INTERMETALLIC BONDING BETWEEN A RING CARRIER AND AN ALUMINUM PISTON ALLOY

Srećko Manasijević[1], Zdenka Zovko Brodarac[2], Natalija **Dolić**[2], **Mile Djurdjević**[3], Radomir Radiša[1]

[1]LOLA INSTITUTE Ltd, Kneza Višeslava 70a, Belgrade, Serbia
[2]University of Zagreb Faculty of Metallurgy, Aleja narodnih heroja 3, Sisak, Croatia
[3]Nemak Europe, Zeppelinstrasse 24, 4020 Linz, Österreich

Abstract

This paper presents an analysis of the intermetallic bond between a ring carrier and an aluminum piston alloy. An optical microscope combined with the SEM / EDS analysis has been used to metallographically analyze the quality of the intermetallic bonding layer. The obtained results show that can be established intermetallic bond between two materials of different qualities.

Keywords

piston alloys, ring carrier, intermetallic bond, Ni-Resist, Al-Fin process analysis of the quality, MAGMA[5], CAE, casting process simulation

INTRODUCTION

Pistons are made mostly of aluminum multicomponent alloys (Al−Si−Cu−Ni−Mg), which are used in the automotive industry due to a combination of good casting and mechanical properties [1−5] high strength at elevated temperatures (up to 350 °C) [1,2] and also resistance to sudden temperature changes [1,3−5]. Depending upon the engine type and operating conditions, there are different design solutions for pistons.

This paper deals with pistons for highly-loaded diesel engines with a ring carrier. The ring carrier is specially designed to form the first piston ring groove. The ring carriers of standard features are made of austenitic cast iron (Ni-Resist) in order to increase the wear-resistance of the first ring groove, especially in engines with high loads [5−9]. Austenitic gray iron castings are used primarily for their resistance to heat, corrosion, and wear, as well as controlled expansion, temperature stability, castability, and machinability. The Ni-Resist ring groove inserts are manufactured into pistons to increase engine and piston life.

In the meantime, they can also improve the air-tightness of the piston in the cylinder, increase the efficiency of combustion, reduce emissions and air pollution, and contribute to the environment.

The alfin process is a method for preparing a ferrous surface for intermetallic bonding [5−9]. The alfin bonding process is commonly used to bond a non-ferrous Al alloy and a ferrous alloy. It is well known that cast iron contains carbon as a result of the casting process [5−9]. During the piston casting, the ring carrier is soaked by the alfin bond process, which results in a strong connection with the piston material. During this process, an intermetallic layer composed of FexAly is formed on the border between the two different materials by the diffusion of atoms [5−9].

The aim of this paper is to conduct a detailed analysis of the intermetallic bonding layer that is formed between the ring carrier and the piston.

EXPERIMANTAL

The tests were performed on an Ø89 mm piston for a diesel engine. A cross-section of the investigated piston casting with its macrostructure and indicated sampling point is shown in Figure 1a. The chemical compositions of the piston alloys and ring carrier given are in Table 1. In this case, the hardness of the ring carrier is 140−150 HBS (the standard is 120−160 HBS) [5].

Table 1. Chemical composition of the experimental alloy (wt. %).

Alloy	Element/chemical composition									
AlSi13Cu4Ni2Mg	Si	Cu	Ni	Mg	Fe	Mn	Cr	Ti	Zr	V	Al
	13.05	3.80	2.01	0.90	0.52	0.19	0.09	0.07	≈0.03	≈0.01	residual
Sample of the ring carrier	Ni	Cu	C	Cr	Si	Mn					Fe
	15.10	6.32	2.81	2.21	1.89	1.23					residual

RESULTS AND DISCUSSION

Figure 1 shows the microstructure of the piston cross-section, where the successful intermetallic bond between the ring carrier and the piston alloy is shown.

