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Fatigue properties of cut and welded high strength steels – Quality aspects in design and production

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Abstract

In this study, several aspects regarding effect of quality on the fatigue strength in welded cut HSS have been investigated and are discussed. A novel numerical algorithm has been developed which assesses the welded surface and calculates and quantifies weld quality parameters and the presence of defects which are critical in fatigue applications. The algorithm is designed for implementation in serial production. It will provide robust and reliable feedback on the quality being produced, which is essential if high strength steels are utilized and high quality welds are necessary for the structural integrity of the welded component. Two welding procedures which can increase the weld quality in as welded conditions have been assessed. It was found that by using these methods, the fatigue strength can be increased with 20% compared to normal weld quality. Furthermore, two fatigue assessment methods ability to account for increased weld quality in low cycle and high cycle fatigue applications has been studied. One of these methods showed sufficient accuracy in predicting the fatigue strength with small scatter and also account for increased weld quality. The influence of surface quality on cut edges was studied and the fatigue strength was estimated using international standards and a fatigue strength model for cut edges. It was found that the fatigue strength in testing was 15-70% higher compared to the estimation, thus proving a weak link between the international standard and fatigue strength.

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Keywords: Fatigue; welded joints; quality; high strength steel

1. Introduction

Design and manufacturing of welded structures is an important task which requires accuracy, especially for robotic welding in serial production. For lightweight welded structures however, where thinner and high strength steels are utilized, the increased nominal stress levels require consideration of other design aspects such as buckling, plastic collapse and fatigue strength. High strength steels suffer from an increased sensitivity to notches and defects

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compared to mild steels. For welded components, the fatigue strength will be the same for high strength steel and mild steel if no improved weld quality is achieved [1]. Thus, improving the design of the welded structure by using high strength steel requires improved weld quality, which in turn demand an improved quality assurance. Today, most of the quality assurance for welded components is carried out by the audit process, separate to the production line, using standard gauges. Hammersberg and Olsson [2] concluded that basic standard gauges and methods for weld quality assurance are out-dated if care is not taken to investigate and improve the used measurement systems relative to the actual variations occurring in production. Thus, to fully achieve lightweight design in welded structures, manufacturing companies which utilize serial production will face challenges in quality assurance when introducing high strength steel in their products.

2. Weld quality

The weld quality quantifies the welded joints ability to perform the functional requirements of the weld during the service life of the structure. Which could be either durability in static and/or dynamic loading, corrosion resistance, appearance or any other mechanical function. Insufficient quality must be avoided due to serious consequences in safety and cost, i.e. failure occur at an early stage. Excessive quality on the other hand may result in increased fabrication cost which does not add more customer value to the product. It is also necessary as a design engineer to specify the sufficient quality in the relevant locations of the structure, as various locations in the structure may experience increased loading due to local stress raisers such as stiffeners, holes and notches [3]. The ISO 5817 [4] standard was designed in the 1960´s using a German design code DIN 5863, by welding workshops which were following the principle of “good workmanship”. However, later studies [5] show that the acceptance limits for different imperfections within ISO 5817 does not correlates with the resulting fatigue life. Fig. 1 illustrates examples of imperfections in ISO 5817. Jonson et al [6] developed a new weld quality system which has become a Volvo Group corporate standard [7] which have the distinct characteristic of relation between each weld quality level should correspond to a 25% increase in fatigue strength, which is approximately a factor 2 increase in fatigue life. In order to account some of the drawbacks ISO 5817 was revised in 2014 in order to incorporate some of the findings in the Volvo standards.

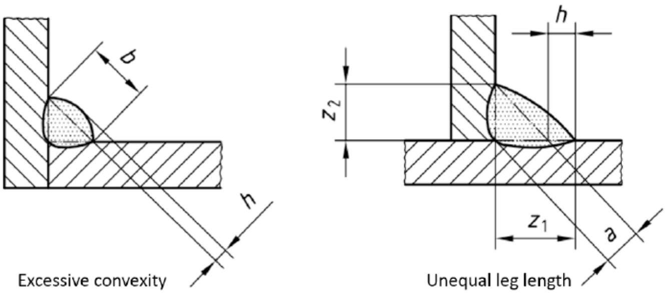

Fig 1. Examples of imperfections in ISO 5817 [4].

3. Measurement systems for quality assurance

Today, numerous handheld manual gauges are available to assess the weld quality in production and inspection. To decide whether a gauge is appropriate for quality assurance or not depends on (i) what feature the system is supposed to measure, (ii) the specified tolerance width of that feature on the part, and (iii) if the gauge’s contribution to the variation is significantly lower than the tolerance width of the part. Hammersberg and Olsson [2] conducted a measurement system analysis on the gauge when measuring the weld throat thickness, see Fig. 2. It was concluded that the gauge had a contribution of almost 60% of the total variation, which is too large for Go/No Go decisions (>9%) and process development (>4%). Other tools available for measuring the local weld geometry are vision systems, where the welded surface is scanned and the evaluation is performed in a computerized environment. A newly developed weld quality control and assurance with concept of a total digitalization and automation of the