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APPLICATION OF FEAL INTERMETALLIC PHASE MATRIX BASED ALLOYS IN THE TURBINE COMPONENTS OF A TURBOCHARGER

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Preliminary Note – Prethodno priopćenje

This paper presents a possible application of the state-of-the-art alloys based on the FeAl intermetallic phases as materials for the manufacture of heat-proof turbine components in an automobile turbocharger. The research was aimed at determining the resistance to corrosion of Fe40Al5CrTiB alloy in a gaseous environment containing 9 % O_2 + 0,2 % HCl + 0,08 % SO_2 + N_2. First the kinetics of corrosion processes for the considered alloy were determined at the temperatures of 900 °C, 1 000 °C and 1 100 °C, which was followed by validation under operating conditions. To do so, the tests were carried out over a distance of 20 000 km. The last stage involved examination of the surfaces after the test drive. The obtained results are the basis for further research in this field.

Key words: FeAl, structure, intermetallic phase, corrosion, turbocharger

INTRODUCTION

Turbochargers are widely used as effective devices to improve the efficiency of combustion engines and to decrease their exhaust emissions [1]. As one of the basic components of a combustion engine, a turbocharger significantly affects its parameters. It consists of a turbine driven by fumes and a compressor, both mounted on one shaft. The main element of the turbocharger is the rotating unit located in the central housing and supported by bearings [2]. An increase in the operating temperature results in better efficiency which contributes to lower fuel consumption, improved engine characteristics and decreased CO_2 emissions. In compression-ignition engines the exhaust fumes temperature is about 700 °C, and in the case of a petrol engine it may reach 1 000 °C [3]. The operating conditions (high exhaust temperature, continuously changing pressure and high rotational speed reaching 200 000 rev·/min) might cause marked damage of the considered element [4]. Exhaust fumes, containing among others nitrogen, carbon and sulphur oxides, are also an important element of a turbocharger operational environment. That is why the selection of adequate materials from which to manufacture turbocharger parts is of great significance. They should prove to be highly resistant to heat, corrosion and grinding [5]. It was concluded from the results of the research in the field of materials and technology selection that it is possible to create a new group of construction materials with specific mechanical properties and a thermally stable structure that would be based on compounds of iron, nickel, and titan and aluminum [6]. Among the materials meeting the above requirements are alloys based on FeAl intermetallic phase, containing from 36 % to 51 % of aluminum atoms, which have good thermal stability across a wide range of temperatures [7]. They are also higher resistant to corrosion when compared with traditional structural materials and resistant to aggressive environments, to sea water, carburizing, and sulphur activity. At the same time, they have very good tribological properties at high temperatures [8]. FeAl intermetallic phase matrix alloys can be applied in such conditions because during the high-temperature processes in oxidizing atmospheres a shielding layer of aluminum oxide forming on the surface of these materials prevent to the degradation of the metallic core [9]. Intermetallic phases are definitely a prospective structural material to be applied in such branches as automotive industry and energetics [7].

MATERIAL AND METHODOLOGY

The investigated material was an FeAl intermetallic phase matrix alloy, the composition of which is presented in Table 1. It was made from ARMCO pure iron and ARO aluminum (purity: 99, 99 wt %). The process was carried out under vacuum, and the samples made of Fe-40Al5CrTiB alloy were subjected hot extrusion in order to ensure plasticity sufficient for practical applications [9, 10]. The extrusion process was carried out by the original method of the author. The developed technology allowed a repeated quality of the components with no cracks [11]. The resistance to corrosion of the Fe-

Table 1 **Chemical composition of Fe40Al5CrTiB alloy/ wt %**

Fe	Al	Cr	Ti	B
68,22	23,69	5,69	0,19	0,015

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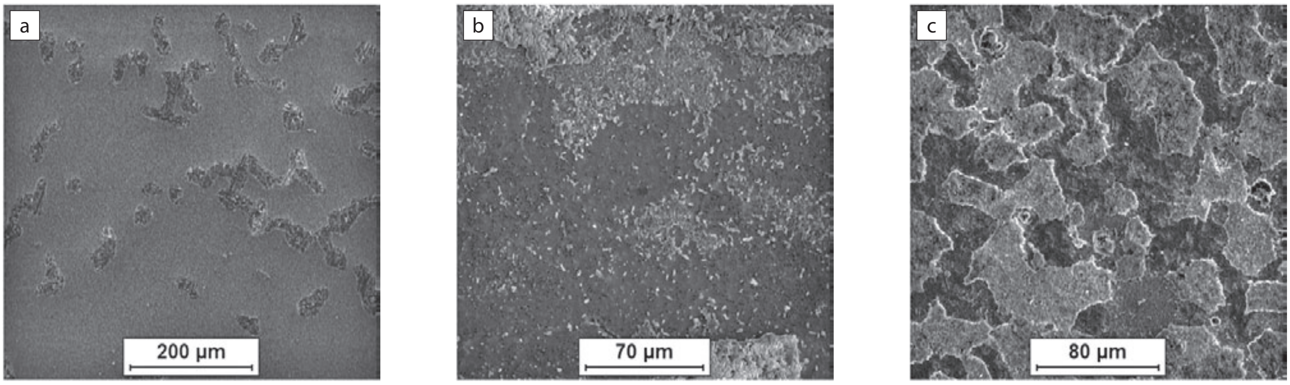

