CORROSION RESISTANCE OF AUSTENITIC VALVE STEELS WITH DIFFERENT CONTENT OF CHROMIUM, MANGANESE AND NICKEL IN COMBUSTION GASES OF PROPANE-BUTANE

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Abstract

The corrosion resistance of three grades of valve steels (X33CrNiMn23-8, X50CrMnNiNbN21-9, X53CrMnNiN20-8) in combustion gases of propane-butane (LPG) under thermal shock conditions has been studied. It was stated that X33CrNiMn23-8 steel, containing highest concentration of chromium and nickel and also the lowest of manganese concentration, showed the best corrosion resistance in comparison to another tested steels. The worse corrosion resistance in combustion gases of propane-butane (LPG) was stated in reference to X50CrMnNiNbN21-9 and X53CrMnNiN20-8 valve steels containing lower chromium and nickel concentrations.

Keywords: *V*alve steels, corrosion resistance, thermal shocks, combustion gases of LPG

1. INTRODUCTION

From the nineties years of previous century, permanent increase of vehicles number supplied by propane - butane fuel is observed. In world scale, in 2011 year, the number of vehicle supplied by propane - butane have reached c.a. 15 %. Unfortunately appliance of propane-butane (LPG) fuel causes of high-temperature in engine combustion chamber, which involves sufficient increase of valves and exhaust seats damages. The authors are taken the studies of corrosion resistance of three commonly used austenitic steels in combustion chambers supplied by this kind of fuel. The examinations were performed under thermal shock conditions simulating of work of heavy loaded, exhaust valves of combustion engines with spark ignition, operated in extremely corrosive environment of hot exhaust gases.

2. MATERIALS AND TEST METHOD

Investigations of an effect of alloying elements additions on corrosion resistance of valve steels in exhaust gases of propane-butane (LPG) were performed on a specimens in form of discs with thickness of about 1mm and diameter of 16 and 19 mm, manufactured by turning operation from a drawn bars respectively, from three grades of highly alloyed austenitic valve steels i.e. X33CrNiMnN23-8 and X50CrMnNiNbN21-9, as well as X53CrMnNiN20-8 grades, which have a chemical composition presented in the **Table 1** [1].

Table 1 Chemical composition of examined, austenitic valve steels

Grade of steel	(wt. %)										
	C	Cr	Ni	Mn	Si	W	Mo	Nb	N	S_{max}	P
X33CrNiMnN23-8	0.35	23.40	7.80	3.30	0.63	0.02	0.11	-	0.28	0.005	0.014
X50CrMnNiNbN21-9	0.54	19.88	3.64	7.61	0.30	0.86	-	2.05	0.44	0.001	0.031
X53CrMnNiN20-8	0.53	20.50	4.10	10.30	0.30	-	0.12	-	0.41	0.005	0.040

Specimens to the tests of corrosion resistance, after machining and drilling Φ2 [mm] holes in distance of about 2 mm from the edge of specimens, underwent operation of grinding and polishing with use of a suitable abrasive paper and abrasive compounds. In the next stage the specimens were washed in methyl alcohol and dried in stream of compressed air. After performing of mechanical treatments as mentioned above, the specimens were weighted with accuracy of up to 10^{-4} [g] in air conditioned room, in the next step the specimens were hanged on kanthal pendants, and next, the specimens located in ceramic vessel were inserted into quartz tube of the reactor.

Corrosion test of examined steels were performed under thermal shock conditions, by rapid heating of specimens in LPG combustion gases up to 1173 K and after annealing X33CrNiMn23-8 at this temperature for 2 hrs and next were cooled in room temperature during 25 min [2, 3]. This cycle has been repeated continuously till to reach about 24 hrs of test duration, after this period specimens were taken from the furnace, cooled in open air to room temperature, and then cleaned from protruded, cracked scale by means of compressed air, and next were weighted with accuracy of up to 10^{-4} [g]. Oxidation process of X50CrMnNiNbN21-9 and X53CrMnNiN20-8 steel was carried out up to complete their degradation, i.e. ca. 200 hrs. Because after above test time, specimen made of X33CrNiMn23-8 steel was not still destructed, it was decided for further oxidation. After additional 80 h of annealing, there wasn't stated significant loss of its mass, so farther oxidation was stopped.

Oxidation rate of the valve steels in exhaust gases has been determined with use of gravimetric method of cyclic measurements of gain or loss of mass of oxidized specimens (Δm), with respect to initial surface of the specimens, S and time of the oxidation, t, while corrosion resistance was estimated implementing commonly used to this purpose diagram of mass change of oxidized specimens in function of number of thermal shocks and time duration of the oxidation [4].

The examinations were performed in exhaust gases from propane-butane (LPG) fuel produced during durability test of combustion engine at engine test bench laboratory (**Fig.1**).