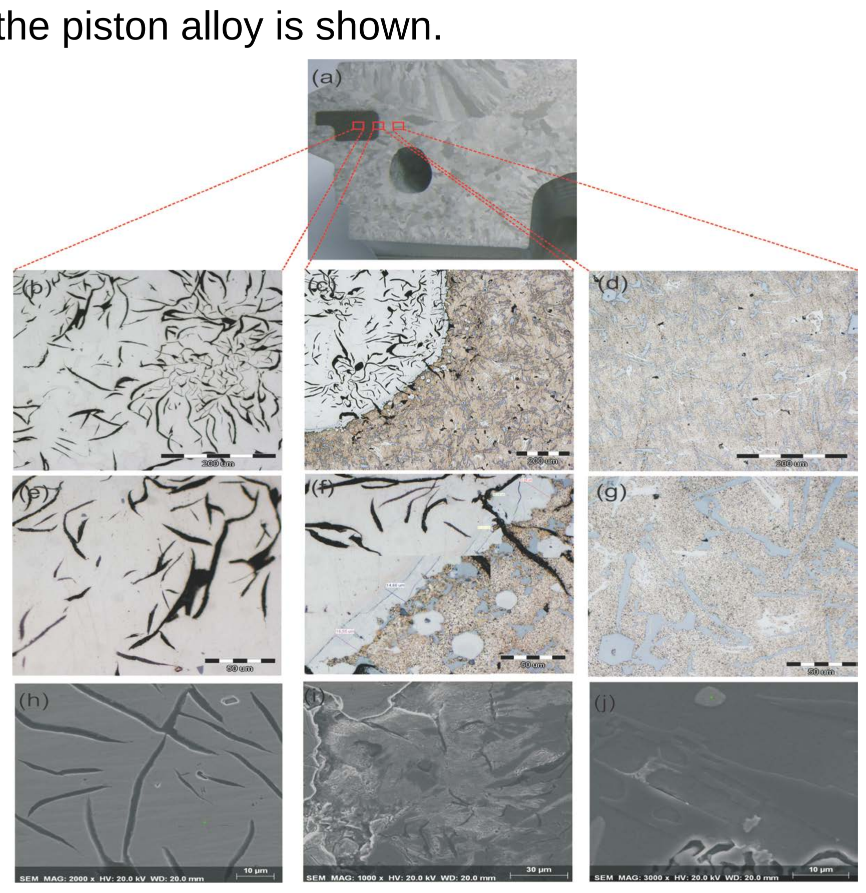


Figure 1. Microstructure of the ring carrier-alfin bond-piston

Figure 2a shows a SEM analysis while Figure 2b shows an EDS mapping of all the elements in the intermetallic bonding layer. Figures 2c to 2h show the EDS mapping of other important elements (Fe, C, Ni, Cu, Si and Al).

