FATIGUE CHARASTERISTICS OF STEELS USED FOR POWER PLANT PARTS - P92 AND 15CH2NMFA STEEL

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Abstract

The paper deals with the use of small samples for fatigue tests of two types of steels used for power plant components. The main advantage of small fatigue samples is the possibility of their use in cases, where sufficient amount of material is not available for standard test specimens manufacturing. This problem can occur in cases of power plant components, e.g. steam turbine rotors or pressure vessels. The results of the small sample tests are afterwards correlated with the results of standard fatigue test specimens. In addition, different ways of sample manufacturing are compared. The small samples are produced either by machining, or waterjet cutting. The stress concentration which occurs in the small fatigue samples was determined by finite element method. The performed tests proved an acceptable correlation of small and standard test specimen results.

Keywords: Small fatigue test, P92, 15CH2NMFA, power plant parts

1. INTRODUCTION

In the present a great interest is given to the Small Punch Test method. Its greatest advantage is almost nondestructive intervention in the integrity of structures thanks to the small amount of removed material which could be advantageous also for production of SFT samples. This "new" (also called) semidestructive method allows to evaluate the current status of operating components on small samples what does not disrupt the integrity of the operating components and enables to evaluate the current status without long outages. To produce fatigue samples, we used the shape according to [2] (**Figure 1**). We began to use the name SFT (Small Fatigue Test) for the miniaturized fatigue specimens.

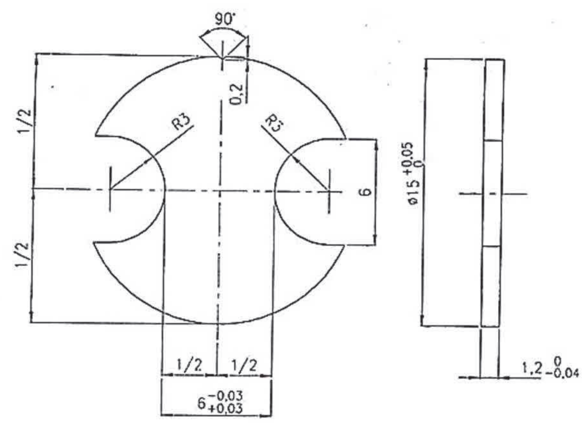

Figure 1 Shape of Small Fatigue Test samples by [2]

In this paper the results of the fatigue tests using two types of samples are compared. The results of the standard fatigue samples from steel P92 were compared with the results of the Small Fatigue Test samples (SFT) from P92 steel produced using 1st machining and also using 2nd water jet cutting. The standard fatigue samples from steel 15CH2NMFA were compared with SFT from this material.

2. MATERIAL FOR TESTING

Steels P92 and 15CH2NMFA were chosen for correlation of small fatigue test and standard fatigue specimens. The microstructure was observed using light microscopy (LM, microscope Zeiss Axio) and scanning electron microscopy (SEM, microscope Zeiss EVO MA25). Hardness of the material (HV1 and also HV10) was measured on device Zwick/Roell ZHU 2.5.

Steel P92 is widely used in the energy industry, Pipes and pipe bends of supercritical steam turbines. Steel P92 is alloyed with 2 % of tungsten compared to steel P91. This increases a creep strength of the material. It is possible to reduce wall thickness of the P92 pipe up to about 20%. Microstructure of P92 samples (material without operation) is formed by tempered martenzite (**Figures 2 - 5**) with the average hardness value of 250 HV10.

