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REHABILITATION OF FATIGUE LOADED STEEL STRUCTURES BY HIGH FREQUENCY HAMMER PEENING

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ABSTRACT

This paper reflects the application of high frequency peening in order to increase the fatigue life of welded steel structures. Recent studies demonstrate that high frequency peening can increase the fatigue life of welded joints by 5 to 15 times. Furtheron high frequency peening methods which are accredited by a German institute (Karlsruhe Institute of Technology , KIT) feature very small scatter in the results. Therefore, the quality control can be achieved by a procedure similar to the quality control system for welding, which is completed by a visual inspection. A developed design concept allows calculating the increased residual fatigue life of the structures by accounting for the locally increased fatigue strength. The present paper reports on an example of a fatigue loaded welded steel bridge which has been repaired by applying high frequency hammer peening in order to extend the remaining service life.

Keywords: High Frequency Peening (HiFIT, UIT) Fatigue Life, Fatigue Strength, Improvement, Welded Structures,

INTRODUCTION

In the last decade rehabilitation of structures gained more importance. For example, in Germany 60 % of the railway bridges are welded steel structures, with a commercial value of nearly 8 billion euros. A large number of those, which are highly stressed by cyclic and changing loads, will reach their service lives in the next years, so that enormous costs for new bridges or for the rehabilitation of old bridges will arise. As another example wind energy plants have been designed for a service life of 20 to 25 years. In the next years an increasing number of these structures will reach their service lives and a reconstruction will be necessary. Methods which can increase their service lives and that of other cyclic loaded welded steel structures would be economically beneficial. In most cases the fatigue life of the whole structure can be increased by enhancing the fatigue strength of key-details. Here, the application of post weld improvement methods which can increase the local fatigue life could be an effective opportunity.

Post weld treatment methods are well known in the field of mechanical engineering in order to increase the fatigue strength of welded details either by reducing the notch stresses or by increasing the local fatigue strength. But in civil engineering only methods were applied which were meant to improve the weld seam geometry. Missing trust in the way of functioning and possible quality control possibilities of other methods prevented their implementation in the rules.

BACKGROUND

Regarding the fatigue behaviour of welds, it has to be considered that the local stresses at the weld toe are higher than the nominal stresses due to the sharp weld transition, the weld toe angle and micro notches. Consequently fatigue crack initiation occurs at these points and improvement methods have to interact here. Therefore, one group of post weld treatment methods like grinding or TIG-dressing, are used to reduce the local notch effects and thus the local notch stresses. These methods deform the weld toe such that the weld toe radius is enlarged or the weld toe angle is reduced leading to decreased notch stresses. The other group of post weld treatment methods, i. e. hammer peening and shot peening, improve the local mechanical properties of the weld toe material by cold working. By plastification of the weld toe compressive residual stresses are produced in the edge layers of the weld transition zone and the surface hardness is increased. An increased local hardness is aligned with an increased local tensile strength and thus with retarded crack initiation. The compressive residual stresses interact with the load induced stresses so that with rising compressive residual stresses the effective tensile stresses at the weld toe are reduced. Consequently, the second group of post weld treatment methods retard the crack initiation and crack propagation velocity.

In the last years research projects focussed on high frequency peening methods, because first fatigue tests proved that the application of these methods result in high fatigue strengths of welded joints. In these studies two high frequency peening methods namely High Frequency Impact Treatment (HiFIT) and Ultrasonic Impact Treatment (UIT) have been analyzed. Fatigue testing has been performed and investigations regarding the mode of functioning have been performed. In earlier papers the beneficial effects of the combination of geometrical and mechanical improvement is stated (i.e. Dürr, 2007; Ummenhofer et al., 2006). Further intensive studies proved the beneficial influence of UIT and HiFIT on the crack initiation and crack propagation. But it could also be demonstrated that the geometrical influence is of minor relevance for the beneficial effects (Weich, 2009). Respecting the increase of the fatigue strength several investigations show an improvement of the fatigue strength of up to 200% (Dürr, 2007), (Kuhlmann, 2006), (Lihavainen, 2006), (Roy, 2006), (Ummenhofer et al., 2005), (Ummenhofer et al., 2006). *Roy* (2006) stated based on experimental studies that the FAT-classes defined by the American Association of State Highway and Transportation Officials (AASHTO) can be increased by 1 to 2 classes after UIT-treatment. Results of comprehensive tests on virgin and preloaded as welded specimens which were HiFIT and UIT-treated prove the high improvement rate for both new and fatigue preloaded details (Weich, 2009).

HIGH FREQUENCY PEENING

Properties

High frequency peening is a further development of the commonly known hammer peening. Whereas ordinary hammer peening methods feature hammer frequencies of 10 to 80 Hz high frequency peening methods cold work the weld toe with a frequency of minimum 200 Hz. The metal pin sizes and shapes are reduced compared to common hammer peening to cylindrical pins with diameters of 3 mm and rounded tips with radii of 1.5 mm. Currently, for two different methods the properties and efficiency of high frequency peening have been proved: HiFIT and UIT. The devices are shown in Figure 1 and Figure 2.

The metal pins are driven along the weld toe so that the weld toe is plastically deformed by the impacts to an uniform weld toe geometry. The surface is hardened and considerable compressive residual stresses are produced up to a depth of 1 to 1.5 mm (Nitschke-Pagel, 2007). Above that cold laps can be removed by the operation. The weld toe radius is smoothened resulting in a radius of 1.5-2 mm combined with a depth of the indents of 0.1-0.3 mm.

First applications on existing bridges have been successfully completed – one has been given above as an example. Besides the high improvement rate, the advantages of these methods compared to alternative improvement methods rely on the good applicability of the devices as well as on the fact that only highly stressed details have to be treated locally. Furtheron, high frequency peening methods feature very small scatter in the results. Therefore, the quality control can be achieved by a procedure similar to the quality control system for welding, which is completed by a visual inspection. A developed design concept allows calculating the increased remaining fatigue life of the structures by accounting for the locally increased fatigue strength.

Concluding it can be stated that high frequency peening methods are effective beneficial means to increase the fatigue and service life of existing and new welded steel structures.

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