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Porosity Discrimination System for Aluminum Alloy Die Castings Using X-ray CT Imaging

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In die casting, it is necessary to decrease porosity defects by taking some of counter measures. Such defects can be observed by using an X-ray CT scanner, which is a non-destructive measurement device. In this study, we propose a discrimination system for porosity defects between gas and shrinkage porosity using blister tests and X-ray CT images. We demonstrate the effectiveness of the system in discriminating between gas and shrinkage porosity defects by applying it to actual die casting.

Keywords: *X-ray CT, blister test, gas porosity, shrinkage porosity, discrimination.*

1. Introduction

Porosity defects in a casting are roughly divided into two types: shrinkage porosity and gas porosity. There are different types of counter measure used for the different types of porosity defects. Porosity can be visualized using an X-ray CT scanner, but the different types cannot be quantitatively discriminated. The blister tests make gas porosity, but not shrinkage porosity, expand remarkably. However, it is difficult to compare the volumes of the porosity. The castings positions and postures in X-ray photography cannot be adjusted exactly before and after blister tests. In addition, the blister tests cause casting products to deform due to thermal stress. Therefore, we propose a method of discriminating porosity defects by comparing volumes before and after blister tests.

2. Discrimination system

Our proposed system uses image registration of X-ray CT images before and after blister tests. Furthermore, the system estimates deviations of a pair of porosities, which cannot be adjusted only the registration. The positions and volumes of the porosity are calculated by image processing. The appropriate discrimination is achieved by calculating the volume ratio between identified porosity before and after blister tests.

An image registration uses homography. The matrix to adjust the castings before and after the blister test is calculated according to feature points of the castings, which are selected on 2-D projection images by the user. The registration is then repeated with each of the tomographic images, operating step by step on the x-y, y-z, and x-z planes.

CT values are given in grayscale intensity, and are normalized from 0 to 1 in this system. Porosity is then extracted from a binary image based on Morphology Reconstruction [1]. However, the precision of extraction has been improved in the proposed system to reflect dynamic changes in thresholds. The volume of the porosity can be calculated based on the method described by Hishida [2]. Each of the points of the porosity is calculated using a specific moment of CT value as the gravity point.

The extracted porosity cannot be exactly identified before and after blister tests. Deviation is estimated by calculating deviations in the cross-section images of the casting. Cross-section images before the blister test are made of the x-y, y-z, and z-x planes, which cross the gravity point of the porosity before the blister test. The size of images is resized as an $l \times l$ square, whose center is the gravity point and l is calculated by the following formula:

$$l = 2\sqrt{\frac{S_1+S_2+S_3}{3}} \tag{1}$$

The cross-section areas of the x-y, y-z, and z-x planes are S_1, S_2, and S_3, respectively. The cross-section areas are calculated using binary images. Cross-section images after the blister test are made of the x-y, y-z, and z-x planes, whose positions are same as before the blister test. Position vectors between the two gravity points before and after blister tests are calculated from the binary images of the cross-sections. Let each of the vectors on the x-y, y-z, and z-x planes be $\boldsymbol{k}_1 = (k_{1x}, k_{1y})$, $\boldsymbol{k}_2 = (k_{2y}, k_{2z})$, and $\boldsymbol{k}_3 = (k_{3z}, k_{3x})$, respectively, with $\boldsymbol{k}$ calculated by the following formula:

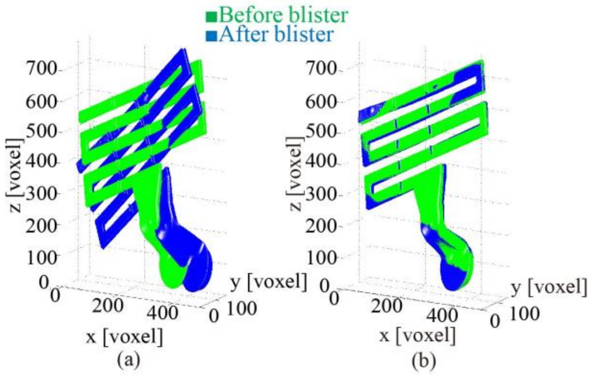

Fig. 1 Comparsion of the forms before and after registration. (a) Before. (b) After.

