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Chosen Aspects of Quality Defects of "Alphin" Inserts in Combustions Pistons

J. Piątkowski^{a*}, P. Kamiński^b^a Silesian University of Technology, Faculty of Materiale Science, Krasińskiego 8 street, 40-019 Katowice, Poland^b Kamsoft – Joint Stock Company, 1-May 133 street, 40-235 Katowice, Poland

*Corresponding author. E-mail address: jaroslaw.piatkowski@polsl.pl

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Abstract

The chosen, typical causes of quality defects of cast-iron „alphin” rings embedded in aluminum cast are being presented in this paper. Diffusive joint of those inserts with the pistons casts is being used, due to extreme work conditions of destructive influence of the fuel mix and variable thermo-mechanical loads, which reign in the combustion motor working chamber.

Keywords: Al-Si casting alloys, Quality defects, „Alphin” inserts, Motor pistons

1. Introduction

On crank-piston system in the combustion motors, apart from many drive elements, are also piston and rings. The task of the piston is to conduct reciprocating movement, as a result of change chemical energy (contained in the fuel mix) to mechanical and heat energy in the burning process. Most of pistons are being casted from silumins, since they are characterized by good mechanical, abrasive and fatigue properties, good heat conductivity, low specific gravity and resistance to corrosion [1÷3]. In case of heterogeneous motors another, important element are the cast iron piston's rings (usually three), which task is to transfer the heat from the piston to cylinder and control oil consumption. First ring, called the sealing ring is responsible for sealing the burning chamber, so the combustion gases cannot get through to the motor hull. The ring fixed at the bottom of the piston, called the collecting ring, gathers the excess oil off the cylinder's plane. There is also middle ring compressing-collecting, which additionally seals the cylinder and gathers excess oil [4, 5]. In order to adjust the shape of the rings to the piston's material and to the cylinder walls, the bimetallic casts are being used with permanent diffusive connection achieved in

alphining process [6, 7]. Such casts are characterized by high durability and abrasive resistance of cast-iron (or steel) and good heat conductivity of Al alloys in connection of their low density.

As it comes from motor's pistons wear, the problem often is the crumbling of the rings, apart from cracking the pistons bottoms. The reason are the casting defects, for example the notches created by the edges created mainly on the connection line of piston and ring, therefore the important thing is the analysis of potential reasons of quality defects while bimetallic casts are being formed [8, 9].

2. Scope and purpose of research

The goal of this article is the analysis of the most important causes of quality defects of motor pistons casts during production process.

In order to achieve the assumed goal, the scope of work includes:

- “alphin” rings production stages, and their casting in pistons,
- quality defects occurrence problem identification,
- defining the reasons of quality defects of „alphin” rings and pistons as well as the connections between them,

- responsibility for detected casting defects,
- proposed ways of improvement in order to limit the defects.

3. Research methods and materials

The analysis of quality defects, while casting pistons of combustion motors along with cast-iron rings, has been started with the description of their production process, through milling, grinding, embedding in the piston's cast, and finally quality control of the „alphin” ring connection with the piston material (AlSi). The reasons for the quality defects were ordered as per the following criteria: human factor, materials, machines, production methods, management responsibility.

4. The results of investigations

The chemical composition of Al-Si cast alloy, used for the production of motor pistons is shown in Table 1, and in Table 2, the chemical composition of the cast-iron used for piston's rings.

Table 1.

Chemical composition of AlSi12Cu3MgNi cast alloy

| Chemical composition [wt.%] | | | | | | | | |
|-----------------------------|------|------|------|------|------|------|------|------|
| Si | Cu | Mg | Ni | Fe | Mn | Zn | Ti | Zr |
| 12.32 | 3.21 | 0.57 | 2.21 | 0.44 | 0.07 | 0.04 | 0.03 | 0.09 |

Table 2.

Chemical composition of the cast iron for piston rings

| Chemical composition [wt.%] | | | | | | | | |
|-----------------------------|------|------|------|------|------|------|------|------|
| Ni | Cu | C | Si | Cr | Mn | Zn | P | S |
| 13.92 | 6.51 | 2.74 | 2.21 | 1.14 | 1.07 | 0.02 | 0.06 | 0.02 |

The typical quality defects are, between other:

- vesicles in rings and on the connection line with the piston,
- metallic and non-metallic inclusions by the insert,
- no adherence of the „alphin” ring (insert),
- improper ring diameter,
- cavities porosity on the connection with the piston (Fig. 1).

The production process of „alphin” rings, until their storage on the casting stand consist of the following stages:

- austenitic cast iron rings casting with centrifuge method,
- machining of cast-iron rings (lathing),
- rings quality control (visual and measurements),
- packing into the foil sleeves and cardboard,
- transportation to the department, where the rings are being prepared for embedding,
- grinding in order to achieve required roughness,
- heating in chamber furnace in order to remove moisture from the insert's surface,
- control of process parameters (grinding and heating registry),
- storing the rings on the stand for casting them in the pistons.



