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# Development of Crack Prediction Simulation Technology

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In aluminum die-casting, we predict by simulation (hereinafter referred to as "CAE") risks to productivity including cavities, leaks, burrs, and soldering marks, and incorporate the results in die design and casting condition settings to make quality improvements. However, prediction technology by CAE has yet to be established for shrinkage cracks, which that is a known defect. Under these circumstances, we focused on shrinkage cracks that would have a significant effect on quality and successfully established related prediction technology. This paper reports on that technology.

***Keywords:*** *die-casting, CAE*

## 1. Introduction

Of the cracks seen in aluminum die-casting, there are cracks caused by mechanical force such as die opening force and those caused by casting stress and inhibited thermal contraction. The latter includes hot cracks and shrinkage cracks. Shrinkage cracks occur in the final section to solidify in the solidification process, such as a thick-wall, due to inadequate supply of molten metal in aluminum die-casting [1]. So, we focused on the solidification process to work on the development of prediction technology.

## 2. Shrinkage cracking tests

### 2.1 Test method and conditions

We conducted casting tests using the I-beam test mold shown in Fig. 1, in order to assess the shrinkage cracking phenomenon with a simple model. We composed a mold of four separate sections using SKD61 hot work tool steel as a mold material, and poured molten JIS ADC12 aluminum alloy at 923K into the mold. Table 1 shows the test conditions. We conducted the test with and without heat insulator to change the solidification rate, and assessed the temperature of casting up on the occurrence of cracks.

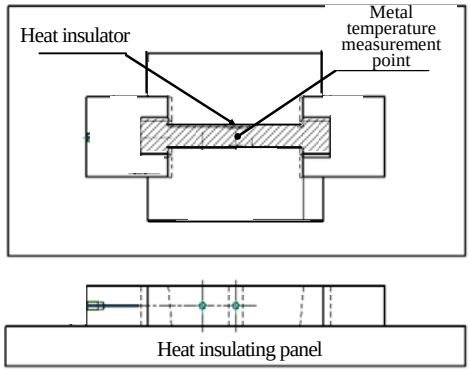


Fig. 1 I-beam test mold

Table 1 Test conditions

| | Condition 1 | Condition 2 |
|---|---|---|
| Heat insulator | Provided | Not provided |
| Pouring temperature | 923K | |
| Initial mold temperature | 473K | |

### 2.2 Test results

In tests, a crack occurred under Condition 1 that delayed solidification (Fig. 2). The temperature of the casting in the center of the test piece where the crack occurred was about 773K. This proved that the crack occurred in the solidification process (Fig. 3).


Fig. 2 Test results

| Molten metal temperature | 893K | 843 to 773K | 773 to 673K |
|---|---|---|---|
| Appearance |  |  |  |
| Remarks | Right after molten metal was poured | External shrinkage occurred | Crack occurred |

Fig. 3 Cracking process (Condition 1)

## 3. Prediction of shrinkage cracking

### 3.1 CAE analysis model and results

We prepared a CAE analysis model like the model used for shrinkage crack assessment tests and analyzed the effects of changes made to the solidification rate. We measured the maximum principal strain in the center of the test piece in which the shrinkage crack occurred during tests. As a result, the maximum principal strain in the solid-liquid zone under Condition 1 was larger than that under Condition 2, as shown in Fig. 4. Consequently, we prepared an index to assess the risks of shrinkage cracks based on the maximum principal strain, and assessed them.

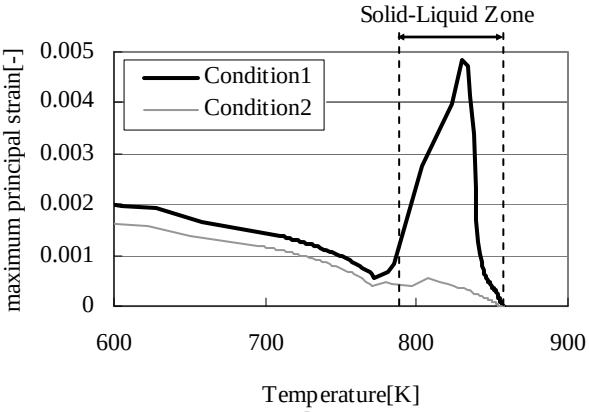


Fig. 4 Maximum principal strain vs. Temperature

As a result, Condition 1 showed a higher risk of shrinkage cracks, on the other hand Condition 2 showed a lower risk, as shown in Fig. 5. Consequently, we considered it possible to predict shrinkage cracks using CAE analysis and established the shrinkage crack prediction technology.

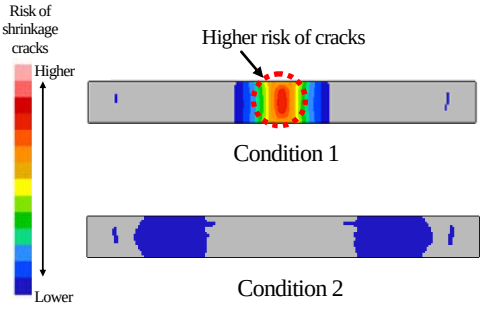


Fig. 5 Results of prediction of shrinkage cracks

### 3.2 Application to aluminum die-cast components

We verified the shrinkage crack prediction technology using an actual aluminum diecast product based on the results of CAE analysis conducted with the use of the I-beam test mold.

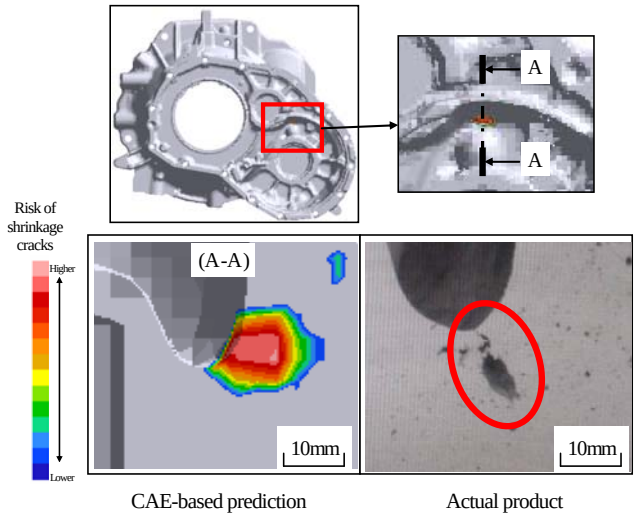


Fig. 6 Comparison between actual product and CAE-based prediction

As shown in Fig. 6, the location of the crack in the actual product was consistent with that predicted by CAE analysis. This proved that this shrinkage crack prediction technology, which takes the maximum principal strain assessed using the I-beam test mold as a threshold, was applicable to aluminum die-cast components.

## 4. Conclusion

We successfully established shrinkage crack prediction technology applicable to aluminum die-cast components by examining the mechanism that causes shrinkage cracks and extracting the maximum principal strain in the solidification process of casting by CAE.

[1] The Japan Foundry Engineering Society: *Case Examples of Casting Defects/Faults in Die Casting and Countermeasures* (2000) pp.43-44