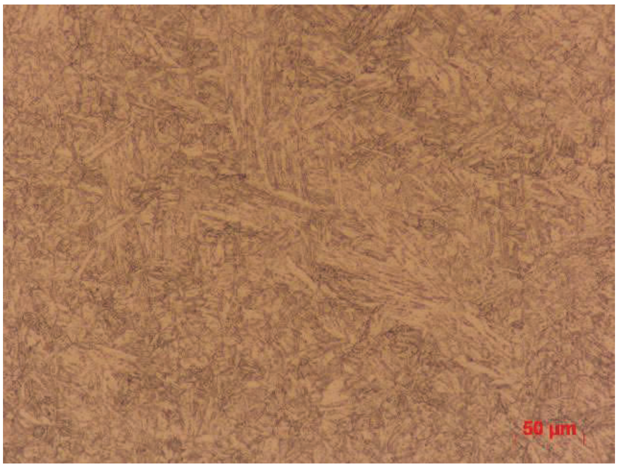

Figure 2 Microstructure of the P92 steel, LM

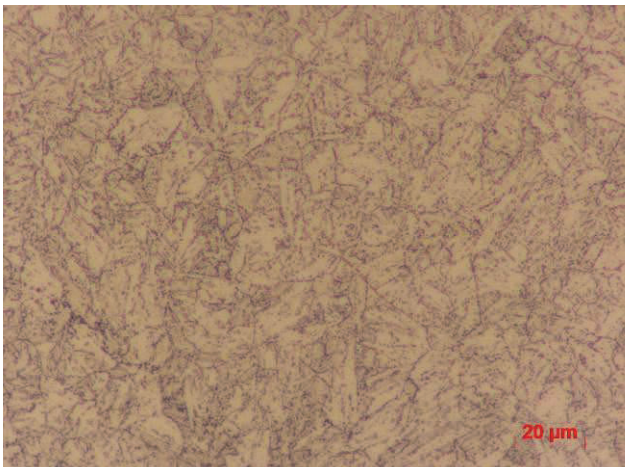

Figure 3 Microstructure of the P92 steel, LM

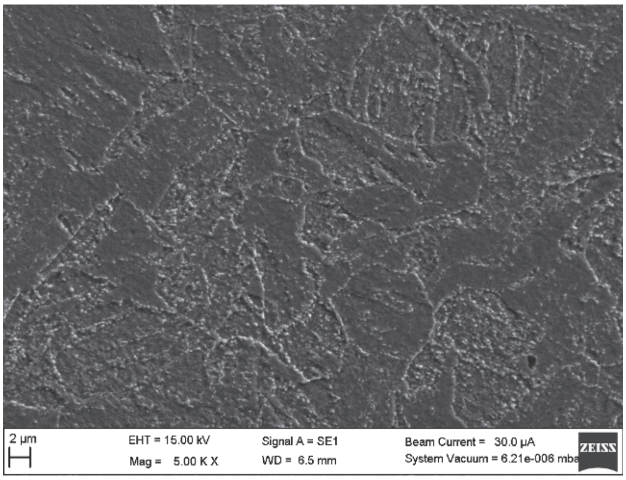

Figure 4 Microstructure of the P92 steel, SEM

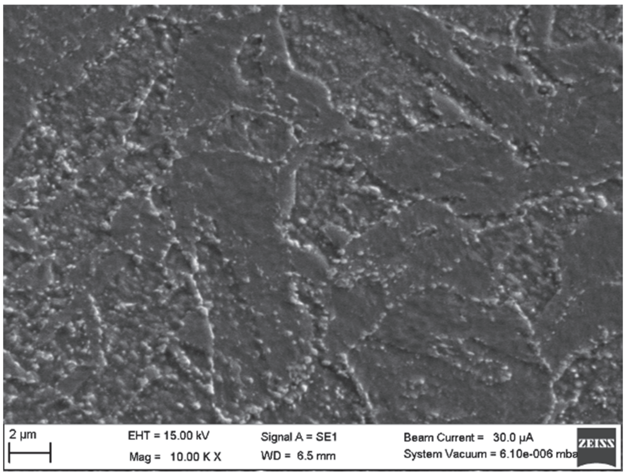

Figure 5 Microstructure of the P92 steel, SEM

Steel **15CH2NMFA** is used for pressure vessels in energy industry. Microstructure of the 15CH2NMFA steel is formed by fine bainite (**Figures 6 - 9**). Hardness was measured on the SFT sample and is about 221 HV1. The main requirements on this steel are weldability of thick-walled components, structural stability, good strength properties during operating temperature, brittle-fracture resistance and degradation resistance influenced by radiation [5].