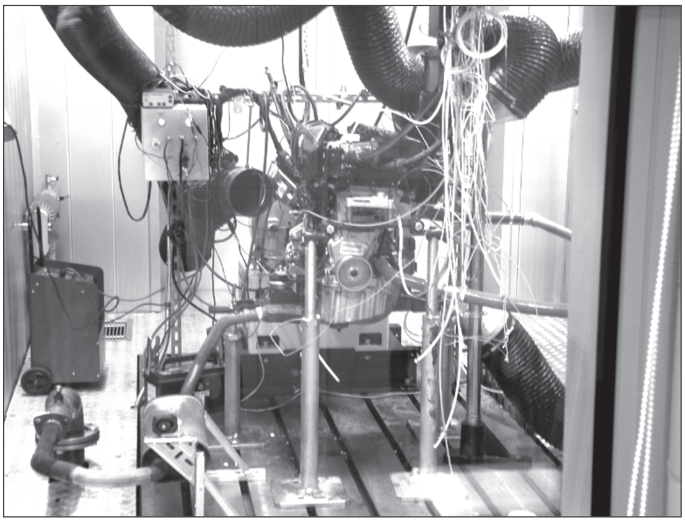

Fig. 1 Durability test of spark ignited combustion engine on engine test bench

3. RESULTS AND DISCUSSION

Performed tests of oxidation rate of the X33CrNiMnN23-8, X50CrMnNiNbN21-9 and X53CrMnNiN20-8 valve steels in exhaust gases of propane butane (LPG) have shown the slowest oxidation rate of X33CrNiMnN23-8 steel having the highest contents of Cr (23.40 %), Ni (7.82 %) and Si (0.63 %), and with the lowest content of Mn (3.30 %), where loss of average mass of the specimens slightly increased to about

0.0007 g/cm^2 after about 120 h of the oxidation at temperature 1173K (**Fig.2**, curve 1). Further increasing of oxidation time up to 280 [hrs] did not cause significant change of average mass of specimens (**Fig.2**, curve 1). In opposite to the X33CrNiMnN23-8 steel, higher oxidation rates shows X50CrMnNiNbN21-9 and X53CrMnNiN20-8 steel, having lower contents of chromium - (19.88 versus 20.50 wt. %), nickel - (3.64 and 4.10 wt. %) and higher contents of manganese - (7.61 and 10.30 wt. %) respectively.

The loss of average mass of specimens made of X50CrMnNiNbN21-9 and X53CrMnNiN20-8 steels after 200 h of the oxidation at temperature 1173 K was significantly bigger and reach values 0.0824 and 0.2155 g/cm^2, respectively (**Fig.2**, curves 2 and 3).

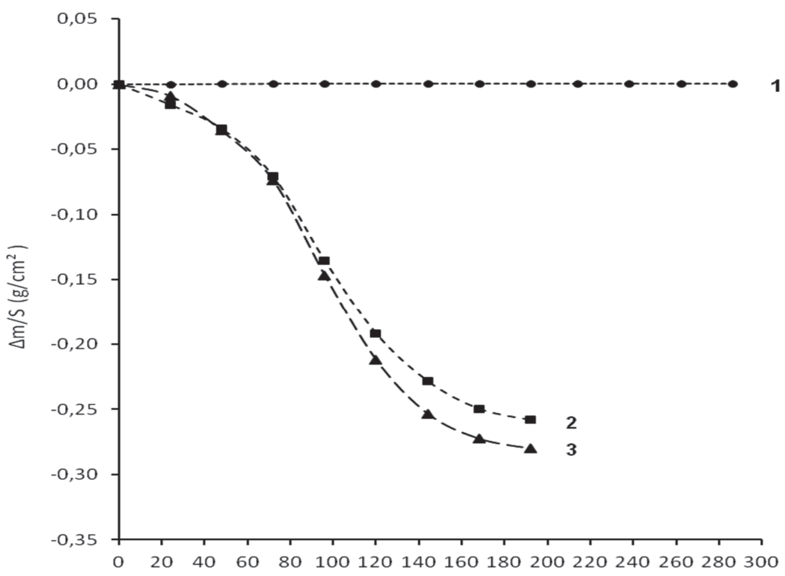

Fig. 2 Corrosion behaviour of valve steels; 1- X33CrNiMn23-8, 2- X50CrMnNiNbN21-9, 3- X53CrMnNiN20-8. under thermal shock conditions at range 1173 K to room temperature, carried out in exhaust gases of propane butane (LPG)

CONCLUSIONS

The results presented of the corrosion behaviour of highly alloyed austenitic valve steels of the X33CrNiMnN23-8, X50CrMnNiNbN21-9 and X53CrMnNiN20-8 grades in combustion gases of spark ignited engine supplied by propane-butane (LPG) shows, that under thermal shock conditions from, 1173 K to room temperature, rate of oxidation of tested valve steels depends on their chemical composition i.e. decrease of chromium content in comparison to X33CrNiMnN23-8 valve steel from 23.4 to 19.88 % and 20.50 %, and nickel from 7.80 % to 3.64 and 4.10 % and increase of manganese from 3.30 % to 7.61 % and 10.30 % cause of significantly worse corrosion resistance of X50CrMnNiNbN21-9 and X53CrMnNiN20-8 valve steels (**Fig.2** and **Table 1**), whereas corrosion resistance of X50CrMnNiNbN21-9 and X53CrMnNiN20-8 valve steels is on comparable level.

REFERENCES

[1] PN-EN 10098 - 1, 2001, *Standard, Valve and Alloys Steels in Combustion Engines.*

[2] GRZESIK, Z., MROWEC, S., JURASZ, Z., ADAMASZEK, K. The Behavior of Valve Materials Utilized in Diesel Engines under Thermal Shock Conditions, *High Temperature Mater. Process.,* 29, 1-2, 2010, 35-46.

[3] GRZESIK, Z., MROWEC, S., JURASZ, Z., ADAMASZEK, K. High Temperature Corrosion of Steel Valves Under Thermal Shock Conditions, *Ochrona Przed Korozją*,53, 3, 2010, 110-114 (in Polish).

[4] NAUMIENKO, D., SINGHEISER L., GUADAKKERS W.J.: Oxidation Limited of FeCrAl Based Alloys during Thermal Cyclic. Proceedings of an EFC Workshop 1999, edited by W.J. Quadakkers and M. Schütze, Frankfurt/Main, 1999, 287-306.