HEAT RESISTANCE OF HK30Nb STAINLESS STEEL PIPE CASTING

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ABSTRACT
The HK30Nb steel pipe casting was obtained by centrifugal casting. This steel is austenitic stainless steel grade AISI HK 30 and is standardized according to ASME SA-351 in as cast condition. HK 30 Nb steels not standardized i.e. it is HK 30 steel modified with niobium. In addition to the required mechanical properties, this steel is also tested for heat resistance because it is used at high temperatures. In this paper, the heat resistance testing was carried out on the HK 30 Nb stainless steel pipe casting for two temperatures (750 and 850 ºC) according to the standard ASTM G 54-84. The mass change and rate of oxidation for different heating times (24, 48, 72, 96 and 120 hours) were determined. The results of the study are significant for the continued use of these materials at high temperatures in exploitation conditions.

1. INTRODUTION

The chemical corrosion occurs in steel at elevated temperatures in atmosphere of hot air, water vapour, corrosive gases, flames and similar conditions, which is conditioned by intense oxidation. In the case of non-alloy steels, layers of iron oxide are formed on the surface, which are not compact enough to prevent further diffusion of oxygen and increase in the thickness of the layer, and over time, the layer is peeled due to compressive stresses and the formation of new oxides. The alloying of steels with elements that have a higher affinity for oxygen than iron (Cr, Si, Al), first facilitates the oxidation of these elements in the surface layer, and thus inhibits further diffusion. Chromium is most favourable for the heat resistance of steel. Heat resistant steels must also have no microstructural transformations, and therefore they are either ferrite or austenitic structures [1]. These steels when used at temperatures above 550 °C, do not form a thick layer of iron oxides and still have good mechanical properties at those temperatures. To be heat resistance, the oxidation rate for steel due to the formation of an oxide layer at a certain temperature should not exceed $1g/m^2h$ at a given temperature. The resulting oxide layer should be as stable as possible at high temperatures with less porosity and good adhesion to the surface [2].The austenitic stainless steel AISI HK 30 is standardized according to ASME SA-351 (UNS J93400). HK 30 Nb steels not standardized i.e. it is HK 30 steel modified with niobium. Centrifugally cast tube was made from this steel and it is intended for making parts in the automotive industry [3].This paper presents the results of testing the heat resistance of HK 30 Nb steel at 750 and 850 °C for 24, 48, 72, 96 and 120 hours. The aim of this work was test of HK 30 Nb steel to oxidation at constant temperature for different times.

2. HEAT RESISTANCE TEST

Conducting a heat resistance test on samples of the HK 30 Nb stainless steel pipe casting was in accordance with the standard ASTM G 54-84 for Simple Static Oxidation Testing. This test is significant for this material because its further use is for making parts that work at elevated or high temperatures.The chemical composition and mechanical properties of HK 30 Nb steel at room temperature according to the standard ASME SA-351, regulation IDM 8365-HK30 (valid for the production of a car turbine ring) are presented in Table 1.

Table 1. The chemical composition and the mechanical properties of HK 30 Nb steel [4]

	Chemical composition (wt.%)								Mechanical properties			
	C	Cr	Ni	Si	Mn	Mo	Nb	Fe	R_m (MPa)	$R_{p0,2}$ (MPa)	A (%)	HV1
ASME SA-351	0,25-0,35	24,0-27,0	19,0-22,0	0,75-1,30	Max. 1,50	0,20-0,30	1,00-1,75	Rest	≥450	≥240	≥10	≥170
IDM 8365	0,25-0,30	23,0-27,0	19,0-22,0	1,00-2,50	Max. 1,50	Max. 0,50	1,20-1,50	Rest	≥450	≥240	≥10	162-229
Relased	0,31	24,3	20,6	1,20	0,33	0,02	1,40	Rest	559	315	12	202

The HK 30 Nb steel tube casting heat resistance test was performed according to the procedure given by a standard in a chamber furnace with an air atmosphere in TMD Ai d.o.o. The test samples were weighed on an analytical balance with a measurement accuracy of ± 0,0001 grams.The heat resistance test was carried out at two temperatures, i.e. 750 °C and 850 °C according to ASTM G 54-84 (Reapproved in 1996). Samples of dimensions 25x25x10 mm taken from the pipe are shown in Figure 1.