$$\boldsymbol{k} = \frac{1}{2}\begin{pmatrix} k_{1x} + k_{3x} \\ k_{1y} + k_{2y} \\ k_{2z} + k_{3z} \end{pmatrix}. \tag{2}$$

A sphere of radius is calculated by $k = \beta \, \| \boldsymbol{k} \|$. The center is the gravity point of the porosity before the blister test. The corrective coefficient for allowance is β. Porosity after the blister test existed in the sphere of radius k and the porosity before the blister test regarded as a pair of porosity. If i porosities after the blister test exist in the sphere, let the vectors between the porosities before and after the blister test be $\boldsymbol{r}_i$, with identical porosities then calculated using the following formula:

$$\arg\min_{i} \| \boldsymbol{k} - \boldsymbol{r}_i \|. \tag{3}$$

The expansion coefficient of the porosity between before and after the blister test is defined as $V_{\mathrm{after}}/V_{\mathrm{before}}$. If the coefficient is less threshold α or porosity before the blister test have non-target to identical that after the blister test, the porosity is determined to be shrinkage porosity. If the coefficient is equal to or greater than α or porosity exists only after the blister test, the porosity is determined to be gas porosity. Threshold α is set as a coefficient of the total volume of porosity before and after blister tests between $1 < \alpha < \alpha_{\mathrm{total}}$.

3. Demonstration of the system

The test piece to which this system was applied was made from aluminum (ADC12) and produced by a die casting machine (DC350I-MS). For imaging, we used a SOMATOM Emotion 6 X-ray CT scanner

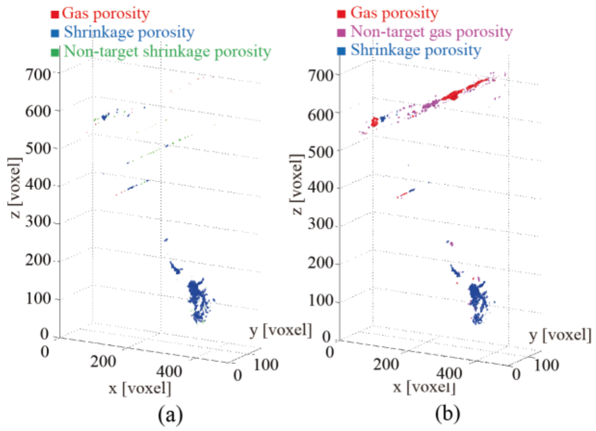

Fig. 2 Results of the porosity discrimination.
(a) Before the blister test. (b) After the bliste test.

manufactured by Siemens Japan K.K. The space resolution was 0.7871^3 mm^3 per voxel.

The thresholds and coefficients in this system were set to obtain stable results by multiple trials: $\beta = 1.5$, $\alpha = 1.3$ (setting in $1 < \alpha < \alpha_{\mathrm{total}} = 2.032$).

Figure 1 shows 3-D images of the test piece before and after the blister test. The results of discrimination are shown in Fig. 2. The volumes of the porosities are shown in Table 1. This system was verified to be able to discriminate between two types of porosity even if mixed and unclear.

Table 1 Volume of porosity before and after the blister test

Porosity	Volume (mm^3)	
	Before	After
Shrinkage	3.484×10^3	3.207×10^3
Non-target shrinkage	52.27	–
Gas	5.238	2.985×10^3
Non-target gas	–	1.088×10^3
Total	3.541×10^3	7.199×10^3

4. Conclusion

In the conventional evaluation of porosity defects, it is possible to calculate volumes, but not possible to discriminate between the two types of porosity. Our proposed system, however, can not only calculate volumes but also identify the type of porosity in various positions.

References

[1] P. Soille: *Morphological Image Analysis*, Springer-Verlag, Italy (1999) pp. 208-210.

[2] H. Hishida, T. Michikawa, H. Suzuki and Y. Ohtake: Precision Engineering Jounal, 76 (2010) pp. 960-965.