OPTIMIZATION OF THE ALPHINIZING TEMPERATURE OF RING INSERTS IN CASTS OF COMBUSTION ENGINE PISTONS

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Abstract

One of the most important parameters of the alphining process, besides the time of immersion in the bath and the chemical composition of the metal, is the temperature of the liquid alloy. Alphinizing is an immersion process of aluminium plating of a part in order to produce a thin adherent layer on its surface which, after casting into a mould, is a bonding layer in a bimetallic connection between ring carrier and piston. This paper presents different alphin temperatures for cast iron ring inserts in order to compare the influence of the process temperature on the quality of the produced diffusion layers. It turns out that lowering the temperature from 770°C to 750°C gives good results in terms of quality of produced layers and in terms of extension of the use of one batch of metal to the furnace by about 25-30%. Temperature optimization makes it possible to reduce the consumption of primary materials, energy consumption and, as a result, to reduce the costs of manufactured products.

Keywords: Aluminum alloys, alphinizing process, casting, quality, automotive

1. INTRODUCTION

Improving the quality of products and services, an important criterion for the success of every business, may be achieved by efforts to prevent problems appearing at the source. This is one element of the concept of quality control [1], which places the major emphasis on those activities that aim to limit various forms of waste and anomalies [2-5].

This particularly relates to the automotive sector, where core quality tools have a particular significance. They include, among others, the control of the process in every phase (Control Process) [6,7]. One of these tools is the optimalization of the parameters of the piston casting process, including the alphinizing of ring carriers. This has a key influence on the strengthening of the upper ring groove on the side of the combustion chambers. The ring carrier, constructed from austenitic iron, is submerged in the aluminum piston casting in order to strengthen its adhesion with the piston. This is called the alfin bonding. Parameters defining high quality alfin bonding are: a uniform diffusive coating of specified thickness and a low share of detrimental iron phases such as $Al_XFe_YSi_Z$, which weaken the alfin layer.

During the alphin process of the Al-Si alloy the iron content increases via a diffusion path, and after attaining the permitted level the metal is poured off and exchanged for new material. The alloy which is contaminated by iron is stored as ingot and treated as scrap. The time of maintaining the alloy until alphinization depends on the size of the crucible, the number of immersed pieces, the temperature and time.

Diffusion processes taking place during alphinizing depend on the temperature of liquid metal [8-13]. The present study proves that reducing the alphinization temperature results in reduction of the intensity of the diffusion process and slows the increase in iron to the border value, thus extends the alloy using time.

2. STUDY OBJECTIVE AND SCOPE

The objective of this study is to determine the optimal temperature of the alloy for alphinizing of ring carrier (alloy AS9) with the goal of limiting the growth of iron content during the alphin process and foremost, guaranteeing the quality requirements of the produced piston castings.

The study was conducted at the casting station equipped with an alfin station at the production plant of Federal-Mogul Gorzyce sp. zo.o (FMG), one representative of so-called OEM's (Original Equipment Manufacturers). The study scope includes:

- A description of the alphinizing process of engine piston rings,
- Alphinizing of ring carriers at the temperatures: 770^{o}C, 760^{o}C and 750^{o}C,
- Analysis of the material defects at the interfacial area of the piston casting with the ring at given temperatures.

3. MATERIALS AND STUDY METHOD

The study focused on the castings of combustion engine pistons intended for car gasoline and diesel engines. The temperature of the alloy for alphinizing of ring was registered with the assistance of a Ni Cr thermocouple and a temperature regulator coupled with the furnace driver. An increase in the iron content of the AS9 alloy was monitored every hour by taking samples for chemical content analysis with the assistance of an emission spectrometer SpectroLAB AMETEC LAV12 until the attainment of a borderline content of Fe 3.5 mass %. The castings underwent the same processes as in normal production until the attainment of the final product after machining.

