engineering proceedings

Proceeding Paper

Quality Assessment of Aluminium Castings Using Computed Tomography †

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† Presented at the 30th International Conference on Modern Metallurgy—Iron and Steelmaking, Kosice, Slovakia, 27–29 September 2023.

Abstract: The article deals with the use of computed tomography, an advanced method for evaluating the quality of aluminium castings. Casting quality is a key factor in ensuring safety and reliability in industrial applications. Computed tomography is a comprehensive method allowing a three-dimensional, high-resolution view of the internal structure of materials. The main focus of this paper is the study of BRACKET REAR aluminium castings, manufactured in two-piece moulds using a high-pressure die-casting technology. In this paper, four castings have been analysed which are produced in one cycle. The focus is on the problem of porosity and open stagnation in the castings. A numerical simulation has also been used to illustrate the occurrence of porosity, which can be used to determine both the occurrence of porosity and the occurrence of unfilled volume. The experimental part of the paper describes the methods used to evaluate the BRACKET REAR castings. The numerical simulation was performed in ProCAST 18.0 to determine the occurrence of porosity in the castings under study. The evaluation of computed tomography was performed in myVGL 3.0 2023 software to analyse the internal defects in the castings. The evaluation focused on assessing internal defects and their subsequent effect on the functionality of the final casting.

Keywords: computed tomography; microstructural analysis; non-destructive testing; secondary aluminium alloys; porosity

Citation: Pinta, M.; Socha, L.; Gryc, K.; Sviželová, J.; Koza, K. Quality Assessment of Aluminium Castings Using Computed Tomography. *Eng. Proc.* **2024**, *64*, 6. https://doi.org/10.3390/engproc2024064006

Academic Editors: Branislav Bul'ko, Dana Baricová, Peter Demeter and Róbert Dzurňák

Published: 21 February 2024

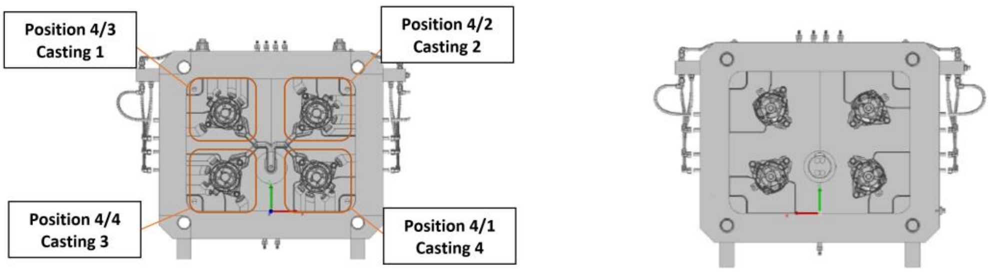
1. Introduction

Aluminium castings are widely used in various sectors. Aluminium alloys have good castability and, therefore, it is possible to produce castings with very precise geometry [1]. Ensuring accurate and reliable quality control of castings is a prerequisite for proper functionality, safety, and long service life [2]. The fatigue properties of aluminium castings are mainly limited by porosity, which is subsequently analysed by computed tomography [3]. Porosity appears in aluminium castings in different degrees, e.g., depending on the casting technology [4]. In terms of porosity, it is necessary to estimate the fatigue limit, which depends on the parameters of pore formation. The advantages of aluminium castings are mainly high strength, low weight, and good corrosion resistance [5]. Traditional methods of quality assessment of castings by metallography provide only limited views of their internal structure and thus hidden defective areas may be overlooked [6]. Especially for complex geometries and large castings, it is difficult to identify flaws that could affect their use [7].

Recent years have seen widespread use of computed tomography to evaluate the internal structures of various materials without damaging the structure [8]. Computed tomography is based on the principle of X-ray imaging and, as a result, allows accurate three-dimensional images of internal structures to be obtained without physically disturbing the casting [9]. This technology allows the discovery of defects such as cavities, cracks, non-homogeneities, and other undesirable structural features [10]. The disadvantage of computed tomography is the possibility of assessing the internal structure of the material up to a thickness of only 30 mm and the very high purchase price of the device [11].

2. Examination Methods

The BRACKET REAR casting was evaluated by two methods. The first was a numerical simulation of the castings in the ProCAST 18.0 software, which predicted the occurrence of porosity in the castings. The manufacturer of ProCAST 18.0 is ESI Group. The other method involved computed tomography, which was evaluated in the myVGL 3.0 2023 program. The manufacturer of myVGL 3.0 2023 is Volume Graphics. This program is presented because of the analysis of internal defects in the castings. A BRACKET REAR casting is made in a two-piece mould, which is designed to cast four BRACKET REAR castings. An example of a CAD model of the mould is shown in Figure 1. A total of six pieces of BRACKET REAR casting were evaluated using computed tomography. Four casting pieces were selected for the purpose of this publication; they are designated as casting 01, 03, 05 and 06.



