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ABSTRACT

Improving the quality of piston castings made from near-eutectic silumins

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Abstract

The main objective of this study was to identify and evaluate the technological parameters of the liquid alloy preparation process that determines the quality of piston castings made from near-eutectic aluminum alloys. The implementation of this goal was aimed at developing material and technological solutions that would reduce the level of defects in manufactured pistons, resulting from casting defects, thereby lowering production costs and minimizing the negative environmental impact of the foundry process.

A review of the literature confirmed the relevance of research on the development of piston engines in the era of the widely promoted transition from combustion to electric engines. The analysis of current market forecasts showed that the demand for various types of pistons will remain stable over the coming decades, confirming the importance of improving their manufacturing technologies. This section of the work also presents a classification of aluminum alloys used for piston castings, characterizes typical casting defects, causes of their formation and methods of their reduction.

For identifying the so-called "weak points" of the production process used in Złotecki Sp. z o.o., a production model was developed that included:

- quality requirements for piston production,
- parameters of the EN AB-AlSi12CuNiMg alloy used in production,
- the design of the piston casting and mold, and their influence on the occurrence of casting defects,
- technological operations such as alloy preparation and mold preheating,
- the casting process itself.

The analysis of the developed model showed that the parameters associated with the preparation of the liquid metal exhibited the lowest stability. Based on this finding, a set of research problems was formulated, and a series of analyses and experiments were carried out to identify the sources of process variability, assess their impact on quality, and develop methods to reduce the risk of casting defects.

The research scope included: analysis of the chemical composition of selected alloys, testing of mechanical properties (hardness measurement, static tensile test), testing of technological properties (testing of coarse-grained inclusions, castability tests, determination of the density index), thermal analysis and assessment of the macro- and microstructure of the tested materials.

Based on the analysis of the results of the research work carried out, it was found that two newly developed and verified technological procedures had the most significant impact on improving casting quality under industrial conditions. The first procedure concerns the control of the minimum hydrogen content in the alloy or secondary gassing. Own research demonstrated that the density index (DI) is an effective indicator of the readiness of the liquid alloy for mold pouring, enabling immediate decisions regarding the need for degassing or secondary gassing. Based on tests conducted in a production environment, a reference value of DI = 1.5% ± 0.2% was determined, which balances the risk of gas porosity and shrinkage microporosity in the produced castings. The second developed procedure concerns the management of production returns. The research allowed for the implementation of new principles for their preparation and sorting, with the result being a reduction in casting scrap from 8.8% to 4.2% and a reduction in the time of preparation operations.

The obtained results confirm that targeted control of liquid metal preparation – supported by DI measurement – and the standardization of return material circulation lead to reduced casting scrap rates and measurable reductions in production costs. The developed solutions are of an implementation nature and now constitute a new standard procedure at Złotecki Sp. z o.o., a manufacturer of pistons for combustion engines and air compressors.