An assessment of the quality of the material defects in the interfacial area of the piston casting and the ring carrier was conducted based on internal quality norms. Adhesion tests of the piston rings were conducted with the help of an ultrasound adhesion method and a dye penetration test. Material tests of the adhesive layer at the ring – piston interface were conducted in FMG materials laboratory by taking metallographic samples and assessing their macro- and microscopic morphology of the alfin diffusion layer with the assistance of a Digital Keyence VHX7000 microscope and a Zeiss Axio Observer metallographic microscope.

The alphinizing station is presented in (**Figure 1**).

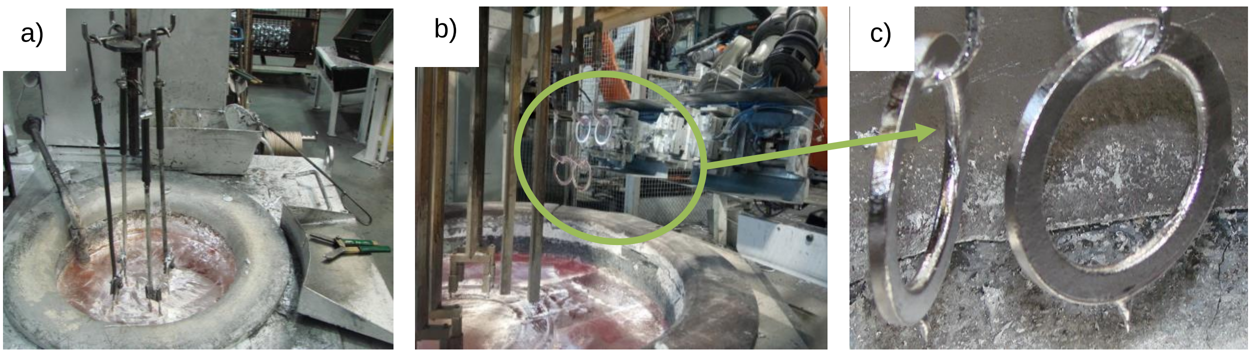


Figure 1 Station for the alphinizing of piston ring carriers: a) manual approach; b) automated approach; c) piston rings after the alphin process

4. STUDY RESULTS

The pistons were produced from the alloy S2N, while ring carriers were produced from GJLA-XNiCuCr15-6-2 austenitic iron, which were alphin in the AS9 alloy. The results of the chemical composition analysis of the combustion engine piston castings are presented in **Table 1**, the ring carrier– in **Table 2**, and the alloy AS9 – in **Table 3**.

Table 1 Chemical composition of the alloy used in casting combustion engine pistons (%)

Element	Content (%)
Si	11.3 – 12.5
Cu	3.0 - 3.6
Mg	0.5 – 1.0
Ni	2.0 – 2.5
Fe	Max 0.5
Mn	Max 0.2
Zn	Max 0.1
Ti	Max 0.05
Pb	Max 0.05

Table 2 Chemical composition of the iron ring carriers for combustion engine pistons (%)

Element	Content (%)
C	2.73
Si	2.21
Mn	1.09
P	0.062
Cr	1.16
Ni	13.91
Cu	6.49
S	0.0255

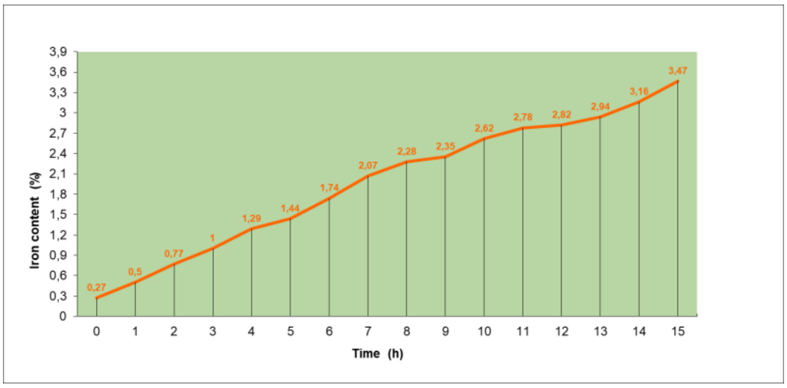
Table 3 Chemical composition of the alphin alloy (AS9)

