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Possibility on Estimation of Fatigue Limit Using Non-Distractive Testing Method in Spheroidal Graphite Cast Iron

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In this study, the axial fatigue test specimen was machined from large size ingot of spheroidal graphite cast iron. Axial fatigue test was also carried out using an electric-hydraulic fatigue tester (made by Shimadzu Corp. Ltd.) with a capacity of ±19.6 kN. The test was conducted using a sinusoidal load control system with a load repetition frequency of 17Hz, and stress ratio, R=-1. The maximum number of repetitions for the fatigue test was 1×10^7 cycles. The test was carried out at room temperature. The approximation of S-N diagrams obtained by the axial fatigue test and the fatigue limits were calculated in conformity with JSMS-SD-6-02. The fracture origins and their peripheral areas of all specimens fractured after the fatigue test were observed using a scanning electron microscope.

The defects in specimen were detected using X-rays CT and estimated fatigue limit by equation of Murakami. And we compare fatigue limit which was estimated from fracture analysis using an equation of Murakami with the fatigue limit of experimental results. The possibility on estimation of the fatigue limit was investigated by the nondestructive technique.

Keywords: *Spheroidal graphite cast iron, Fatigue limit, High-resolution X-ray CT, Fracture origin, Defect size*

1. Introduction

It is desired to establish a safe and simple method using for strength design because experimental determination of fatigue limit spends enormous time and effort [1]. Murakami et al. proposed the 4-parameters method to estimate the fatigue limit in consideration of the hardness of the matrix and defect size in a material, and showed that the fatigue limit can be evaluated with a good accuracy for a material with defects whose sizes are less than 1,000 μm [2].

Hardness of the matrix can be obtained conveniently, but for defect size, many fatigue specimens are required and also the statistical analyzing of defect size from fracture surface observation is necessary.

In this study, authors estimate the fatigue limit by using the defect size of the specimens observed by X-ray CT and actual value of fatigue limit obtained by carrying out axial fatigue test in the observed specimens. We will compare measured fatigue limit with estimated value and estimation of fatigue limit using Non-distractive testing method in spheroidal graphite cast iron carried out.

2. Sample materials

Specimens targeted chemical components shown in Table 1 and Rare-earth element in spheroidizing agent was performed casting by adding so as to be 200 ppm in the melt. Figure 1 shows the shape of the axial load fatigue test specimen followed by JIS Z2273 [3]. The specimens were taken from h500×w500×t500 mm ingot.

Table 1 Chemical composition of material used (mass%)

C	Si	Mn	P	Mg	S
3.4~ 3.5	2.5	0.9	≤0.03	0.05	≤0.01

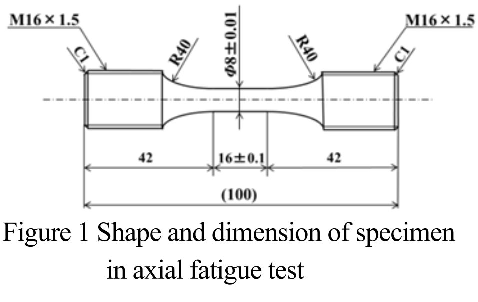

Figure 1 Shape and dimension of specimen in axial fatigue test

3. Experimental methods

Two in Axial fatigue test specimens (We call as FCD-1 and FCD-2) before fatigue test were observed using high-resolution X-ray CT, TOSCANER-32300μFD manufactured by Toshiba IT & control systems Co.,LTD.

In the axial fatigue test, electro-hydraulic servo pulsar was used with a loading frequency of 17 Hz and stress ratio R=-1 at room temperature in the atmosphere. The number of cycle to discontinue test was set to 1×10^7 cycles. The fracture origins were observed by scanning electron microscope (SEM).

4. Experimental Results and Discussion

Figure 2 shows the maximum defects in two test specimens observed by high-resolution X-ray CT and secondary electron image of fractured surfaces observed by SEM.

In the measurement of the defect size of the maximum defect observed by X-ray CT and fracture origins observed by SEM, they were approximated by a square and the square root of the area assumed to be the defect size $\sqrt{area}$. As a result of observation, the kinds of maximum defects in two specimens observed by X-ray CT were confirmed micro-shrinkages. The fracture origin in FCD-1 was confirmed aggregate graphite and the fatigue of FCD-2 was confirmed micro-shrinkage that was the same as maximum defect observed by X-ray CT. As the reason in FCD-1 that fracture origin was different from a maximum observed defect, the maximum defect may not become the fracture origin to lead to destruction that the cracks that occurred from plural defects transmit. Fatigue limit was obtained by experimental axial fatigue test was 145 MPa.

It is known that the fatigue limit of a material with a defect (crack) can be estimated using the 4-parameter model [4].

Region II is a region mainly ruled by the resistance against the propagation of a small defect (crack), the fatigue limit could be accurately estimated using Eq.(1) for the material with defects of the size smaller than 1,000μm[2].

$$\sigma_w = \frac{\alpha(HV+120)}{\sqrt{area}^{1/6}} \qquad (1)$$

HV is the Vickers hardness of matrix, α is a coefficient, which depends on the position of a defect. Table 2 shows the fatigue limit, the defect size $\sqrt{area}$,Vickers hardness, the fatigue limit

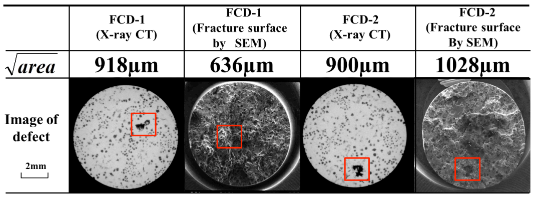

Figure 2 Maximum defects observed by X-ray CT and fracture surfaces observed by SEM

Table 2 Comparison of experimental fatigue limit, defect size, fatigue limit estimated by equation (1) and ratio of σ_w/σ_{wR}

Material		Fatigue limit determined by S-N curve σ_w,MPa	$\sqrt{area}$ μm	Vickers hardness $HV_{1.96}$	Fatigue limit estimated by eq.(1) σ_{wR}(1),MPa	σ_w/σ_{wR} (1)
FCD-1	X-ray CT	145	918	184	139	1.06
	Fracture Surface		591		150	0.98
FCD-2	X-ray CT		900		140	1.05
	Fracture Surface		1028		137	1.07

estimated using Eq.(1) and the estimate accuracy of the fatigue limit. The evaluation is rated as precise as the ratio comes close to 1. The Fatigue limit estimated using Eq.(1) (Region II) in the 4-parameter method obtained good result.

5. Conclusions

A axial load fatigue testing was carried out and specimen observed by high-resolution X-ray CT. Obtained conclusions as follows.

(1) X-ray CT is possible to observe internal defects of spheroidal graphite cast iron.

(2) Fatigue limit estimated by Eq.(1) using size of the defects observed by X-ray CT and hardness of the matrix was a good result.

Acknowledgements

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