Fig. 1. Shrinkage cavity on the connection place of „alphin” ring with the piston (a-c), piston's rings (d)

The „alphining” process of cast-iron rings and embedding the combustion motor pistons includes:

- collecting the ring for „alphining”,
- placement of defined number of rings on ceramic hook,
- cleaning the liquid metal surface for „alphining”,
- immersion of the hook with rings in the “alphining” alloy, inside the heating furnace,
- vibration exciting of the ring in order to intensify the diffusion process, (time around 180 to 240 seconds),
- placement of the ring in the mold for pistons casting,
- flooding the mold with silumin after the ring is fixed,
- removing the cast from the mold,
- cutting off the inlet system and milling process for the piston.

The piston with inlet system and ready product (Fig. 2).

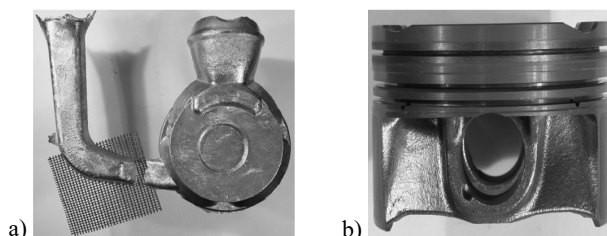


Fig. 2. Piston with inlet system (a) and final product (b)

The Fig. 3 shows the microstructure of piston's AlSi12Cu3MgNi alloy and austenitic cast-iron.

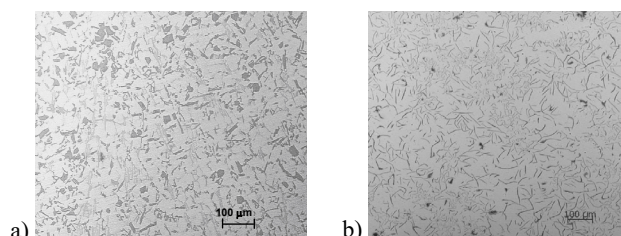


Fig. 3. Microstructure: a) piston's silumin AlSi12Cu3MgNi, b) austenitic cast-iron of pistons ring

Considering the stages of cast-iron rings production and alphining process, as well as the embedding of combustion motor's pistons, at first the identification of the causes and results of quality defects has been identified, considering human aspect (Table 3). The reasons of the quality defects of combustion motor's pistons due to the material deficiencies are shown in Table 4.

Table 3.

The reasons and consequences of quality defects from production process of combustion motor's pistons due to human aspect

| The reason for detected defect | Reasons of the occurrence |
|-----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Touching the rings with bare hands, contamination, greasiness | <ul style="list-style-type: none"> ○ making one's work easier, ○ uncomfortable technical-organizational solutions, ○ employees negligence, ○ no improvement on production. |
| Improper actions while alphining the insert | <ul style="list-style-type: none"> ○ negligence and haste, ○ bad Staff management, ○ many operations to be completed. |
| Improper installation and dismounting of the ring from the mold during embedding in the alloy | <ul style="list-style-type: none"> ○ haste and carelessness, ○ lack of work experience, ○ monotony at work, ○ lack of personnel motivation, ○ lack of post rotation , ○ no development of personnel management methods. |
| Extensive burdening of work posts | <ul style="list-style-type: none"> ○ limiting the employment, ○ need for higher profitability, ○ limiting the cost of work. |

Table 4.

The reasons and consequences of quality defects from production process of combustion motor's pistons due to the used materials

| The reason for detected defect | Reasons of the occurrence |
|---------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Improper preparation process of liquid alloy for "alphining" | <ul style="list-style-type: none"> ○ low quality materials, ○ founds savings, ○ employees negligence, ○ no improvement on product. |
| Gassed alloy, non-metallic inclusions | <ul style="list-style-type: none"> ○ carelessly conducted refining process and haste, ○ bad Staff management, ○ no measurement for refining |
| Improper (too high) iron level in the alloy for "alphining" process | <ul style="list-style-type: none"> ○ technological mistakes, ○ lack of effective method, ○ lack of post rotation, ○ no personnel engagement |
| Overly polluted surface of liquid metal (alloy) | <ul style="list-style-type: none"> ○ alloy oxidation, ○ complicated process, many technological operations, ○ obsolete machines, no improvement on equipment, |
| Careless chemical content analysis of the alloy for "alphining" | <ul style="list-style-type: none"> ○ no supervision, procedures, ○ no time, ○ excess of duties. |

The reasons and consequences of the quality defects after production of combustion motor's pistons due to the anomalies in the machinery (Table 5). The reasons and consequences of the quality defects after production of combustion motor's pistons due to the improper methods used for production (Table 6).