Element	Content (%)
Si	9.5
Cu	≤ 0.1
Mg	≤ 0.1
Mn	≤ 0.5
Fe	≤ 0.65
Ti	≤ 0.15
Zn	≤ 0.15
Ni	≤ 0.05
Pb	≤ 0.05

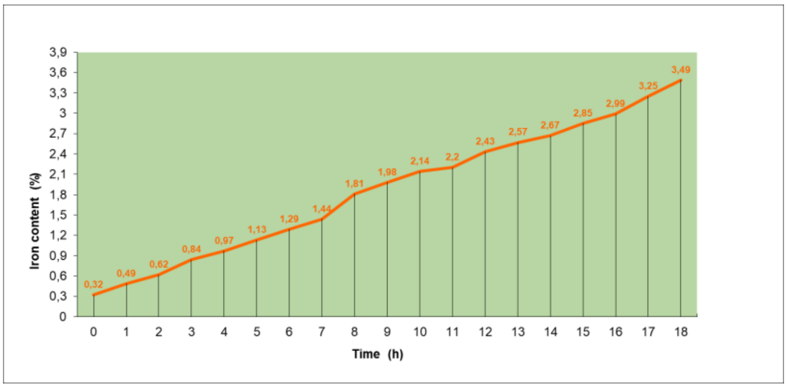
Results for the increase of percent content of iron in the AS9 alloy in the temperatures 770°C, 760°C, 750°C presented in (**Figure 2**).

Correctly produced alfin coating and microstructure in the interfacial area between the piston material with the ring carrier in temperatures 770°C, 760°C, and 750°C are presented in **Figure 3**.

a)



b)



c)

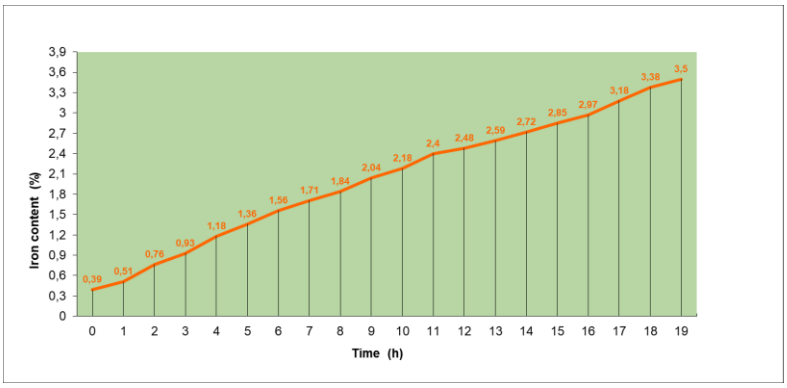


Figure 2 Change in the percent share of iron in alloy AS9 at temperatures: **a)** 770^{o}C; **b)** 760^{o}C; **c)** 750^{o}C

The conducted study points to the optimal temperature for alphinizing of ring carrier with respect to the increase in iron content, which should be 750^{o}C. This implies that the maximum iron content in alloy AS9 is attained after approx. 19 hours of the alphin process. This allows for the extension of the alphinizing time of one batch of metal by 26% in comparison to the standard process conducted at a temperature of 770^{o}C. Extension of the processing time of the metal at a temperature of 750^{o}C is dependent on the size of alfin crucible and the number of rings being deeping in alloy during the process. **Figure 3** presents the results of the analysis of the microstructure and thickness of the layers in the studied areas at the interface of the ring and the piston material at defined temperatures.

