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3D scanning based mold correction for planar and cylindrical parts in aluminum die casting

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Abstract

Aluminum die casting is an important manufacturing process for mechanical components. Die casting is known to be more accurate than other types of casting; however, post-machining is usually necessary to achieve the required accuracy. The goal of this investigation is to develop machining- free aluminum die casting. Improvement of the accuracy of planar and cylindrical parts is expected by correcting metal molds. In the proposed method, the shape of cast aluminum made with the initial metal molds is measured by 3D scanning. The 3D scan data includes information about deformations that occur during casting. Therefore, it is possible to estimate the deformation and correction amounts by comparing 3D scan data with product computer-aided design (CAD) data. We corrected planar and cylindrical parts of the CAD data for the mold. In addition, we corrected the planar part of the metal mold using the corrected mold data. The effectiveness of the proposed method is demonstrated by evaluating the accuracy improvement of the cast aluminum made with the corrected mold.

Keywords: Geometric modeling; Aluminum die casting; Mold correction; 3D scanning; Mesh deformation

1. Introduction

Die casting is a type of metal casting that can generate a large number of castings with excellent surface quality in a short time by pressing molten metal into metal molds at high temperature, speed, and pressure [7]. Generally, die cast products have superior dimensional accuracy, surface quality, and strength compared to other casting processes. However, the precision of die casting is not yet sufficiently accurate, particularly for dimensional accuracy.

Thermal deformation in die casting causes a decrease in the dimensional accuracy of cast aluminum. When molten metal is pressed into metal molds at a high temperature, the shape of the mold cavity changes by thermal expansion. Furthermore, cast aluminum shrinks when it gets cold. Because of these deformations, casting aluminum with a precise shape is difficult. Therefore, in many cases, die cast aluminum is machined to improve its accuracy.

Machining after die casting is undesirable for both productivity and quality. For example, a chill layer, which improves strength, is formed on the surface of cast aluminum during die casting. However, machining breaks this layer and reduces strength. A second problem relates to blowholes. Blowholes are casting defects caused by the formation of gas bubbles or voids within a casting as it cools. If a blowhole is close to the surface, it can be exposed by machining. Moreover, machining a complex shape is expensive. For these reasons, the machining process is undesirable.

In this paper, we propose a method to improve the accuracy of die casting by correcting metal mold. In the proposed method, we adopt 3D scanning to measure the shape of cast aluminum. The 3D scan data of cast aluminum includes information about deformation in die casting; consequently, deformation and correction values can be estimated by comparing scan data with product CAD data. In general, 3D scanning technology is utilized for inspection of mechanical product [3,5]. However, to the best of our knowledge, all of the previous attempts are only for inspection, and 3D scanning-based mold correction for die casting has not been reported.

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Another possible mold correction method is based on physical analysis. However, in die casting, mold correction methods based on physical analysis have not led to satisfactory results because thermal deformations during die casting are complex. We show the results of solidification contraction simulation on 3D scan data in Fig. 1. These color maps illustrate the differences from product CAD data. The left color map is the difference of the result of simulation and right color map is the difference of the 3D scan data of cast aluminum. This figure shows that simulation cannot capture small deformations as effectively as 3D scanning. We consider that simulation of thermal expansion is necessary to estimate such small deformations. However, thermal expansion is difficult to simulate due to high temperatures. Therefore, in this research, we adopt 3D scanning to capture the shape of cast aluminum.

