# Analysis of reinforcing particles distribution in composite die-cast pistons

*Mariusz Bigaj, Sonia Boczkal, Marzena Lech-Grega, Monika Mitka and Maciej Gawlik*
*Institute of Non-Ferrous Metals in Gliwice Light Metals Division*
*Skawina, Poland*
*mbigaj@imn.skawina.pl*

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## Introduction

Composite materials are characterized by a number of physical and mechanical properties which allow not only to replace existing materials, but also to create new design solutions. Nowadays produced on an industrial scale composite elements, such as brake discs and pads, are operating in conditions of high friction loads. Wider implementation of the composite materials production is conditioned by the material and the development of complex technology solutions. The paper presents the results of studies of the percent content and distribution of the reinforcing particles of silicon carbide (SiC) and glassy carbon (Cs) in cast composite pistons with the AlSi7Mg2Sr003 alloy matrix. Three test casting operations were performed to obtain pistons with different volume fraction of the reinforcing particles. Studies covered samples taken at the beginning and end of the casting process. The analysis of particle content was performed on the side surfaces of pistons in the direction from the gating system to the riser [1, 2].

## Materials and Methods

Surface studies of the percent content and distribution of reinforcing particles were made on the ALSi7Mg2Sr003 cast alloy containing SiC as well as SiC and Cs (the values of percent volume fraction are given in Table 1). For each series, tests were performed on samples taken from pistons at the beginning and end of the casting process.

Table 1. Volume fraction of the reinforcing particles in cast pistons

| Alloy matrix | Sample symbol | Casting stage | Volume fraction of reinforced particles [%] | |
|---|---|---|---|---|
| | | | SiC | Cs |
| AlSi7Mg2Sr003 | ZW I B | beginning | 5 | - |
| | ZWI E | end | | |
| | ZW II B | beginning | 10 | |
| | ZW II E | end | | |
| | ZW III B | beginning | 5 | 2 |
| | ZW III E | end | | |

Cross-sections of the cast pistons were prepared (Figure 1). The side surface of each piston was divided into eighteen measurement points, numbered in the direction from the gating system to the riser (Figure 2). Samples were prepared by mechanical grinding and polishing.

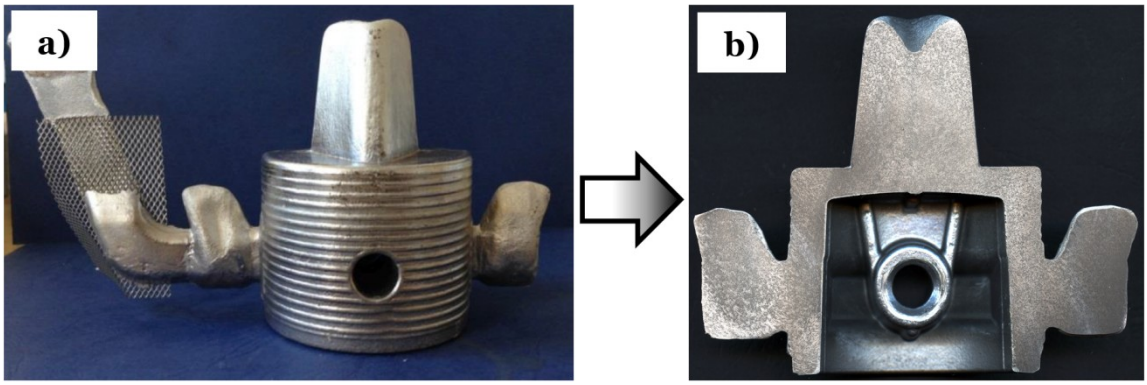


Figure 1. Cast piston (a) and its cross-section (b)

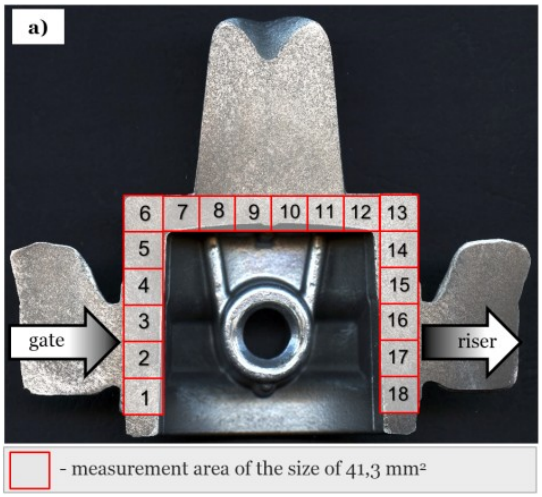


Figure 2. Cross-section of the cast piston with marked locations where the content of reinforcing particles was examined

On polished sections prepared for each measurement area, photographs of structures were taken using an Olympus GX71 light microscope (each measurement point had an area of 41.3 $mm^2$). The photographs were taken under the same lighting conditions. Examples of structures in the ZWI and ZWIII castings are shown in Figures 3a and 4a, respectively.

