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INFLUENCE OF FATIGUE LOAD TO BEHAVIOUR OF WELDED JOINT ON ALLOYED STEEL FOR HIGH TEMPERATURE

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ABSTRACT
The results of experimental investigations performed for the analysis of high-cycle fatigue properties in welded joint of steel for elevated temperatures and high pressure application are presented. Alloyed steel A-387 Gr. 11 Class 1 (SRPS Č.7400) and its welded joint for high-temperature and under high-pressure application, had been tested. The analysis is performed by testing standard specimens in order to establish the effect of at it is necessary to determine and evaluate the effect of heterogeneity of microstructure and mechanical properties of welded joints on high-cycle fatigue properties .
Key words: A-387 Gr. 11 Class 1 (SRPS Č.7400) alloyed steel, high cycle fatigue, fatigue strength,

1. INTRODUCTION
Service behaviour of alloyed steel A-387 Gr. 11 Class 1, aimed for manufacturing of pressure vessels for high temperature and high pressure, depends on the properties of its welded joint, consisted of parent metal (BM), heat-affected-zone (HAZ) and weld metal (WM) as constituents. Critical locations regarding integrity of welded joint and structure present HAZ and WM, since in them local brittle zones, sensitive to cracking, can be formed [1].
Welding technology specification of steel A-387 plates, 96 mm thick, is defined according to standard EN 288-3 [2]. However, this standard requires neither testing at operating temperature (540°C) nor testing of in-service behavior of base metal and welded joint constituents at room and operating temperatures. Welded joint, is characterized by homogeneous microstructure and mechanical properties. Irregular distribution of stress field is also important, affected by various factors as well as residual stresses after welding. These principal problems, however, do not exclude experimental determination of high-cycle fatigue properties, of welded joint or of its critical zones, presenting more the troubles in interpretation of measured values. [3-5].
For service safety of structures in processing equipment for operation in thermal power plants, very important properties are those describing the phenomenon of crack initiation and growth under variable loading. Fatigue crack initiation at structurally smooth and homogeneous forms still cannot be described by some simple functions of loading, stress, material properties and cross-section; therefore, empirically derived functions are used, as a rule induced by thorough experimental and laboratory testing. Generally accepted property for that case is fatigue strength that determines the level of loading at which no crack occurs on smooth specimens.
The effect of service conditions (service life and temperature) on high-cycle fatigue properties in A-387 steel was analysed by testing the new and used BM and welded joint at room temperature and at operating temperature of 540°C [6].

2. MATERIAL

The steel A-387 welded joint sample 350x500x96 mm with double "U" weld metal in the middle had been prepared for this investigation [6]. The view of welded sample and shame for specimens taken from welded joint and BM are shown in Fig. 1. The chemical composition and mechanical properties of A-387 1 steel are given in Tables 1 and 2.

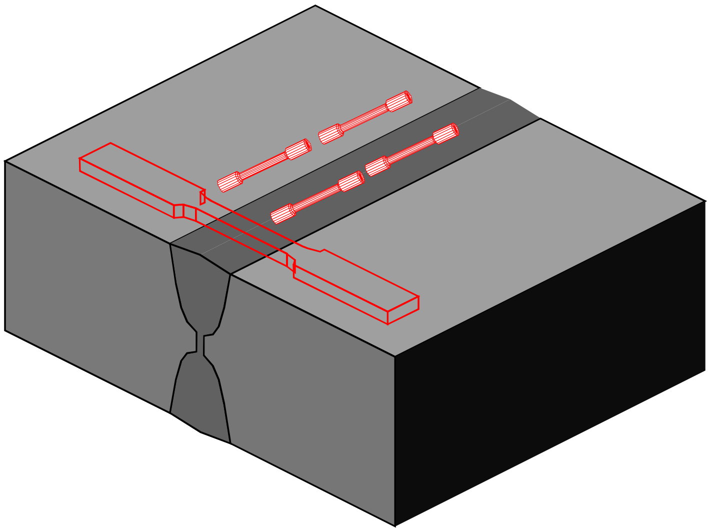

Figure 1. View of testing coupon with double "U" weld metal and specimens sampling [6]

Table 1. Chemical composition of tested material [6]

	Chemical composition, mass %						
	C	Si	Mn	P	S	Cr	Mo
A-387 Gr. 11 Class 1	0.15	0.29	0.54	0.022	0.011	0.93	0.47

Table 2. Mechanical properties of tested material [6]

Material	Yield stress, min. $R_{p0,2}$, MPa	Tensile strength, R_m, MPa	Elongation A, %	Impact energy KV, J
A-387 Gr. 11 Class 1	315	490-620	25	> 85

Two welding procedures were applied [6]:
- for root weld passes metal manual arc welding (MMA) with coated electrode LINCOLN Sl 19G (AWS: E8018-B2),
- for filler passes submerged arc welding (SAW) applying as consumable wire LINCOLN LNS 150 and flux LINCOLN P230.