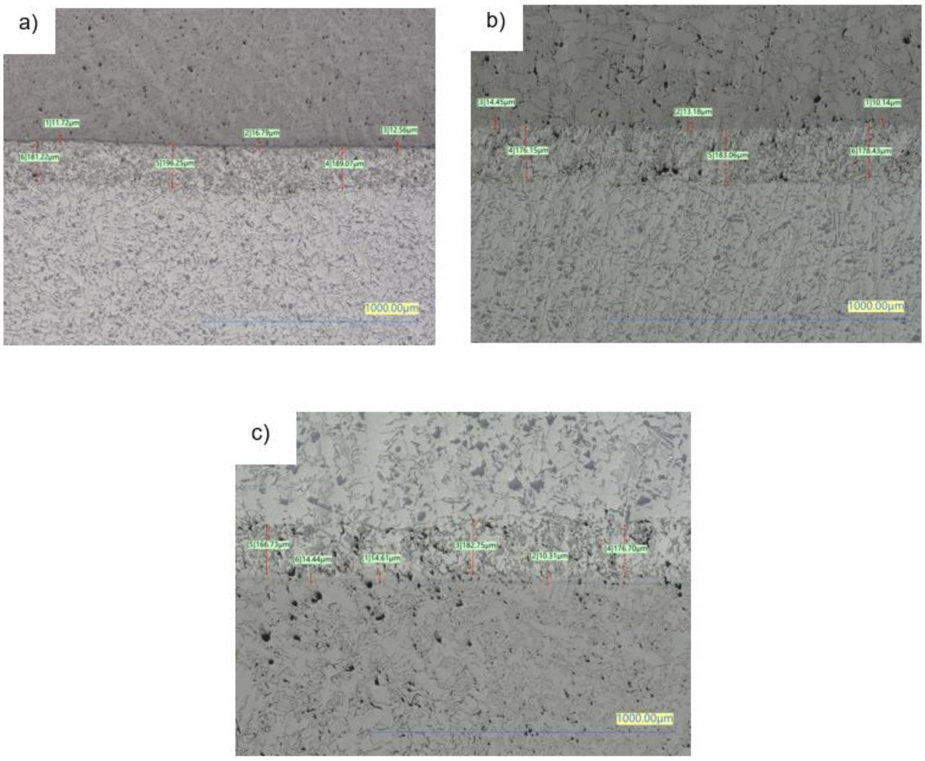


Figure 3 Microstructure of the interface area of the piston casting and ring carrier at the temperature: **a)** 770°C; **b)** 760°C; **c)** 750°C. Magnification X 200

Table 4 presents the results of the measurement of the diffusion and drag out layers depending on the alphinizing temperature. They indicate that the thickest drag out layer attained a temperature of 770°C, and the thinnest layer was produced in the temperature of 750°C. All of the layers are found within the norms and requirements for an appropriately strong alfin bonding layer.

Table 4 Comparison of the thicknesses of the alphin layers

Alphinizing temperature	Thickness of the diffusion layer (µm)	Thickness of the drag out layer (µm)
770°C	11.72	181.22
	16.79	196.25
	12.56	189.07
average	**13.69**	**188.85**
760°C	14.45	176.15
	13.18	183.06
	10.14	178.43
average	**12.59**	**179.21**
750°C	14.44	166.73
	14.61	182.75
	10.31	176.70
average	**13.12**	**175.39**

5. CONCLUSION

On the basis of the conducted technical tests and laboratory study, an optimal alphinizing temperature was determined for the iron ring carriers applied into the engine piston castings, that is, 750 °C. The optimalization of the process temperature allows for the extension of the use of one batch of metal for alphinizing by 25 – 30 %, and so for the limitation of its consumption. Reduction of the temperature of the alloy for alphinizing did not worsen the quality of the bonding of the ring with the piston casting or the morphology of the components of the microstructure occurring in this layer. Only an insignificant reduction of the thickness of the bimetal layer was determined, which may be explained by the reduced intensity of the developing diffusive processes in the area of the interface between the ring carrier and the piston casting. The use of a reduced temperature for the alphin bath is justified from a quality and economil perspective, and a reduced use of materials and energy allows for a reduction in costs of the produced parts. This study may be the beginning of further development possibilities regarding the optimalization of the alphinization process of iron ring carriers in engine pistons.

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