Image analysis was performed with ImageJ software (version 1.48) [3]. For each measurement area, the area occupied by the reinforcing particles of SiC and Cs was determined and the average surface fraction of particles was calculated. A fragment of the structure with the image analysis performed is shown as an example in Figures 3b and 4b for the ZWI piston and ZWIII piston, respectively.

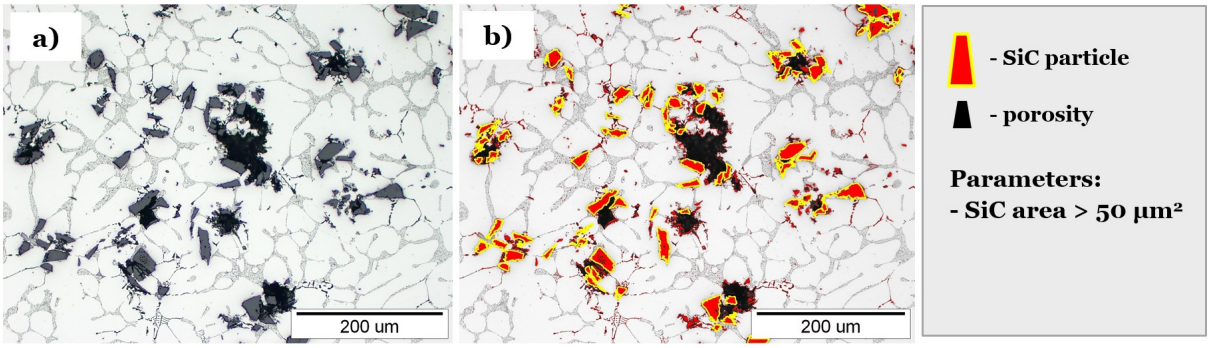

Figure 3. Example of microstructure obtained in ZWI piston (a) with marked SiC particles (b)

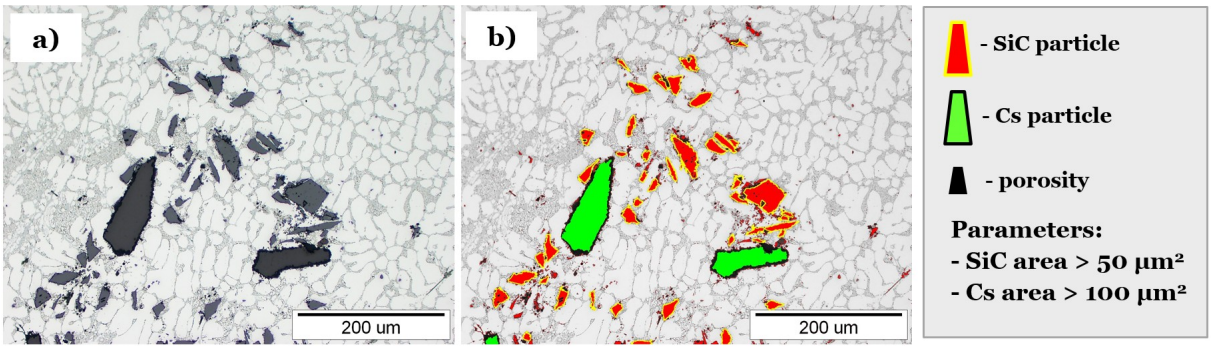


Figure 4. Example of microstructure obtained in ZWIII piston (a) with marked particles of SiC and Cs (b)

## Results and Discussion

Table 2 shows the average content of particles calculated for each piston and for all the measurement points. Smaller percent fraction of the reinforcing particles was observed in cast piston samples taken at the end of the casting process as compared to the samples taken at the beginning of the process. The decrease in the surface content was 3.4% SiC for ZWI series, 2.2% SiC for ZWII series, and 4.2% SiC and 1.8% Cs for ZWIII series.