Chemical composition of electrode LINCOLN Sl 19G and wire LINCOLN LNS 150 according to certificates is given in Table 3. Mechanical properties according to certificates are given in Table 4.

Table 3. Chemical composition of filler metal [6]

Filler metal	Chemical composition, mass %						
	C	Si	Mn	P	S	Cr	Mo
LINCOLN Sl 19G	0.08	0.045	0.35	0.025	0.025	1.10	0.50
LINCOLN LNS 150	0.11	0.18	0.37	0.020	0.020	1.04	0.47

Table 4. Mechanical properties of filler metal [6]

Filler metal	Yield stress $R_{p0,2}$, MPa	Tensile strength, R_m, MPa	Elongation A, %	Impact energy KV, J
LINCOLN Sl 19G	505	640	23	> 95
LINCOLN LNS 150	490	610	26	> 100

3. TEST RESULTS

Testing of the effect of service conditions on behaviour of A-387 steel under variable loading was performed on the sample of new BM and BM after service of 40 years and welded joint at room temperature and at operating temperature of 540°C [6]. These tests were performed in order to determine the spot in *S-N* diagram (design of Veler's curve) and determination of permanent fatigue strength, S_f. The specimens were shaped and sized according to ASTM E466 [7], Fig. 2. Tests were performed on high-frequency pulsating device AMSLER.

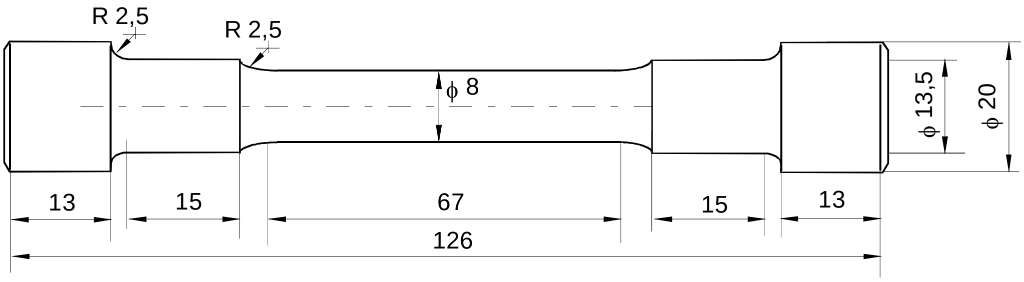

Figure 2. Specimen for dynamic testing to ASTM E466 [7]

High-frequency pulsator can induce sinusoidal alternating load ranging from -100 kN to + 100 kN. Mean loading and loading amplitude were registered with an accuracy of ±50 kN. Achieved frequency varied from 125 to 165 Hz, depending on loading value and test temperature. In order to make an assessment of steel behaviour under variable loading completely, and having in mind the size of specimens, the most critical case of variable loading was treated, i.e. alternating variable loading tension-compression (R = -1), Fig. 2. The results of testing under variable loading are presented in a form of *S-N* (Veler's) curve in Fig. 3 for new BM, Fig. 4 for used BM, and Fig. 5 for welded joint.

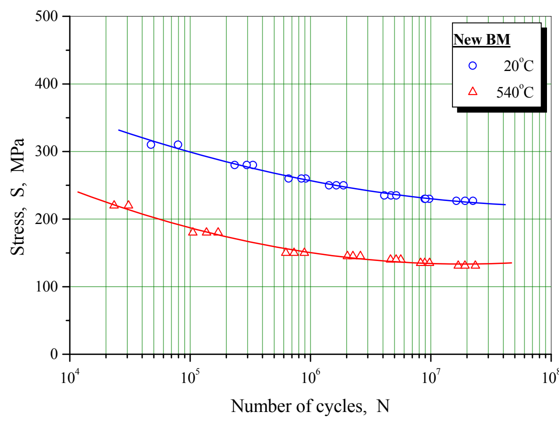

Figure 3. S-N diagram of the specimens taken from the sample of new BM made of A-387 steel [6]

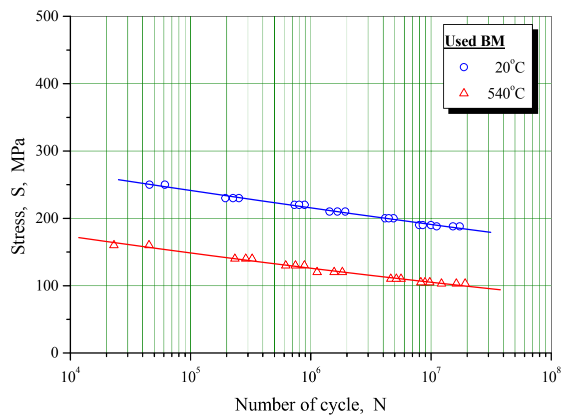

Figure 4. S-N diagram of the specimens taken from the samples of used BM made of A-387 steel [6]

In this test, as a rule, only the number of load variations until fracture is determined at constant-range loading, and the standard requires only a datum on stress level at which fracture does not occur after certain number of cycles (usually between 10^6 and 10^8 cycles). For steel materials, ASTM E468 defines permanent fatigue strength, S_f, after 10^7 cycles. Therefore, this test is extremely expensive and justifiable only when the data are necessary for design, mainly from the point of view of fatigue and fracture mechanics, i.e. when the components exposed to long-term variable loading within total designed life of structure [6].