(**a**) (**b**)

Figure 1. Example of a CAD model of the mould with marked positions of BRACKET REAR castings: (**a**) Movable part of the mould; (**b**) Fixed part of the mould.

3. Results and Discussion

Figure 2 shows the result of the numerical simulation of porosity occurrence in BRACKET REAR castings. As seen in Figure 2, there are larger areas of porosity (87–88% total shrinkage porosity) in the castings with a high proportion of unfilled volume. These defects are mainly found in the more massive parts of the casting around the cores where the thermal nodes occur. Under the present conditions, the occurrence of porosity in real castings can be assumed. All castings in the mould were comparable in terms of porosity content.

In the BRACKET REAR casting, the problem was the area of the parting plane, in the vicinity of which undesirable open depressions occurred. Therefore, increased attention was paid to these areas in the CT (Computed Tomography) analysis. In Figure 3, a CT image of casting 01 can be seen with the cavities detected and the characteristics of the five largest cavities.

Figure 3a shows a CT image of a detail of the parting plane of casting 01, BRACKET REAR from position 4/1 with the cavities detected. Figure 3a shows that the five largest cavities in casting 01 were not in the parting plane region. Cavities with volumes of 5–10 mm^3 were present in the parting plane region, together with an open depression (indicated by the arrow in Figure 3b). Figure 3c shows details of the places containing defects in casting 01.

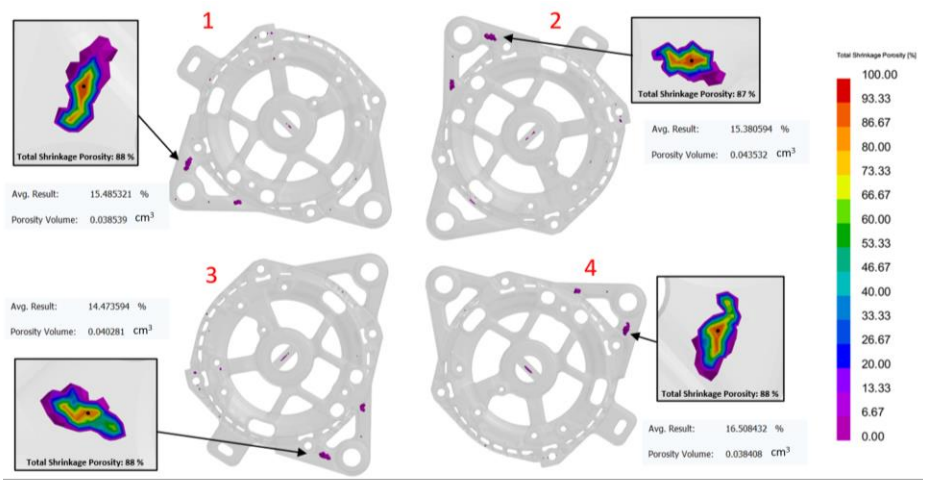
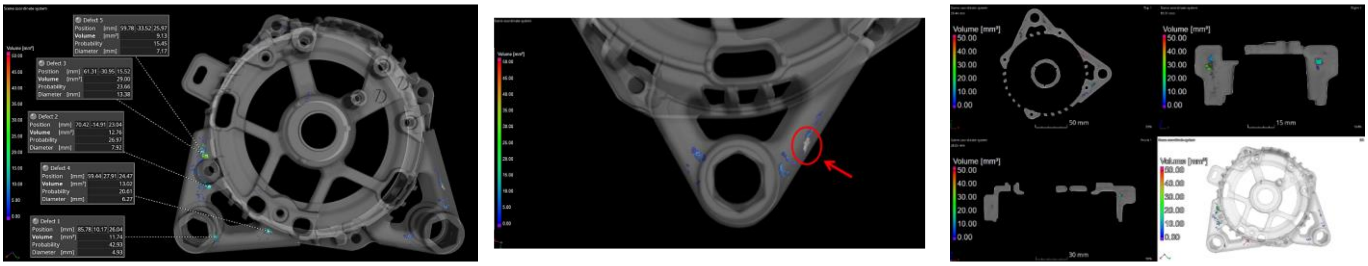