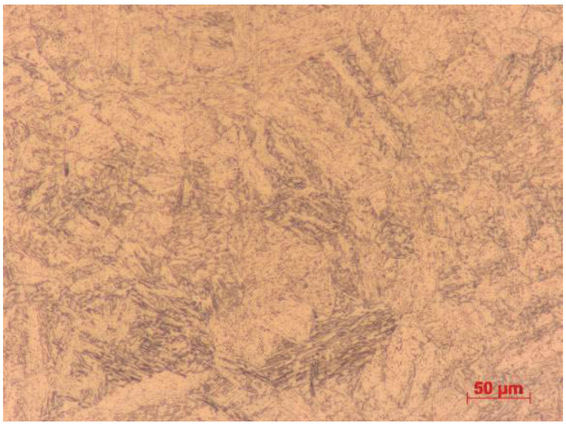

Figure 6 15CH2NMFA - microstructure, LM

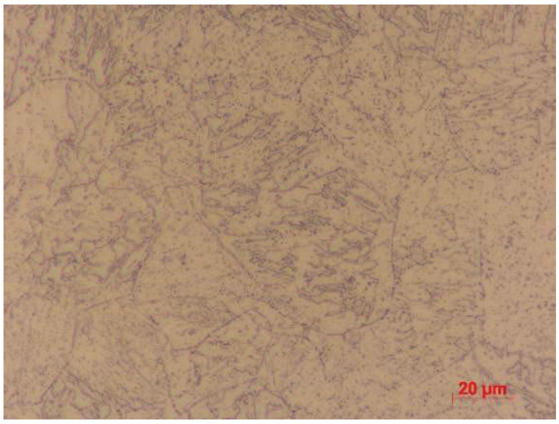

Figure 7 15CH2NMFA - microstructure, LM

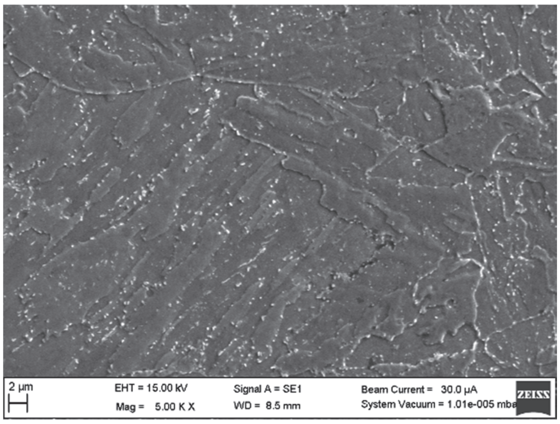

Figure 8 15CH2NMFA - microstructure, SEM

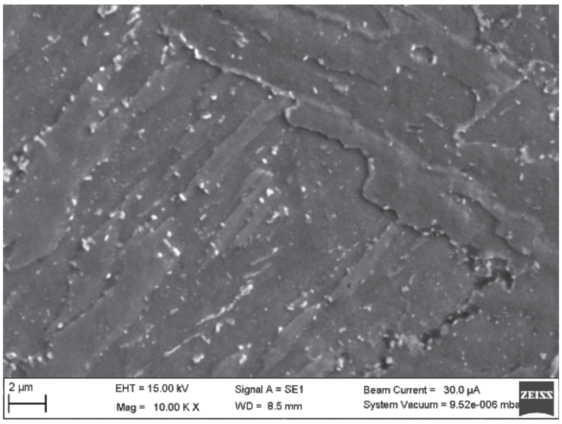

Figure 9 15CH2NMFA - microstructure, SEM

3. SAMPLES PRODUCTION

Traditional specimens (**Figure 10**) for fatigue tests were made according to standards. SFT samples were made by traditional methods of machining. First, a 15 mm diameter shaft was made, then the longitudinal groove was milled on both sides of the shaft (**Figure 11**), then the samples were cut to approximately 1.3 to 1.5 mm and finally grinded. Another set of samples was produced by water jet cutting **(Figure 12**). First, the sheet sample was about 290 mm long, 60 mm wide, 8 mm thick and the thickness was then reduced by milling and grinding by the plane grinder to the final 1.2 mm. The objective was to compare the results of conventional fatigue tests with small samples and to compare the influence of SFT production types on the results of fatigue tests.

Figure 10 Standard testing samples

Figure 11 SFT samples

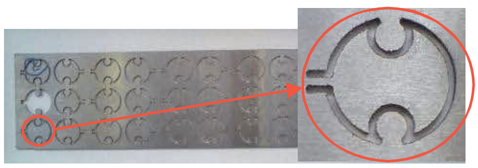

Figure 12 Samples cut by the water jet

4. FATIGUE TEST PERFORMANCE

Amsler 10 HFP 5100 (high-frequency pulsator) ZWICK//Roell machine was used for the realization of fatigue experiments. For the clamping of standard cylindrical specimens, accessories of the machine were used and threads were adapted to the possibilities of this device. To clamp the SFT samples, special grips have been designed and manufactured. Standard fatigue tests were carried out according to the standard ČSN 420363. SFT samples were newly designed in MMV laboratory, Czech Republic by Prof. Matocha. There is no valid standard for the testing therefore.

5. EXAMINATION PROCESS

The tests were performed by cyclic loading in the force control regime, the frequency was 120 Hz - 145 Hz with a cycle asymmetry R = 0.1. Termination of fatigue limit was set at 10^7 cycles which corresponds to the fatigue limit of steel materials. Stress concentration factor was 1.33.

5.1. Test Results

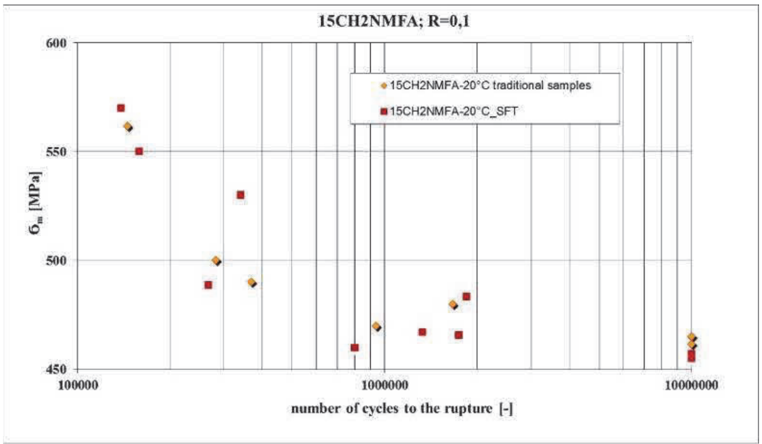

Figure 10 Comparison of results of traditional and SFT samples from steel 15CH2NMFA, cycle asymmetry R=0.1