Table 2. Average surface content of reinforcing particles in cast pistons

| Sample symbol | | ZWI | | ZWII | | ZWIII | |
|---|---|---|---|---|---|---|---|
| Casting stage | | beginning | end | beginning | end | beginning | end |
| Average share [%] | SiC (standard deviation) | 5.7 (0.62) | 2.3 (0.55) | 16.4 (1.12) | 14.2 (1,01) | 9.2 (1,21) | 5.0 (0,69) |
| | Cs (standard deviation) | - | | | | 3.3 (0.42) | 1.5 (0.28) |

The graph in Figure 5 shows differences in the percent content of reinforcing particles in different measurement areas. The greatest variations in the percent content of the reinforcing particles of silicon carbide were observed in the ZWIII piston cast at the beginning of the process. The standard deviation for this piston was 1.21%. The ZWI piston cast at the end of the process was characterized by the smallest differences in the percent content of SiC particles with the standard deviation amounting to 0.55%.

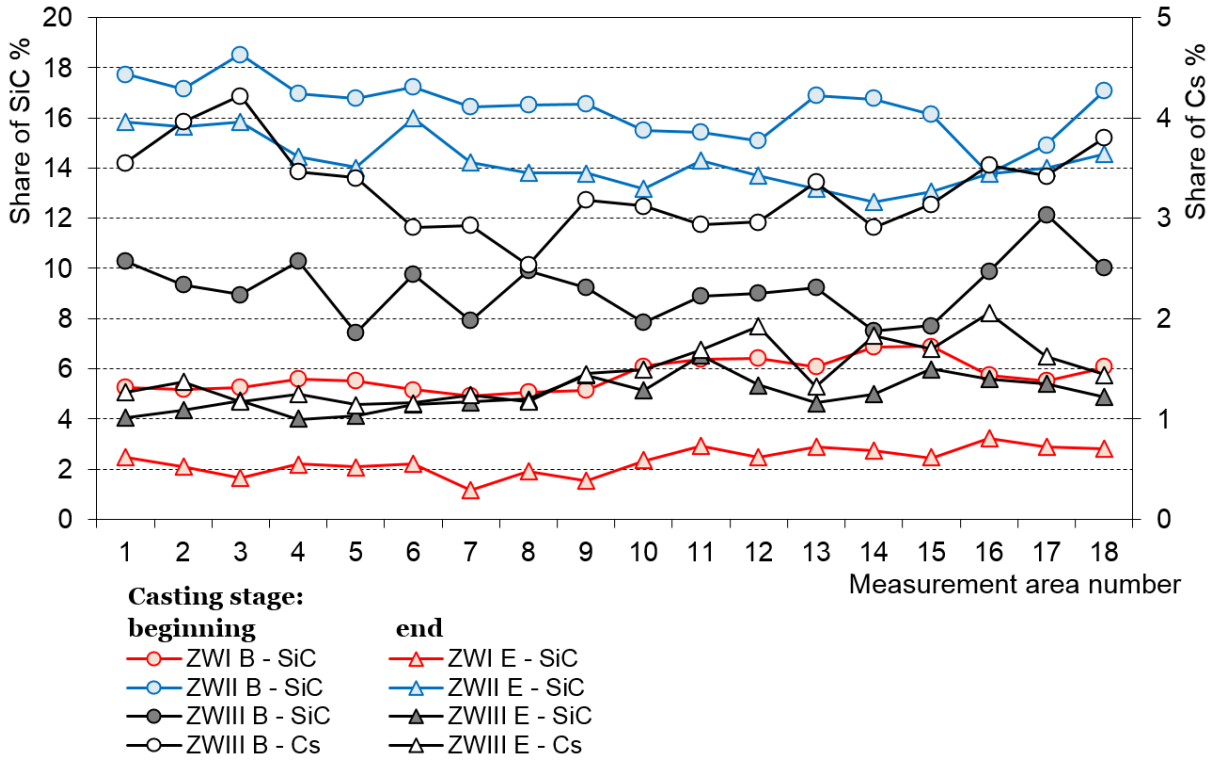


Figure 5. Percent content of the reinforcing particles of SiC and Cs in the examined ZWI, ZWII and ZWIII pistons

## Conclusion

Based on the results of tests and studies it was stated that the percent content of the reinforcing particles was lower in samples taken at the end of the casting process. The cause of the decrease in percent content of these particles might be the sedimentation process of reinforcing particles during casting.

Additionally, significant differences in the percent content of SiC and Cs particles were observed in individual measurement areas.

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## References

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