Concepts for fatigue design of welds improved by high frequency peening methods

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ABSTRACT

Recently research has been initiated on fatigue improvement effects of high frequency peening methods. Experimental results show that the fatigue strength of butt welds, welded transverse and longitudinal stiffeners can be highly improved.

In this paper design concepts for the determination of the fatigue resistance of such posttreated welds are presented. Local approaches are adopted in order to consider the geometric improvement of the weld toe. Further, the application of the peening methods is simulated and the resulting stress field is incorporated in the model. As another simple method a local concept is presented, which calculates the local fatigue strength also considering the local hardness and residual stress field.

KEY WORDS: high frequency peening, weld improvement, fatigue design, local stress approach

INTRODUCTION

Designing fatigue loaded structures like offshore structures, the fatigue strength becomes often decisive. Therefore, an improvement of the fatigue strength can yield to more economic design.

Investigations carried out in the last decades prove that some weld improvement methods may raise the fatigue strength of welded details significantly.

Recently, research has been initiated on the effects of high frequency hammer peening methods on the fatigue strength. Laser measurements of the weld seam show that these methods increase the overall weld toe radii, so that the notch stresses are reduced. Furthermore the fatigue resistance is enhanced by an increase of the surface hardness and also by induced compressive residual stresses. Measurements verify inherent compressive stresses at least up to a depth of 1 mm with values up to the yield strength. The experimental results prove that the fatigue strength can be highly increased compared to as welded details combined with a reduced slope of the SN-curve.

The improvement of the fatigue strength can be defined by new SN-curves. Extensive experimental investigations become necessary to derive these SN-curves for various weld details. Therefore, alternative local concepts are in demand which consider for fatigue improvement effects and can be applied to various details.

In this paper specific design approaches based on existing design approaches and further ideas are discussed. The notch stress method is applied to incorporate the change of the weld toe geometry by simulating the measured weld toe after treatment. Further, the material mechanical effects are accounted for by simulating the indents of the high frequency peening. The resulting cyclic stress ranges are valued using different approaches regarding the retarding effect of compressive stresses on the crack initiation and crack growth compared to tension stresses.

As another simple method a local concept is presented, which considers the material mechanical effects (increased hardness and induced residual stresses) by applying reduction factors on the local fatigue strength. The concept has been developed for heat treated material and has been applied qualitatively to welds improved by material mechanical post weld treatment methods (Nitschke-Pagel, Wohlfahrt, 2006). It has to be quantified in further fatigue tests for welded details treated by high frequency peening methods.

STATE OF THE ART

Weld Improvement

Recently the application of high frequency hammer peening methods like High Frequency Impact Treatment (HiFIT) and Ultrasonic Impact Treatment (UIT) on fatigue loaded welded structures has been studied.

Investigations prove that the positive effect on the fatigue strength is based on the combination of geometrical and material mechanical effects (Dürr 2006; Roy 2006; Ummenhofer, Weich and Nitschke-Pagel 2005a, 2005b, 2006a, 2006b, 2007). During treatment pins with diameters of 3 to 5 mm are hammering with frequencies between 100 to 200 Hz on the weld toe and cause local plastic deformations in the treated zone. This leads to an increase of the notch radius causing reduced notch stresses. Secondly, the methods are causing a higher surface hardness and are inducing compressive residual stresses in a thin zone at and beneath the surface. The resistance against crack initiation is increased due to the raised hardness. Further, the induced compressive residual stresses, interfering with the load induced stresses, lead to an increased resistance against crack propagation.

Regarding the effects on the fatigue strength several tests on 8 to 30 mm thick were conducted with specimens of steel grade S355J2G3 and S460TM with butt welds and welded transverse stiffeners.