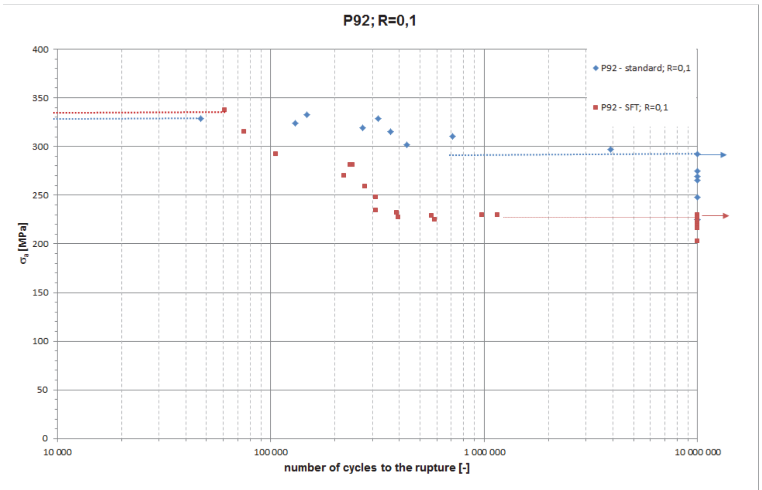

Figure 11 Comparing results of traditional and SFT fatigue samples from steel P92, cycle asymmetry R=0.1

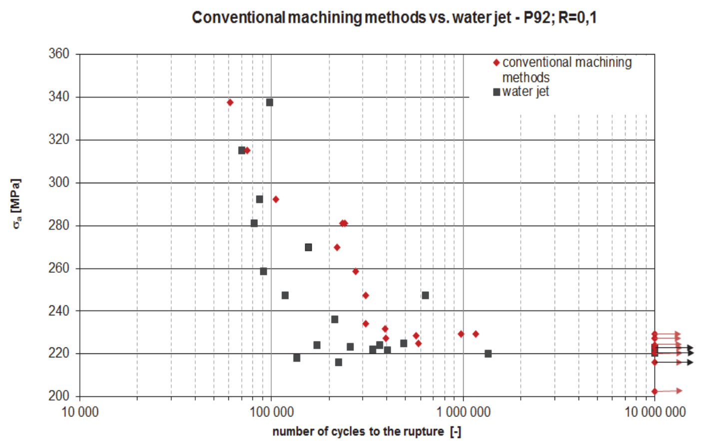

Figure 12 Comparing results of SFT fatigue samples from steel P92, cycle asymmetry R=0.1

CONCLUSION

In case of samples from steel 15CH2NMFA and stress concentration factor 1.33, the results of traditional fatigue test samples and SFT samples are similar. Also, the results of fatigue limit were identical.

When considering the stress concentration 1.33 at the SFT samples neck (this concentration is already included in **Figure 11**), the results are in both the low cycle and high cycle fatigue range lower than the results of conventional tests.

Fatigue strenght of the material P92 was in case of traditonal samples 293 MPa (σ_a, assymetry of the cycle R=0.1. In case of new-shaped samples the fatigue strength of the material P92 is 227 MPa (σ_a, asymmetry of the cycle R=0.1).

Fatigue strenght of the material 15CH2NMFA was in case of traditonal samples 465 MPa (σ_{max}, assymetry of the cycle R=0.1). In case of new-shaped samples the fatigue strength of the material 15CH2NMFA is 460 MPa (σ_{max}, asymmetry of the cycle R=0.1).

The results of steel 15CH2NMFA corresponds (SFT vs. traditional samples) and the results of steel P92 differ after the stress concentration is taken into consideration. That is why we decided to try to test new shape of samples, which are not influenced by stress concentration. The fatigue behaviour at these new-shaped samples is assumed to be similar as standard samples without stress concentration.

Despite the scatter of the results (especially in low-cycle fatigue range) the evaluated fatigue limits vary by less than 5 MPa and impact of the production procedures in the standard way or by water jet to determine the fatigue limit is thus negligible (**Figure 9**).

Use of this small fatigue test samples is necessary f. e. at the applications, where not enough material for testing is aviable. This should be for instance at the branch of energy industry, power plant parts, pressure vessels, steam piping etc. That is why we have chosen materials suitable for these fields of application.

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