Journal of Metals, Materials and Minerals. Vol. 14 No.1 pp. 75-78 , 2004.

FAILURE OF MICRO-ALLOYED STEELS UNDER CREEP CONDITIONS

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ABSTRACT

This paper analyses the influence of temperatures ranging from 400 to 500°C on the creep, as well as on the failure process of micro-alloyed steel KODUR 460 MC. The failure character in tensile test conditions was changeless and in the fracture transcrystalline ductile mode. The microstructures near the fracture surface showed a marked deformation texture (reduction of area = 76%). The fracture strain and the fracture stress was decreased considerably with the increase of the fracture lifetime and the by the increase of temperature in the creep conditions. Secondary intercrystalline cracks were formed except the central crack in the fracture surface. Intercrystalline cracks were started step-by-step to be connected to each other. The fracture was mixed mode and the intercrystalline (creep) fracture part began to increase.

The obtained results show that micro-alloyed steels can be used to construct boiler systems or equipment working up to 500°C and in such a way the weight of the systems can be reduced when compared with carbon steels and more expensive low-alloyed steel can be replaced.

Keywords : micro-alloyed steel, precipitation hardening, creep test, thermo-mechanical treatment .

INTRODUCTION

Micro-alloyed steels, which rank among non-alloyed high-grade steels, had been developed with the aim to increase strength properties while keeping or improving further service properties, when compared with usual steel grades (Parilák, *et al.*1984; and Šlesár, *et al.*1993). The improvement of service properties of micro-alloyed steels is achieved by an increased purity of steels and by micro-alloying elements, such as Nb, V, Ti up to 0.15% in combination with thermo-mechanical treatment. By modifying their chemical composition and technology of thermo-mechanical treatment, their properties can be optimized for various fields of application. Therefore research has also been aimed at possibilities of application of these steels to components or equipment in power plants (Foldýna, *et al.* 2000; and Buršák, *et al.* 2002).

The microstructure of micro-alloyed steels consisting of substitution-hardened elements, fine-grained matrix and uniformly distributed fine-precipitates in the matrix gives an assumption that their properties at elevated temperatures will be better than that of usual creep-resisting steels. The aim of the paper is to analyze the properties of selected micro-alloyed steels under creep conditions.

Based on this analysis, the suitability of their application to power equipment can be assessed.

EXPERIMENTAL MATERIAL AND TESTING METHODS

The experimental procedure was performed on microalloyed steel strip-steel with a thickness of 8 mm in the type KODUR 460MC produced by U.S.STEEL Košice. The chemical composition of the tested steel is given in Table 1.

Table 1 Chemical Composition of Tested Steel (wt. %).

Material	C	Mn	Si	P	S	Al	N	Ti	Nb	V
KORUR 460MC	0.07	0.86	0.02	0.011	0.005	0.037	0.007	0.013	0.038	0.003

Tested samples were prepared and round probe bars were made (d = 6mm) for tensile and creep tests. The tensile test was performed in the temperature range from 20°C to 500°C and the creep tests were performed at temperatures of 400°C, 450°C and 500°C.

RESULTS AND DISCUSSION

The results as shown in Table 2 and Figure 1 show that adjusted creep tensions near shorter times up to fracture were higher than YS and so the bars were plastic deformed immediately. The adjusted creep tensions at longer times are lower than YS and, therefore, the only creep deformation is from the start of the test. According to the break tension σ_f the creep conditions are considerably lower than that in the tensile test.

Table 2 Tested Steel fracture conditions.

T [°C]	Tensile Test			Creep			
	YS [MPa]	UTS [MPa]	Reduction of Area [%]	R_o [MPa]	t_f [h]	Reduction of Area [%]	σ_f [MPa]
20	495	590	76				
				300	190	57	695
400	357	525	79	282	1080	45	520
				230	3650	36	360
				260	95	42	449
450	329	474	78	200	800	40	336
				166	4440	26	225
				150	190	35	228
500	304	428	78	120	1310	35	187
				100	4020	23	131

Remark: σ_f - fracture stress, R_0 - creep stress, t_f – fracture time.