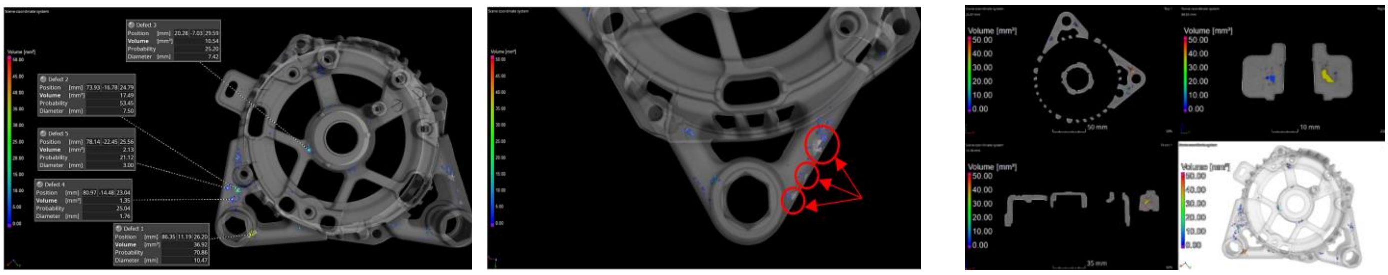
Figure 2. Results of numerical simulation of porosity occurrence in the BRACKET REAR casting.



(**a**) (**b**) (**c**)

Figure 3. CT image of the BRACKET REAR, casting 01, position 4/1: (**a**) Example of the five largest cavities in the casting; (**b**) Example of an open depression; (**c**) Details of places containing cavities.

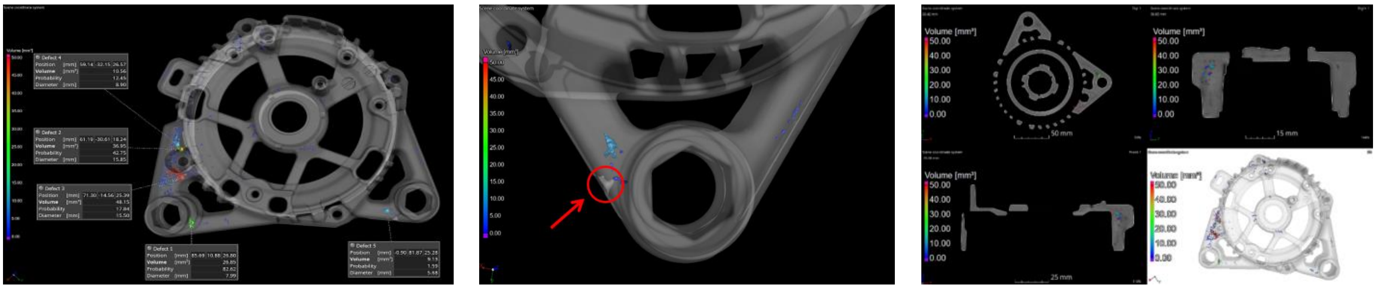
Figure 4 shows a CT scan of BRACKET REAR casting 03 from position 4/2 with the cavities detected and the characteristics of the five largest cavities. Figure 4a shows a CT image of the parting plane detail of casting 03, BRACKET REAR from position 4/2 with the cavities detected. Figure 4b shows that the five largest cavities were not present in the parting plane region in casting 03. Nevertheless, cavities with volumes of 5–10 mm^3 did occur in the parting plane region. Furthermore, there were open depressions, indicated by arrows in Figure 4b. Figure 4c shows the places containing defects in casting 03.



(**a**) (**b**) (**c**)

Figure 4. CT scan of the BRACKET REAR, casting 03, position 4/2: (**a**) Example of the five largest cavities in the casting; (**b**) Example of an open depression; (**c**) Details of places containing cavities.

