Nondestructive Evaluation of Cracking Process in Aluminum Alloy Die-Casts Containing Cold Flakes

A.K.M. Aziz Ahamed, Graduate Student, Saitama University
Hiroshi Kato and K. Kageyama, Faculty of Engineering, Saitama University, 255 Shimo-Okubo, Sakuraku, Saitama 338-8570

Key Words: Die-casting, cold flake, nondestructive testing, acoustic microscopy, bending test, aluminum alloy

ABSTRACT
Aluminum alloy die-cast plates (ADC12) were subjected to scanning acoustic microscopy measurement for developing a nondestructive method to detect cold flakes in the die-cast. Acoustic images inside the aluminum die-cast specimen were obtained at 0.1 mm interval from 0.5 mm to 2 mm depth, and compared with optical micrographs of cross-sections at the same depth as the acoustic images. The acoustic images of the cold flakes were good agreement with those observed in micrograph. Then the crack appearance inside the specimen was observed through ultrasonic microscopy during the bending test. The crack can easily start from the surface oxide layer or near the surface(0.1mm ~ 0.3mm inside), when the oxide layer is perpendicular to the applied stress. But no major effect of the oxide layer parallel to the applied stress on the crack initiation even in the near surface. A crack did not initiate from the inside cold flakes.

1. INTRODUCTION
Cold flakes [1], are of irregular structures with fine grain size compared to the matrix of aluminum die-cast alloy, cause unexpected failure of products when suffered from repeated loading and thermal cycling. The strength of the die cast product is largely reduced [2] due to this casting defect. So it is important to detect the cold flakes nondestructively.

Ultrasonic wave intensity reduces in metallic materials depending on grain size. Recently, Kato et. al. [3] showed that the cold flakes in die-cast were not detected by X-ray radiography and rather it can be partly detected by using a probe generating a longitudinal wave of 20 MHz in frequency but not their actual size and shape. Acoustic microscopy can provide the high sensitivity and resolution. The present work aims to examine the possibility to detect and evaluate their size, shape and position in aluminum die cast alloys non-destructively by acoustic microscopy and then examine the possibility of crack appearance from the cold flakes inside the specimen during the bending test.

2. EXPERIMENTAL PROCEDURE
(a) Preparation of Materials for nondestructive testing
Materials used in this study were aluminum alloy die-cast plates (JIS H5302 (ADC12)) with 6.8 mm thickness, 174 mm length and 50 mm width. In the present work, die-cast plates were separated into three equal pieces and prepared by finishing surfaces and edges of the specimen. Dimensions of test specimens were 53 mm length, 47 mm width and 6.5 mm thickness as shown in Fig. 1.

(b) Preparation of specimen for bending test
Aluminum alloy die-cast plates (JIS H5302 (ADC12)) with 4 mm thickness, 300 mm length and 100 mm width, were cut in to two-piece with 150mm length. Then cold flakes were searched within the 90mm × 140 mm area from 0.5 mm to 3.5 mm depth with an interval 0.5 mm by taking the acoustic image. After confirming the cold flakes, specimens were prepared with 98 mm length and 8 mm width (Fig.2) containing the cold flake at the middle position. A direction of Cold flake was selected both perpendicular and parallel to the bending stress direction.

(c) Acoustic Microscopy
The acoustic microscopy was carried out with a probe generating a longitudinal wave of 50 MHz in frequency and with a focal distance of 12 mm in water. Ultrasonic images were taken at positions 0.5 mm to 2 mm below the surface at an interval of 0.1 mm within 40 mm × 40 mm in area. This area was composed with 16 segments. Each segment was 9.9 mm² area with a pixel of 16.5 μm within the gate 0.075μs and time division 100 ns/div.

Acoustic image were also taken during gradual bending condition within the selected cold flakes region.

(d) Structure Observation
Structures were observed at the same depth by sectioning the specimen with 0.1 mm interval. Surface was etched with a water solution of 2-wt% NaOH.

(e) Bending test
Applying a monotonic load in specimen by moving a screw, bending tests was performed with a bending device (Fig.3). The specimens were bend gradually and acoustic image were taken in the bending condition.
3. RESULTS AND DISCUSSION

3.1 Comparison of acoustic image and microstructure

Acoustic images were obtained at different depths from the surface. Three different regions, namely black, comparatively less black and bright regions were observed. Comparisons of acoustic images with cross-sectional structures are shown in Fig. 4. The position and shape of the bright region in the acoustic images were in good agreement with cold flakes having oxide layer as observed in the cross sections. The position and shape of the black regions in the acoustic images were in good agreement with the cold flakes having no oxide layer.

![Fig. 4 Comparison of acoustic image with cross section](image)

**Fig. 4** Comparison of acoustic image with cross section (a) Acoustic images at 1.6 mm below the surface, (b) Cross section at 1.6 mm below the surface, (c) Enlarged view of cold flakes without oxide layer, (d) Enlarged view of cold flake having oxide layer.

3.2 Inspection of crack appearance

For inspection of crack appearance, cold flakes were placed in several depths from the bottom surface remaining the oxide layer parallel and perpendicular to the stress direction. Cold flakes were placed 2 mm to 4 mm inside from the bottom surface. Acoustic images were observed by gradual bending to confirm the possibilities of crack initiation from the inside cold flakes. No major change occurred in oxide layer up to breaking (Fig. 5).

![Fig. 5 Acoustic image during gradual bending](image)

**Fig. 5** Acoustic image during gradual bending (9.9 mm²)

Oxide layer placed in surface perpendicular to the applied stress break at 1 mm bending (Fig. 6). Oxide layer parallel to the applied stress placed 0.1 mm inside from the bottom surface breaks after 4.25 mm bending. Crack start position further confirmed by comparing image of real microscopic and SEM (Fig. 7).

![Acoustic Image direction](image)

**Fig. 7** Real and SEM image of the crack position

Figure 8 shows the relationship between the oxide layer position and required bending for breaking. The oxide layer perpendicular to the applied stress largely reduced the bending strength of the die-casts.

![Deflection at breaking vs. Distance from the surface](image)

**Fig. 8** Change in deflection at bending with position of cold flakes

4. CONCLUSION

Following conclusions were obtained.

1) The bright and dark spots shown in acoustic images were coincident with the cold flakes. These results confirm ability of nondestructive detection of cold flakes with the ultrasonic microscopy.

2) A crack can easily start from the surface oxide layer and oxide layer of near surface (0.1 mm ~ 0.3 mm inside) when the oxide layer is perpendicular to the applied stress. But no major effect of the oxide layer parallel to the applied stress in the bending strength, even in the near the bottom surface (stress side). A crack did not initiate from the inside cold flakes.

5. REFERENCE