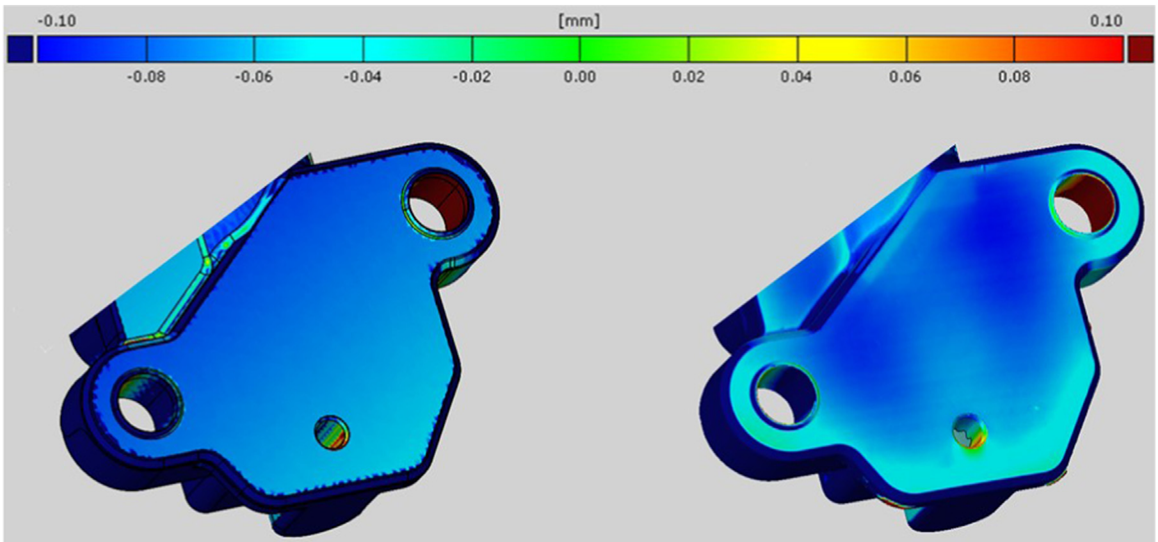

Fig. 1. Comparison between product CAD data and the simulation result (left) and 3D scan data (right).

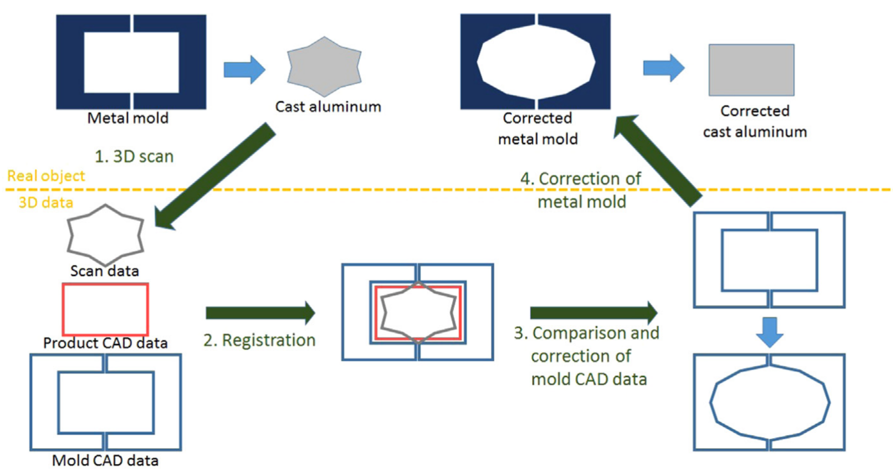

Fig. 2. Overview of this research.

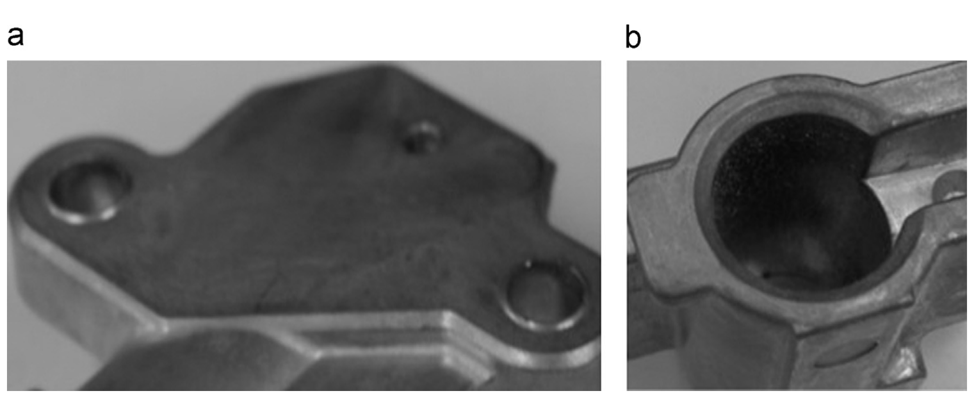

Fig. 3. Mechanical component for planar and cylindrical correction, (a) planar part and (b) cylindrical part.