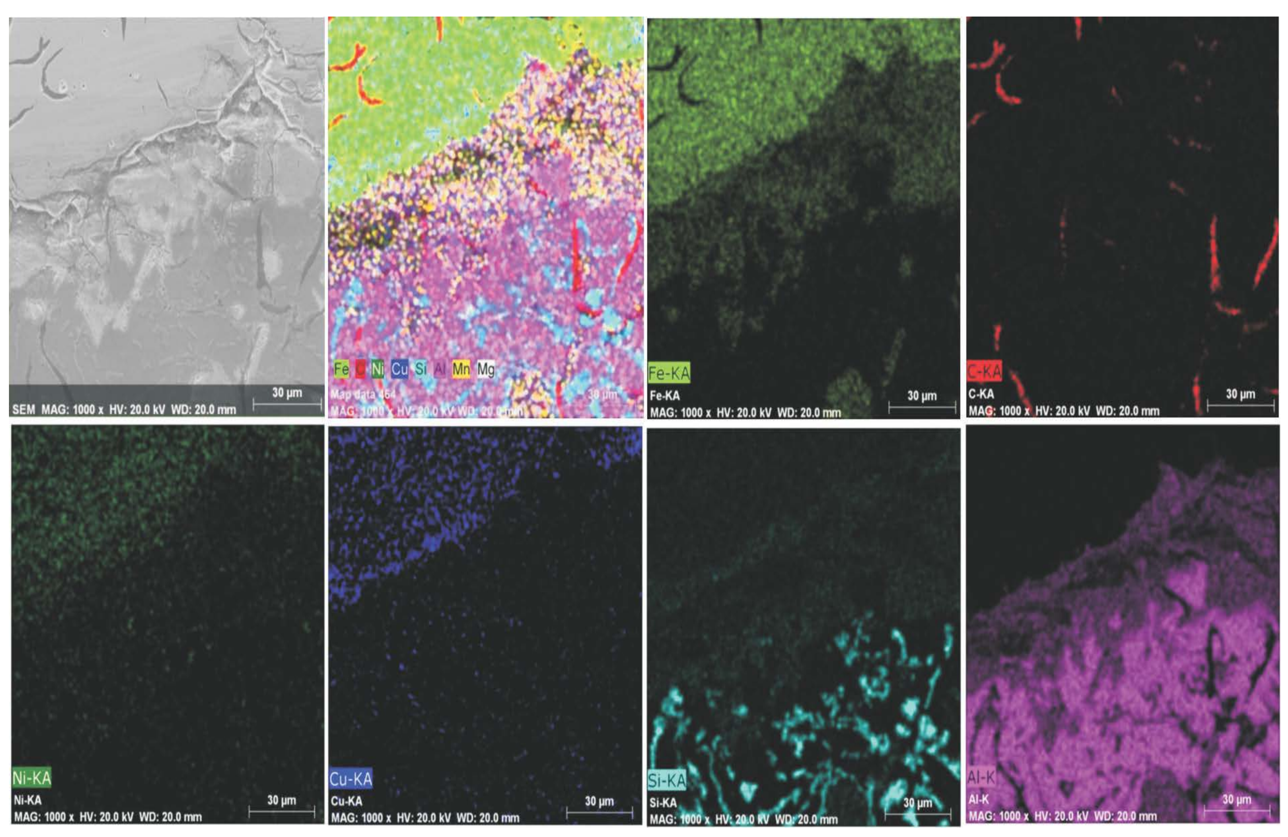
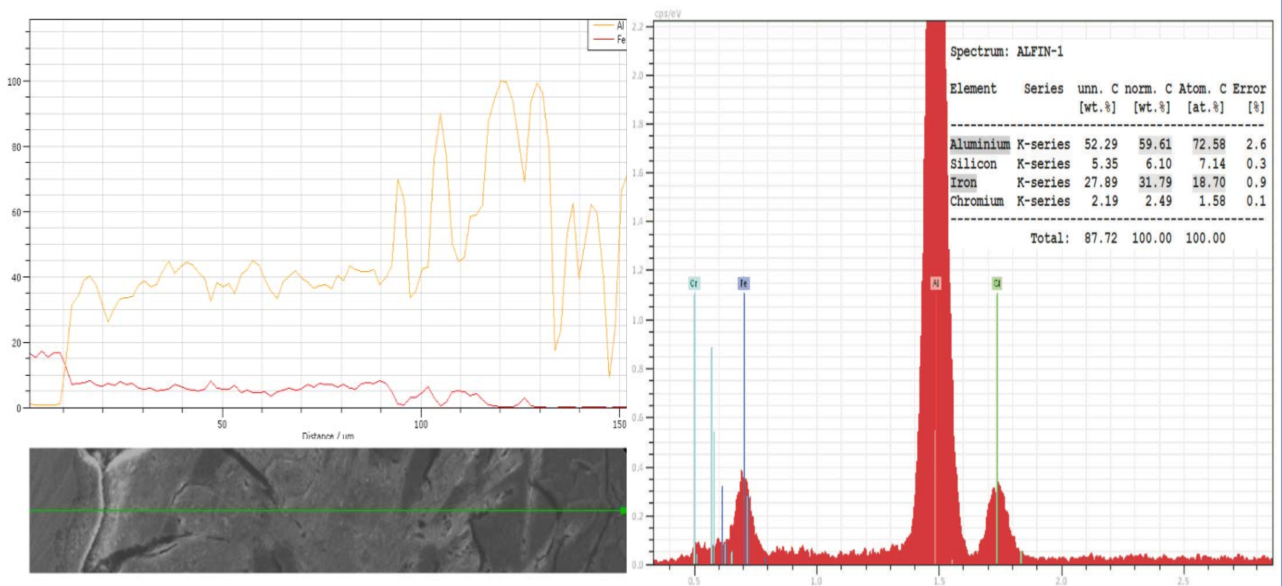


Figure 2. The intermetallic bonding layer: a: SEM, 1000x; b: EDS mapping of all elements and EDS mapping; c: Fe; d: C; e: Ni; f: Cu; g: Si; and h: Al [15]

In the second step, a line EDS analysis of element distribution in the intermetallic bonding layer was made. The results of this analysis are shown in Figure 3. The point of line analysis is indicated in Figure 3a while in Figure 3b only for Al and Fe.



a) b)

Figure 3. Analysis of the intermetallic bonding layer: a: SEM, 1000x; b: EDS analysis changes in all elements; c: EDS analysis, changes in Al and Fe; and d: EDS identification of FexAly [15].

CONCLUSIONS

Based on the analysis of the experimental test results presented in this paper and the available data from the literature, it can be concluded that if the manufacturer's instructions defined for casting pistons with the ring carrier are applied completely, a good metal connection can be formed between the two quality materials.

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Corresponding autor: Ph.D. Srećko Manasijević, srecko.manasijevic@li.rs