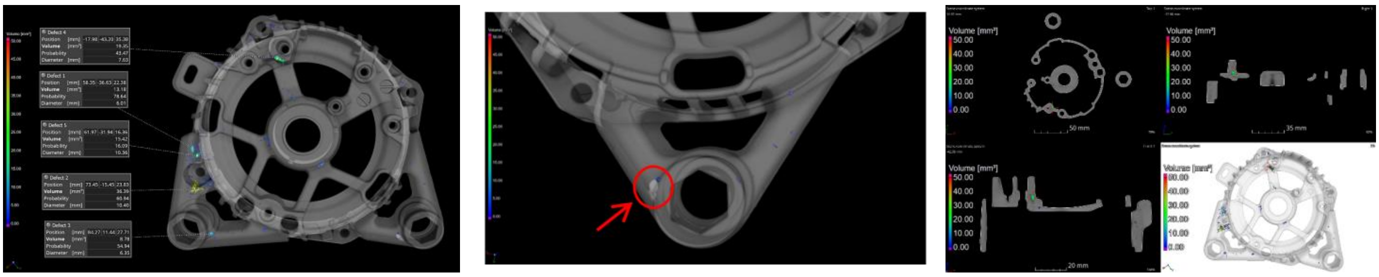
Figure 5 shows a CT image of the BRACKET REAR casting 05 from position 4/3 with the cavities detected and the characteristics of the five largest cavities. Figure 5a shows a CT image of the detail of the parting plane of casting 05 of the BRACKET REAR casting from position 4/3 with the cavities detected. As seen from Figure 5b, a cavity with a volume of 9.13 mm^3 and other cavities with volumes up to 5 mm^3 are present in the parting plane region in casting 05. There are open depressions in the casting, indicated by an arrow in Figure 5b. Figure 5c shows the places containing defects in casting 05.



(**a**) (**b**) (**c**)

Figure 5. CT scan of the BRACKET REAR, casting 05, position 4/3: (**a**) Example of the five largest cavities in the casting; (**b**) Example of an open depression; (**c**) Details of places containing cavities.

Figure 6 shows a CT scan of casting 06, BRACKET REAR from position 4/4 with the cavities detected and the characteristics of the five largest cavities. Figure 6a shows a CT scan of the parting plane detail of casting 06, BRACKET REAR from position 4/4 with the cavities detected. As seen from Figure 6a, the five largest cavities are not present in the parting plane region of casting 06. The parting plane region contains a minimum of cavities with volumes up to 5 mm^3, and an open depression also occurs here, indicated by the arrow in Figure 6b. Figure 6c shows the places containing defects in casting 06.



(**a**) (**b**) (**c**)

Figure 6. CT scan of BRACKET REAR, casting 06, position 4/4: (**a**) Example of the five largest cavities in the casting; (**b**) Example of an open depression; (**c**) Details of places containing cavities.

It can be assumed from the CT analysis of the BRACKET REAR casting that most cavities occur around the two hexagonal cores representing the attachment arms, as seen in Figure 7. However, a greater representation was found in the core further away from the parting plane, where the cavities were more numerous and larger in size (indicated by the arrow in Figure 7). In the parting plane region, a higher occurrence of cavities can be found at positions 4/1 and 4/2, while at positions 4/3 and 4/4 the cavities are smaller and lower in numbers. However, undesirable open depressions were found in all four positions.

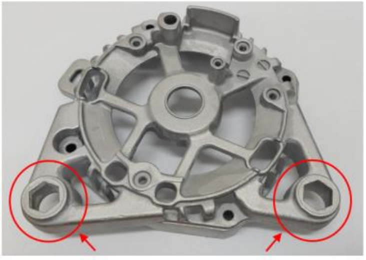


Figure 7. BRACKET REAR casting demarking of regions.

4. Conclusions

Two methodologies of analysing aluminium castings have been described in this paper. Valuable insights into their internal defects were obtained from computed tomography performed on BRACKET REAR castings. These castings were analysed using computer tomography in the software myVGL 3.0 2023 and through numerical simulation in the ProCAST 18.0 program. A total of four castings were analysed, with defects identified. These defects are mostly found in the hexagonal cores, representing the arms of the castings' attachment. In castings from positions 4/1 and 4/2, cavities appear in the parting plane region, while in castings from positions 4/3 and 4/4 they occur to a lesser extent. It is important to note that open depressions occur in all four castings. Overall, the article emphasises the importance of using computed tomography and numerical simulation to identify internal defects in aluminium castings. Defects in castings can affect the functionality of the final castings, which highlights the importance of careful quality assessment of aluminium casting production.

Author Contributions: Conceptualisation, M.P.; methodology, L.S.; validation, K.K. and M.P.; formal analysis, M.P.; investigation, M.P., K.K. and J.S.; data curation, K.K., M.P.; writing—original draft preparation, M.P.; writing—review and editing, J.S.; visualisation, K.K.; supervision, L.S.; project administration, L.S. and K.G.; funding acquisition, L.S. All authors have read and agreed to the published version of the manuscript.

Funding: The paper was funded by the Technology Agency of the Czech Republic within the TREND program, as part of project Reg. No. FW03010609 "Research and development of shape moulds made of H-13 and DIEVAR for die casting of aluminium alloys in the application of modern technologies of additive production, heat treatment, surface treatment and numerical simulations".

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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