Table 5.

The reasons and consequences of quality defects from production process of combustion motor's pistons due to the machinery

| The reason for detected defect | Reasons of the occurrence |
|-----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Improper parameters of the machine, too long time until the mold inundation | <ul style="list-style-type: none"> ○ limited efficiency of casting machines, ○ obsolete machines, ○ no investments, ○ high production cost |
| Improper preparation of the casting mold | <ul style="list-style-type: none"> ○ heating break-down, ○ no check-ups for the machines, ○ belittling the problem, ○ unawareness of the losses |
| Improper casting ladle alignment for casting liquid alloy | <ul style="list-style-type: none"> ○ haste and carelessness, ○ lack of experience, ○ improper choice of parameters, ○ programmer's mistake, ○ often omissions at work, ○ personnel's haste. |
| Manual fixing of the rings | <ul style="list-style-type: none"> ○ lack of process authorization, ○ too high cost ○ investment and labor cost profitability analysis, ○ variable production assortment. |

Table 6.

The reasons and consequences of quality defects from process of combustion motor's pistons due to improper production methods

| The reason for detected defect | Reasons of the occurrence |
|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Damaged casting tongs, lost connection | <ul style="list-style-type: none"> ○ no innovation at work, ○ old production methods, ○ uncomfortable technical-organizational solutions, ○ no trainings for employees, ○ limited funds |
| Improper fixing the rings on the hook (sling) | <ul style="list-style-type: none"> ○ lack of better method, ○ lack of supervision people, ○ excess of duties, ○ big production orders |
| Manual operations during the "alphining" process of the piston rings | <ul style="list-style-type: none"> ○ lack of better method, ○ work limitations, ○ market risk, ○ variable requirement of automotive market |
| The whole procedure, manual cycle of the employees | <ul style="list-style-type: none"> ○ lack of automatisisation, ○ high investment cost, ○ excessive machinery, ○ biggest producer |

The reasons and consequences of the quality defects after production of combustion motor's pistons due to the bad responsibility of the management are shown in Table 7.

Table 7.

The reasons and consequences of quality defects from production process of combustion motor's pistons due to bad responsibility of the management

| The reason for detected defect | Reasons of the occurrence |
|----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Improper conditions of piston's rings storage at the production department | <ul style="list-style-type: none"> ○ unawareness of influence, that bad conditions has on quality, ○ no trainings for employees, ○ certainty of the decision's validity. |
| Too long production time from heating and grinding to piston's embedding | <ul style="list-style-type: none"> ○ bad product organization, ○ bad logistics organization, ○ lack of people's awareness, ○ lack of trainings |
| Rings deliveries to embedding stands logistics | <ul style="list-style-type: none"> ○ unawareness of the management and supervision staff, ○ old management methods, ○ negligence at work, ○ limited development |
| No "technical culture" of the employees while dealing with the rings | <ul style="list-style-type: none"> ○ lack of mechanization work, ○ lack of automatization work, ○ no quality control, ○ numerous irregularities of the piston's process, ○ limited company development possibilities, ○ high labor cost, ○ monotony at work. |

5. Conclusions

This article is about identification of quality defects of "alphin" inserts and combustion motors pistons in one – chosen – automotive factory. Assembled expert group, with the use of brainstorming, helped with finding and determining the reasons for quality defects. Each stage of production and embedding the „alphin” ring in piston's material was described, as well as problems that occurred, with the help of examples of typical quality defects (Draw.1).

The reasons for rings and motor pistons defects were divided into five groups: human factor, materials, machinery, production methods and management responsibility. On this basis the following angles of improvement were advised.

In the aspect of human factor, the advices are:

- keeping the hygiene while touching the rings,
- increased diligence of blue-collar workers,
- motivation for better work through the bonuses e.g. financial,
- increased awareness of the responsibility through more frequent trainings on the subject of "common" responsibility,
- more frequent controls in the casts quality departments.

In the aspect of methods, it was proposed to:

- automation for the rings and pistons production process,
- mechanical fixing of the inserts in the "alphining" process,
- logistics improvement for internal transportation.

As for the machinery aspect, expert team suggested to:

- conscientious checking the dimensions and shape tolerances,
- periodical testing of the surface roughness,
- exchange of the old machines with modern ones.

The area of materials, the angles of limiting the quality defects occurrence during the process of combustion motor pistons are:

- more frequent controls of the charge materials and/or materials acquired from outside, (analysis of chemical composition of cast-iron and aluminum molds,
- supervision and control over the melting and casting process,
- exchange of the machine-tools.

As for the responsibility of the management it has been advised to:

- synchronize the production process to the volume of the order,
- use computer support for the product planning and storing process, the ABC method,
- introducing the motivation methods for the employees,
- change or modernization of the company's infrastructure,
- acquiring new finance e.g. from European structural investment funds.

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