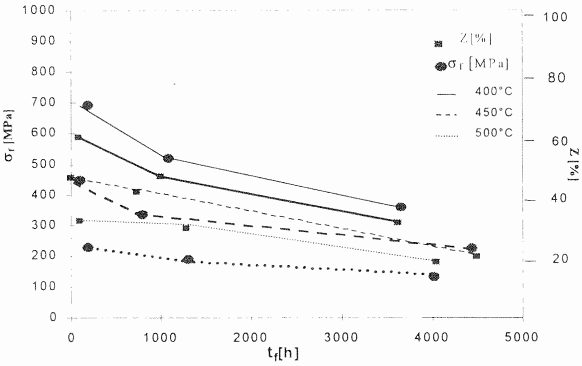

Figure 1 The fracture stress function σ_f on the fracture time t_f at the temperatures of 400, 450 and 500°C in the creep.

According to σ_f reduction of area fell with time increase up to fracture time.

The intensity of the decrease characteristics is a function of temperature. This decline is less intensive with temperature increase. According to this analysis we can claim that by the time increase up to fracture (lower starting tension) the yield points will be more intensive. . The fracture metallographic analysis should be done to confirm this supposition.

The KODUR 460MC steel has a fine-grained ferrite - pearlite structure with a low volume of the pearlite (about 8%). The ferritic grain size is about 8 μm. The essential part of the value of the slide limit is created by the new reinforcement. The microstructures near the fracture that started to form in these conditions are documented in Figure 2.

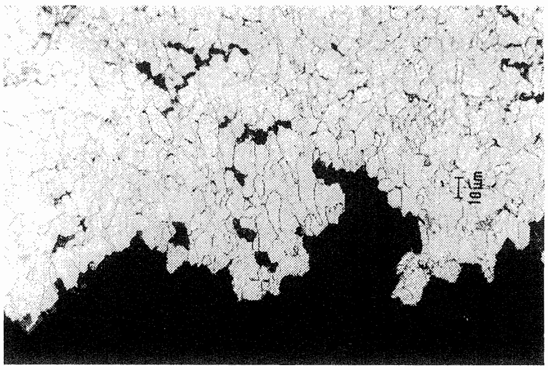

Figure 2 Microstructure steel KODUR 460 in creep condition 400°C, 140 h.

The structure near the fractures that had been formed by the tensile test showed a plastic deformation degree (Figure 3). The fracture is a transcrystalline-ductile one and does not show a more essential difference against the fracture at 20°C. The character of the fracture lines and the structure near the fracture in the creep conditions was significantly changed. According to the process of the fracture lines the change of the mechanism of transgresses occurred. The character of the fracture lines and of the microstructure was similar (except for the deformation degree) at the temperature of 400°C and fracture time up to 140 hours (see Figure 2).

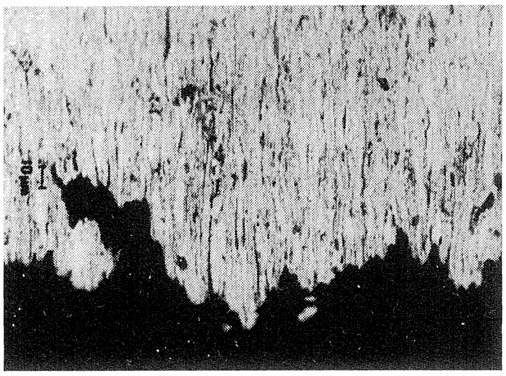

Figure 3 Microstructured steel KODUR 460 in tensile test 400°C.

At Figure 2 cracks were formed along the grain boundaries and their growth (binding) was created later. The band of the formation of these cracks was retreated from the fracture line according to the increase of the temperature and the time up to fracture although σ_f was falling.

The presented results show the creeps breaking of the tested steel were different from the breaking process of the carbon low-alloyed steels. This fact should be reflected in the microalloyed steel character reviewing.

CONCLUSIONS

The paper analyzes the influence of a temperature ranging from 400 to 500°C to the strength and the failure process of micro-alloyed steels. The fracture lines and the microstructure on the microalloyed steel KODUR 460MC fracture area in the tensile test and in the creep conditions in temperature range from 400 to 500°C metallographic analysis.

The fracture was crystalline formed (ductile), the fracture area structure was deformed considerably, but secondary cracks were not observed in the tensile test conditions.

The character of the fracture line was changed in the creep conditions. The intercrystalline (creep) deformation was increased step-by-step according to the increase of the fracture time and of the temperature until all fracture was intercrystallic. The number of the secondary cracks was increased step by step like on the grain boundaries near the fracture area.

On the basis of the test results and analysis it can be stated that micro-alloyed steels can be used to construct power equipment working at elevated temperatures up to 500°C.

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(Revised version accepted August 30, 2004)