Figure 1 State of the surface of Fe40Al5CrTiB alloy after the corrosion tests at the following temperatures a - 900 °C, b - 1 000 °C, c - 1 100 °C

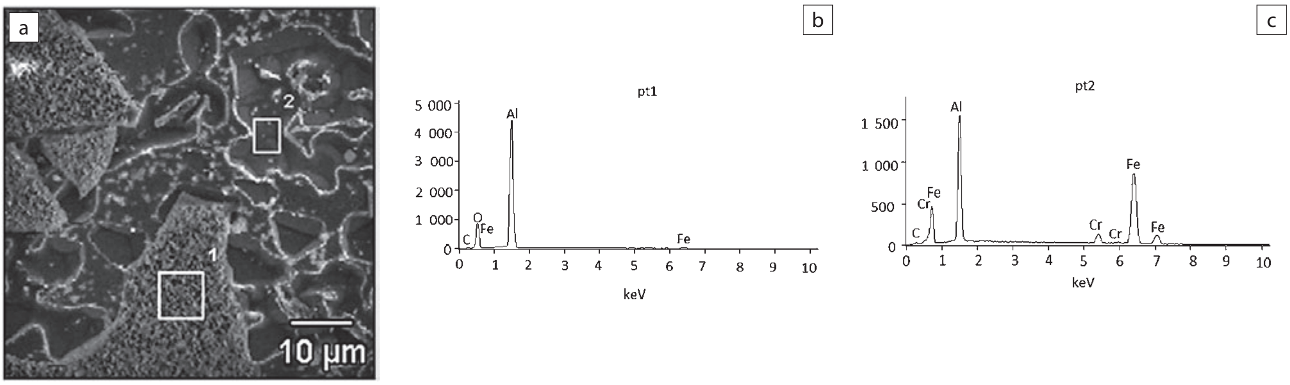

Figure 2 X-ray energy spectra (EDS): a - state surface, b - analysis in point 1, c - analysis in point 2

40Al5CrTiB alloy was investigated in the atmosphere of 9 % O_2 + 0,2 % HCl + 0,08 % SO_2 + N_2 at 900, 1 000 and 1100°C during 500 h. The samples were weighed before and after the test on a laboratory balance with an accuracy of 10^{-4} g [12].

RESULTS OF TEST

The study of Fe40Al5CrTiB alloy being oxidized for 500 hours showed a change in the samples weights which can be linked to the occurrence of scale on the surface of the material. It was demonstrated that aluminum oxidized selectively, forming passive layers of Al_2O_3. Diffusion rate is determined by the oxidizing process, and the oxidization kinetics are parabolic. The condition of the surface after the corrosion test was determined using scanning electron microscope HITACHI S 4200 equipped with an X-ray detector EDS (Energy Dispersive Spectroscopy). It was found that some areas of the surface of Fe40Al5CrTiB alloy are covered by an Al_2O_3 layer (Figure 1). EDS chemical analysis revealed areas of oxygen and a substance with a chemical composition corresponding to that of the native material on the initial state of FeAl intermetallic phase matrix (Figure 2). The research concerned two components of a turbocharger, that is the rollers of the pressure control regulator in the intake manifold and the part of the bush where the ring sealing the turbine rotor axle is placed.

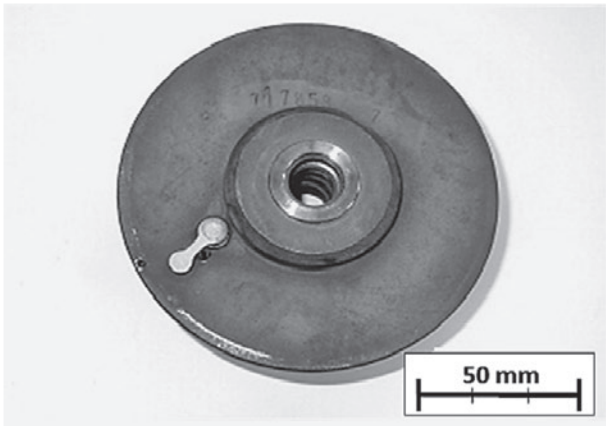

Figure 3 Turbine lid. The arrow indicates the sealing made of the alloy based on FeAl intermetallic phase matrix.

