Multiscale Modeling and Analysis of Die Cast Aluminum Alloy to Consider Clustered Shrinkage Pores

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A multiscale stress analysis method is demonstrated to evaluate the strength of die cast aluminum alloy including the clustered shrinkage pores (CSP), which is sometimes generated around large gas pores(1). The CSP has extremely complicated shape of cavity, which leads to locally high elastic compliance and high stress concentration(2). Hence, it considerably reduces the fatigue strength and structural reliability. To evaluate the effect of porosities on the fatigue strength of die cast aluminum alloys, we carried out the image-based finite element analysis(3). The X-ray CT was employed to construct a geometrical model of actual macroscopic pores. Due to the lack of resolution of the X-ray CT used in this study, the microscopic pores such as CSP could not be visualized. However, the region of CSP can be recognized as an ambiguous grey area in the CT image, because of high X-ray transmittance by the porous geometry.

To compensate for the lack of resolution of CT image, we carried out successive polishing and digital optical microscopy of CSP specimen, and constructed microscopic model of CSP based on the serial sectioning images. Moreover, we utilized the homogenization method with the microscopic model and obtained the relationship between porosity and equivalent elastic constants, which were used for the macroscopic property of CSP region. Thus, we carried out the multiscale analysis by using the two-scale images of CT and micrograph. The macroscopic model was separated to bulk region and CSP regions depending on the pixel intensity in X-ray CT images. The microscopic model based on the serial sectioning images was embedded in the CSP region, and its equivalent elastic constants were used as the macroscopic material property of CSP region.

The multiscale analysis was carried out for the fatigue specimen(3) of ADC12 high-pressure die cast aluminum alloy, whose fatigue life was 14694 cycles under the stress amplitude of 90 MPa and stress ratio of −1. Young's modulus and Poisson's ratio of ADC12 were set to 74.5GPa and 0.3, respectively. The static extension corresponding to the stress amplitude was analyzed. Large gas pores and CSP, as shown in Fig. 1, were included in the fatigue specimen. The CSP was expanding among the gas pores. Figure 2 shows the microscopic model of porosity volume fraction of 11.4% obtained elsewhere and used in the multiscale analysis. The obtained distribution of maximum principal stress in longitudinal section was shown in Fig. 3, and compared to the fracture surface. The good agreement between the point of maximum stress and the fracture surface was confirmed as a validity of the present simulation.

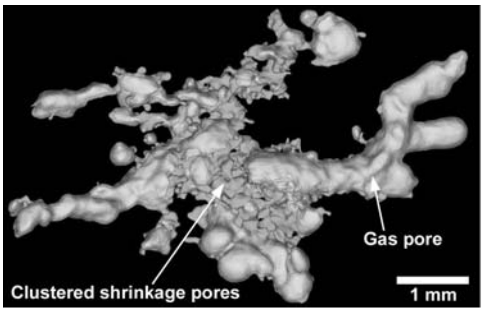

Fig. 1 Geometry of CSP

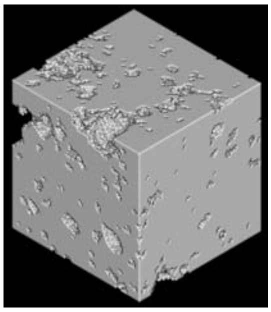

Fig. 2 Micro model of CSP

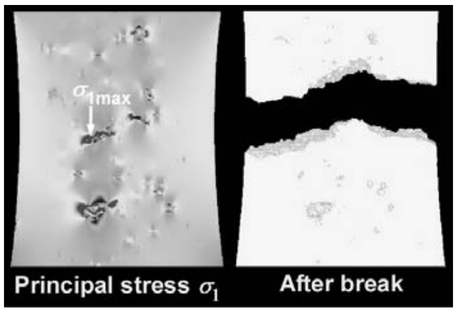

Fig. 3 Stress and fracture surface

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