PROPERTIES OF WELDED LOW-ALLOY STEEL AFTER ULTRASONIC IMPACT PEENING APPLICATION

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1. Introduction

The fatigue of structural materials is the dominant mechanism in the threshold state of material field and is very frequent cause of unexpected structural failures. The reasons of fatigue failures of structural components have been investigated for more than 170 years. The Wöhlers curve incl. fatigue limit (referred to $N = 2\times10^6 \div 10^7$ cycles) is known since year 1858. The strain or stress vs. number of cycles plot ($\varepsilon_a = f(N)$, $\sigma_a = f(N)$) incl. fatigue limit are the main factors used at evaluation of fatigue properties of structural materials [1-3].

The mechanical, metallurgical and environmental variables can influence the fatigue properties of structural materials. The welding is one of them because the weld is a place with highly inhomogeneous microstructure and high residual stresses, which cause that the weld is preferential place for initiation and propagation of fatigue cracks. The fatigue properties are lower due to weld imperfections [4].

The fatigue degradation mechanism in the high-cycle region usually initiate in the place of maximum stress, on the open surface of cyclic loaded components. With regard on this fact, it is important to eliminate the possibility of fatigue degradation mechanisms to take place in the structural materials. The technological surface treatment is possible way. There are the methods which use changes of the chemical composition and microstructure of the surface layers (carburizing, nitriding, hardening or their combination), methods of different coating deposition (CVD, PVD, plasma, metal coating), pre-deformation of static or dynamic repeated loading and methods which mechanically, by deformation, strengthen the surface layers (shot peening, roller burnishing, sand blasting) and so on [3]. Especially shot peening or severe shot peening are the methods used to increase the fatigue properties of structural materials. These methods causes creation of compressive residual stresses in the sub-surface layers of the treated material and mainly increase the time necessary for fatigue cracks initiation and can increase the total fatigue endurance of structural components [5-7].

The High Strength Low-Alloy steels (HSLA) are due to their high mechanical properties and good weldability used in the transportation industry. In the field of transportation are very high requirements on the safety, reliability, economy and ecology of operation, what has direct connection with the increase of fatigue degradation mechanism resistance [8]. One way how increase the fatigue properties of welded HSLA steels is to use methods of ultrasonic impact peening.

In this paper authors publish their own results about mechanical properties of welded HSLA steel after ultrasonic impact peening application with reference to the reliability and safety.

2. Experiments and results

Experimental works (quantitative chemical analysis, tensile tests, ultrasonic impact peening and fatigue tests) were carried out on the HSLA steel Strenx 700 MC. Quantitative chemical analysis (emission spectrometry on an ICP-JY 385 spectrometer) showed following chemical compositions (in weight %), C 0.11, Si 0.093, Mn 0.64, S 0.017, P 0.009, Al 0.017, Nb 0.088, V 0.19, Ti 0.14 and tensile tests (ZWICK Y050 machine) after heat treatment the mechanical properties, Re = 741 MPa, UTS = 823 MPa, A5 = 11.5 %, Re/Rm = 0.90. Specimens for rotating bending fatigue tests (2 sets of 12 pieces, ϕ 7 mm) with welded joint in the middle of the gauge length were treated with ultrasonic impact peening technology (Fig. 1), at impact frequency of f = 20 kHz, displacement amplitude of contact tip ± 10 μm and 85 N contact force. Fatigue testing was carried out on a rotating bending testing device ROTOFLEX with loading at cycle asymmetry ratio R = -1, frequency f = 20 Hz and temperature T = 21 ± 3 °C. The run – out value was $N = 1 \times 10^8$ cycles and obtained the values of fatigue limit σ_{oc} were $\sigma_{oc} = 370$ MPa (welded HSLA steel) and $\sigma_{oc} = 410$ MPa (welded HSLA steel + ultrasonic impact peening at 85 N contact force).

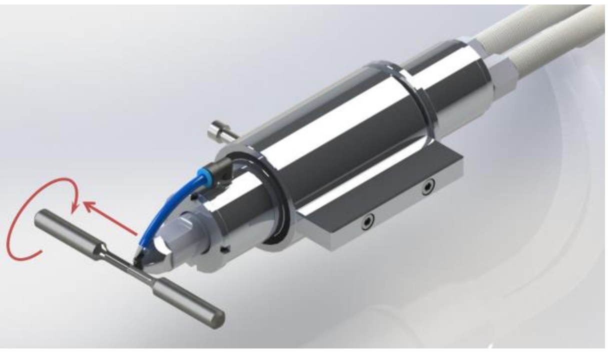

Fig. 1. Ultrasonic impact peening equipment.

The threshold value K_{ath} is very important information used by engineers for an optimal design of structural components. The approximate threshold value K_{ath} of tested HSLA steel was calculated with following equation [9], $K_{ath} = -0.052 \times UTS + 8.5906$ ($MPa\cdot m^{1/2}$), where UTS is the ultimate tensile strength (equation is valid in the region from UTS = 360 MPa to UTS = 1040 MPa). The obtained value was $K_{ath} = 4.32 MPa\cdot m^{1/2}$. Consequently, approximate intrinsic crack lengths a_{01} and a_{02} were calculated for $N = 1 \times 10^8$ cycles of loading using the equation $K_a = 0.656 \times \sigma_o (\pi . a_0)^{1/2}$, ($MPa.m^{1/2}$),

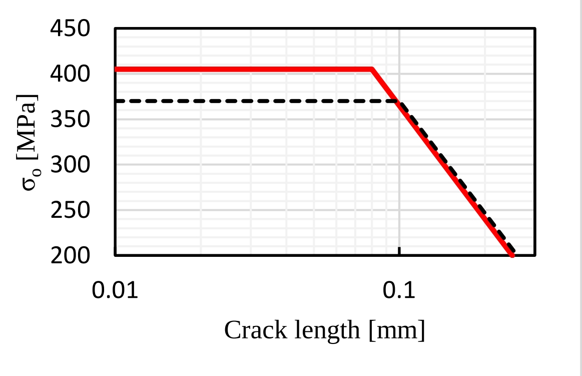

Fig. 2. Kitagawa-Takahashi diagram for welded HSLA steel and welded HSLA steel + ultrasonic impact peening drawn for $N = 1 \times 10^8$ cycles.

where σ_o is bending stress and a_0 is the intrinsic crack length. The intrinsic crack lengths were $a_{01} = 0.10$ mm (welded HSLA steel) and $a_{02} = 0.08$ mm (welded HSLA steel + ultrasonic impact peening at 85 N). The results are shown also in the Fig. 2. The results are in agreement with general conclusions published in works [10-12].

3. Conclusions

With regards to the experimental work carried out on HSLA welded and welded + ultrasonic impact peened steel, can be concluded, that ultrasonic impact peening increased the fatigue limit at $N = 1 \times 10^8$ cycles about 9.45 %.The resistance to crack initiation is the best after ultrasonic impact peening and area of safe loading is more extensive. These facts can be taken into consideration with reference to reliability and safety when designing welded structural components.

Acknowledgements

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