An effective application of Very High Strength Steels (VHSS) can be expected in truss-like structures, typically made of hollow sections. Improved design of VHSS truss structures could incorporate the application of cast joints, since an appropriate design of cast joints limits the stress concentrations in the joint and welds are shifted out of critical zones. The main objective of the research was to determinate the fatigue strength of welded connections made of VHSS. Truss specimens made of circular hollow sections (CHS) and cast joints were fatigue tested. In the V-girth-welded connections of cast steel joints and CHS made of S690-G10MnMoV6-3 and S890-G18NiMoCr3-6, weld root cracks were initiated by applying cyclic loading. The fatigue results of the truss specimens exceeded detail class 71, although the detail class for girth welds is only valid for wall thickness t < 12,5 mm, whilst the average wall thickness of the specimens was 23 mm.

Keywords: very high strength steel; cast joints; fatigue; circular hollow sections; bridges.

1. Introduction

Recently developed technology makes it possible to produce cast steel parts up to yield strength of above 1.000 MPa. Use of cast steel gives freedom to the designer in choice of geometry and steel quality. In the past decade, more and more cast steel parts have been used in bridges, offshore-structures and building structures. An effective application of Very High Strength Steels (VHSS) can be expected in truss-like structures, typically made of hollow sections. The modulus of elasticity of steel is independent of the yield strength. Truss structures could enable full exploitation of the high material strength of VHSS, because in such stiff structures the deflection is not the governing design criterion. An appropriate design of cast joints could limit stress concentrations and locate welds out of fatigue critical zones.

EN1993-1-9 [1] gives no specific detail categories for the fatigue strength of welded connections of circular hollow sections and cast members. Category 71 applies for girth welded CHS connections. Nussbaumer et al. [2] proposed new fatigue strength curves for details of CHS-cast joints for structural steels up to S460, with differentiation for bending and tension (See Figure 1). In case the CHS are not bevelled and made without backing ring or with a tack welded backing ring, class 100 is suggested for bending and 71 for tension loading; given inverse slope of the fatigue strength curve m = -5.

Within the current research, truss specimens made of cast steel joints and CHS made of S690-G10MnMoV6-3 and S890- G18NiMoCr3-6, with V-girth-welded connections were tested under fatigue loading for comparison with detail categories according to [1] and [2].

2. Experiments

The truss specimens were designed based on the available length of the CHS and the possibilities of testing in the Stevin II Laboratory of the Delft University of Technology. The test frame consisted of a hydraulic jack (F_{stat} = 10.000 kN / F_{dyn} = 6.000 kN), pull bars and H-girders. Forces were

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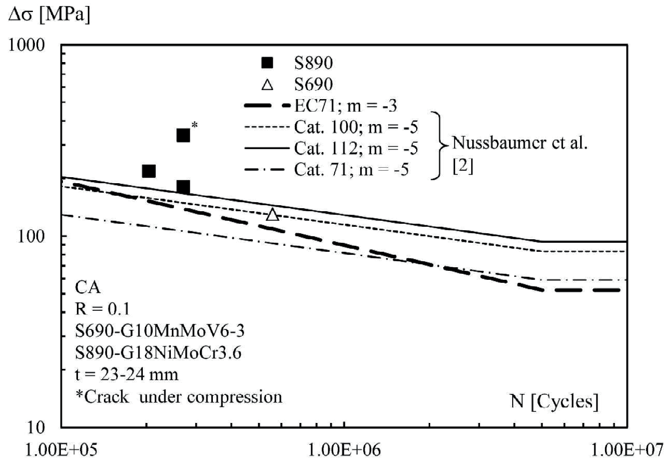
transmitted to the girders through rotating blocks in the plane of the truss, to which a hinge and a rolled support were connected. The current setup made it possible to load the truss specimens up to a maximum of 6.000 kN with frequency of 0,3 Hz. The specimens were loaded in constant amplitude, with R value 0,1, defined by the strain ratio.



All cracks initiated in the weld root. The fatigue results of both the S690 and the S890 specimens are presented in the fatigue strength curve of Figure 1. The number of cycles until through thickness crack is plotted against the stress range for the various crack locations. All cracks initiated in the weld root. The graph compares the fatigue results with the detail categories according to [1] and [2].

Figure 1, Fatigue strength results of trusses compared to [1] and [2].

3. Discussion, Conclusions and Acknowledgements

3.1 Discussion and conclusions

The results of the trusses, with average wall thickness of 23 mm, easily meet detail class 71 according to [1]. The S890 truss results also meet class 100 and are close to 112 according to [2], but the trusses contain stresses as a result of tension and bending. The S690 truss just meets class 100 according to [2]. However, the number of test results of the trusses is very limited for a proper comparison. The root part of the girth welded connections of cast steel joints to rolled parts, plates or CHS, is found to be the weakest part with regard to the fatigue strength. Improvement of the weld root is therefore expected to be the key to increase the fatigue strength of a cast joint, especially if made of VHSS. This means assessment of the weld root quality, with emphasis on locations that cannot be monitored visually.

3.2 Acknowledgements

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4. References

[1] EN 1993-1-9, “Design of steel structures - General - Part 1.9: Fatigue strength of steel structures”, European Committee for Standardization, Brussels, 2005.

[2] NUSSBAUMER, A., HERION, S., VESELCIC, M., DIETRICH, R., “New S-N curves for details in bridges with steel truss tubular Superstructure”, *Proceedings of the 13th international symposium on tubular structures*, Hong Kong, 2010, pp. 481-489.

[3] PIJPERS, R.J.M., “Fatigue strength of welded connections made of very high strength cast and rolled steels”, *Dissertation,*, Delft, 2011.