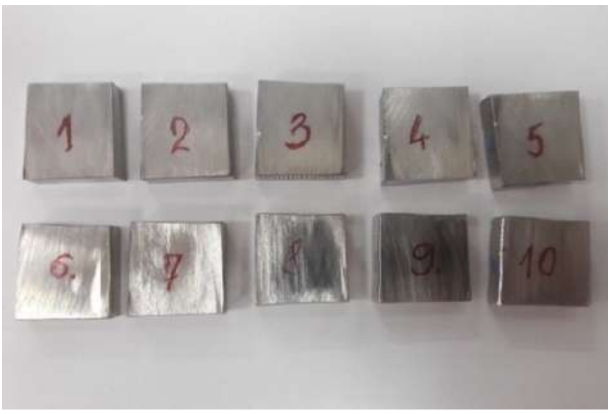

Figure 1. Samples for testing heat resistance [3]

Before heating in the furnace, the samples were ground, cleaned and degreased in acetone. Mass and dimensions were measured in accordance with the ASTM standard G 54-84 and standard G1-90 [5,6]. After that, the samples were heated in a furnace without a protective atmosphere at temperatures of 750 °C and 850 °C. After being kept at 750 °C and 850 °C for 24, 48, 72, 96 and 120 hours the samples were removed from the furnace and cooled to room temperature, after which they were re-measured their masses after each time cycle. According to equations (1 and 2), the mass change and the rate of oxidation were determined for all samples.

The mass change is determined per unit area by the equation:

$$\Delta m = \frac{m_k - m_0}{A} \quad , \quad \left(\frac{g}{m^2}\right) \qquad (1)$$

whereis :
m_0 - original mass, g
m_k - mass after testing, final mass, g
A – original surface area, m^2

The equation for determining of the oxidation rate is:

$$V = \frac{\Delta m}{t} \quad , \quad \left(\frac{g}{m^2 h}\right) \qquad (2)$$

where is:
Δm - mass change per unit area, g/m^2
t - test time, h.

The results of the tests are given in Table 2, and a graphical presentation of these results is given in Figures 2 and 3.

Table 2. Results of heat resistance tests [3]

Sample mark	Starting mass, m_0(g)	Mass after testing, m_k(g)	Mass change, $\Delta m(g/m^2)$	Oxidation rate, $V(g/m^2h)$	Test time, t (h)	Test temperature, (°C)
1	49,9013	49,8998	-0,67	0,0278	24	750
2	50,9215	50,9194	-0,93	0,0194	48	
3	55,3685	55,3648	-1,64	0,0228	72	
4	52,0765	52,0708	-2,53	0,0264	96	
5	52,8782	52,8688	-4,18	0,0348	120	
6	48,1521	48,1501	-0,89	0,0370	24	850
7	54,2692	54,2659	-1,47	0,0306	48	
8	55,5657	55,5604	-2,36	0,0327	72	
9	47,2863	47,2794	-3,07	0,0319	96	
10	53,2889	53,2784	-4,67	0,0389	120	

Figure 2 shows the change in mass of the samples as a function of the holding time at temperatures of 750 °C and 850 °C, and Figure 3 shows the changes of the oxidation rate for the same test parameters.