4. THE ANALYSIS OF RESULTS

Analysing the results obtained by fatigue testing of smooth specimens in order to design Veler's curve and to determine permanent fatigue strength, one can see that service life and testing temperature affect the values obtained for permanent fatigue strength. At room temperature, obtained value of fatigue strength is 71% of yield stress for new steel, 64% for used steel, and 67% for welded joint. At operating temperature of 540°C, obtained value of yield stress is 57% for new steel, 51% for used steel, and 56% for welded joint. If consider the effect of the loading type, one can see that the effect of service life is much stronger in fatigue testing than in static testing.

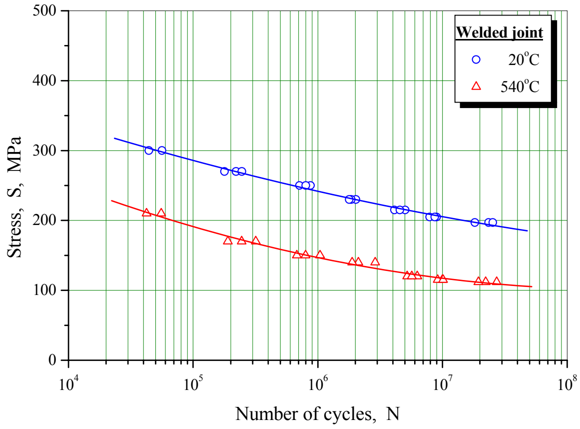

Figure 5. S-N diagram of the specimens taken from the sample of welded joint made of A-387 steel [6]

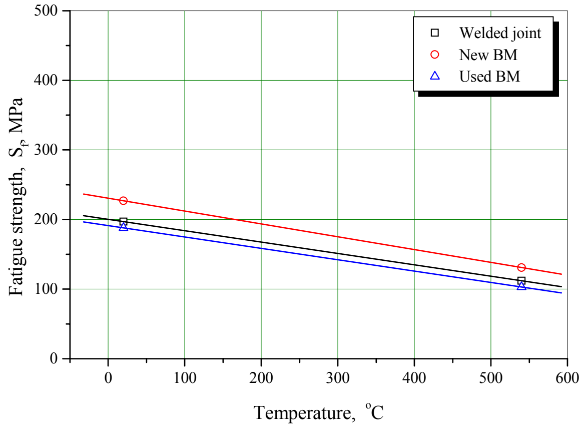

Figure 6. Dependence of fatigue strength of new and used BM, and welded joint A-387 steel, on testing temp. [6]

5. CONCLUSIONS

Based on the presented consideration, one can conclude that:

Period of service (new and used steel) affects the values of permanent fatigue strength so that new material has higher resistance to crack initiation in smooth structural components.

Testing temperature also affects the values of permanent fatigue strength. The value of permanent fatigue strength decreases with increase of testing temperature.

6. REFERENCES

[1] S. Sedmak, A. Sedmak, Integrity of Penstock of Hydroelectric Power plant, Structural Integrity and Life, Vol.5, No2, 2005, pp. 59-70.

[2] JUS EN 288-3:1992, Kvalifikacija tehnologije zavarivanja metalnih materijala Deo 3: Kvalifikacija tehnologije elektrolučnog zavarivanja čelika (Specification and approval of welding procedures for metallic materials - Part 3: Welding procedure tests for arc welding of steels), Službeni list SRJ, br. 25/95, 1995.

[3] A. Sedmak, "Primena mehanike loma na integritet konstrukcije", Monografija, Mašinski fakultet, Beograd, 2003.

[4] E.O. Argoub, A. Sedmak, M.A. Esasamei, Structural Integrity Assessment of Welded Plate with a Crack, Structural Integrity and Life, Vol.4, No1, 2004, pp. 39-46.

[5] K. Gerić, PhD Thesis, University of Belgrade, Serbia TMF, Beograd, 1997.

[6] M. Burzić, PhD Thesis, University of Novi Sad, Department of Technical Faculty, Serbia, 2008.

[7] ASTM E466-89, "Standard Practice for Conducting Constant Amplitude Axial Fatigue Tests of Metallic Materials", Annual Book of ASTM Standards, Vol. 03.01, p. 571, 1989.