The components were made of Fe40Al5CrTiB intermetallic phase matrix alloy and tested over a distance of 20 000 km in a turbocharger of an automobile Diesel engine. (Figures 3÷5).

A comparison of the surface of the components made of FeAl alloy before and after the test shows no traces of tribological wear. Scanning electron microscope tests of the surfaces of the axles after 20 000 km showed small quantities of corrosion products and carbon deposit (from burnt engine oil). The tests also revealed a few rough areas that might have resulted from metallurgical defects like microshrinkage (Figure 6).

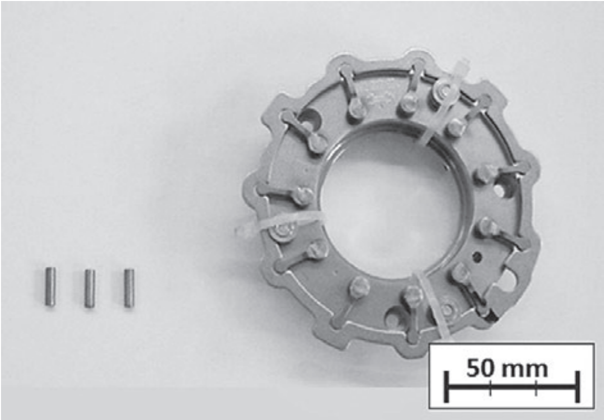

Figure 4 The axles of the pressure control regulator rollers before the test

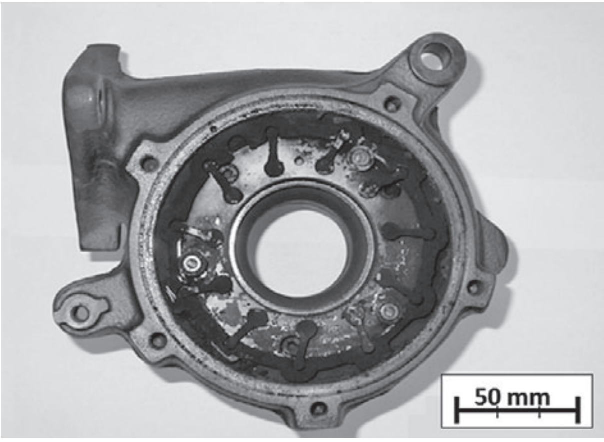

Figure 5 The turbine after 20 000 km

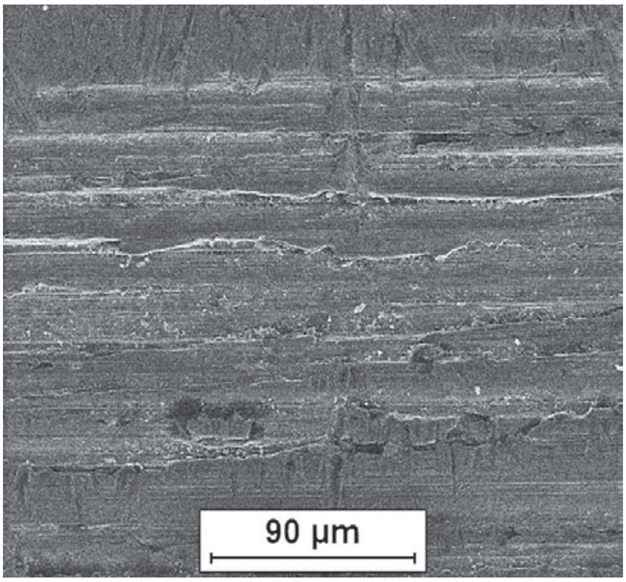

Figure 6 Surface of the roller axle of the control unit made of FeAl alloy. SEM

CONCLUSIONS

FeAl intermetallic matrix alloy tested for heat-resistance in a gaseous environment containing 9 % O_2 + 0,2 % HCl + 0,08 % SO_2 + N_2 at the temperatures of 900 °C, 1 000 °C and 1 100 °C shows very good corrosion resistance. The alloy was used to produce some components of a turbine in a car that was exploited through 20 000 km. The air pressure regulator in the intake manifold was operating property throughout the test. It has been proved that FeAl matrix alloy meets the requirements for heat-resistant materials used in corrosive environments, and the extent of degradation after the tests is so small as to be said that the alloys could potentially be used as the material for the manufacture of turbocharger components.

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Note: The responsible translator for English language is M. Kingsford, Katowice, Poland.