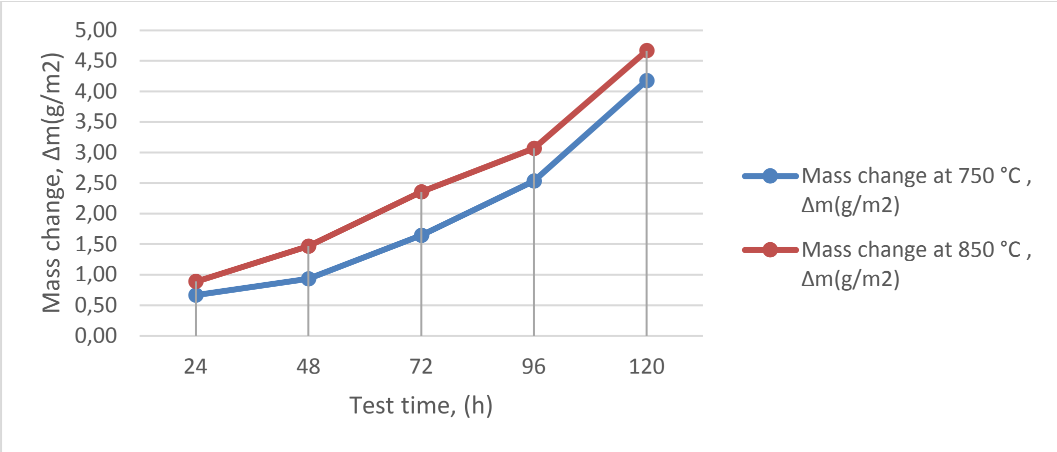

Figure 2. Change of sample mass during oxidation at 750 °C and 850 °C depending on holding time at tested temperatures [3]

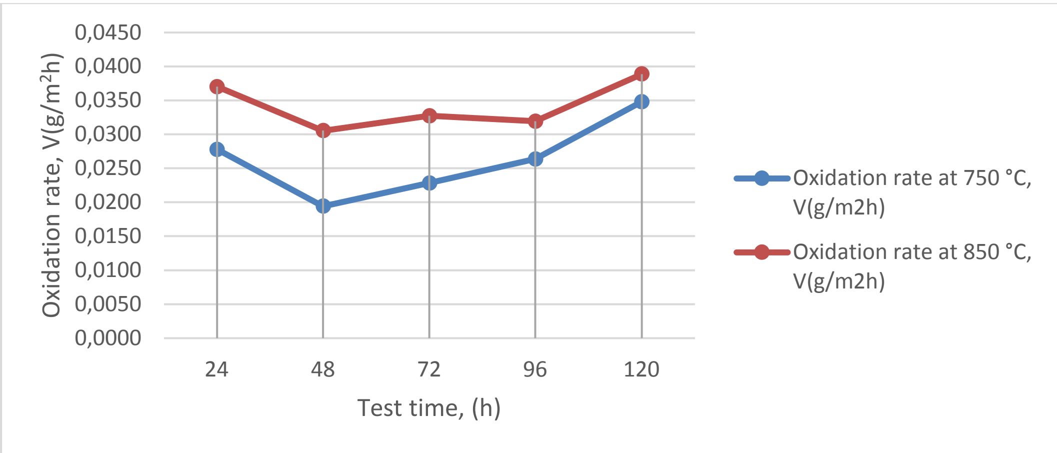

Figure 3. Oxidation rate at 750 °C and 850 °C depending on the holding time at tested temperatures [3]

Analysis of the test results given in Table 2 and graphical presentations of sample mass change and oxidation rate at 750 °C and 850 °C in Figures 2 and 3 showed:

- The mass change is negative because there is a loss of mass during heating,
- The change in mass and oxidation rate is smaller for samples treated at a lower temperature, i.e. 750 °C,
- Mass change increases with increasing test time for both 750 °C and 850 °C,
- In the first holding phase, oxidation rate decreases for up to 48 hours for samples heated at both test temperatures,
- At the oxidation time from 48 hours to 96 hours in samples heated at 850 °C, stagnation at the oxidation rate is observed, ie no significant changes, unlike the samples heated at this time interval at lower temperature, ie 750 °C, where a continuous increase in the rate of oxidation is observed,
- In the 96 hour to 120 hour interval, for both test temperatures, the oxidation rate increases continuously with increasing time,
- General analysis of the results shows that the value of oxidation rate for all tested samples is below 0,04 g/m^2h.

3. CONCLUSIONS

For all samples, the mass change is negative because of losing mass during heating and it increase with temperature and time. The prescribed value of oxidation rate for the heat resistance steels according to EN 10295 is less than 1 g/m^2h for a test temperature of 1100 °C. As all test results showed an oxidation rate of less than 1 g/m^2h, it can be concluded that the test results completely satisfactory, especially at 750 ° C, which is the operating temperature of the engine in which this material is installed.

4. LITERATURE

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