SMiRT–12 / K. Kussmaul (Editor)

SD105/6

THE INFLUENCE OF PRE-CRACKING ON MEASUREMENT OF CERAMICS $Si_3N'_4SK_{IC}$*

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ABSTRACT
This article discussed the influence of pre–cracking on measurement of ceramics $Si_3N'_4$s K_{IC}. A new method which is used to make fatigue pre–crack in the specimens made of brittle materials was introduced.

Two kinds of three–point–bend specimens were made of the ceramics: the radius of notch of one kind specimens was 0.15mm, the other kind crack was prepared by means of fatigue.

The method and its apparatus making fatigue crack is unique, effective, and especially suitable for brittle materials.

The K_{IC} value of the ceramics was measured with the two kinds of specimens. It was found that there was only a little difference between K_{IC} values of the two kind specimens calculated with relative data.

In addition, results of similar experiment of other brittle materials were introduced to make a comparison.

Keywords: ceramics, fatigue, pre–crack, fracture toughness, brittle material

1 INTRODUCTION

Ceramics is a material possessing many excellent property such as high strength, wear–resistance, corrosion–resistance, etc. So it is widely applied in machinery, medical apparatus and instruments, energy, and other fields.

K_{IC} is an important parameter of materials. When the K_{IC} value is determined by experiments, specimens with fatigue cracks are generally used.

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*Sponsored by the National Natural Science Foundation of China.

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During fatigue pre–cracking process, brittle failure easily occurs and controling the crack length is difficult.

One viewpoint considered that it was necessary to make a fatigue pre–crack in specimens made of brittle materials when K_{IC} value was determined by experiments. On the other hand, there was another viewpoint opposit to the former. At present there were no theoretical or experimental conclusion which was generally accepted. Particularly, compared with a notch, a fatigue pre–crack is more similar to a real crack. In brief, it is a developing subject to study the influence of pre–cracking on measurement of K_{IC} value of brittle materials.

2 METHODS OF INDUCING FATIGUE PRE–CRACKS

There were some current methods which can induce fatigue pre–cracks, for example static press cracking, wedge open cracking method, bridge press method, etc. Although these methods were fit for brittle materials to a certain degree, each method had shortcomings such as high technical demand, scatter of experimental data, limit of specimen size, etc.

The method adopted in this article is a new method invented by Engineer Zhang Jinsheng of Beijin Research Institute of Mechanical and Electrical Technology, and he acquired a patent in China because of it. The fundamental principle of the method is: except three–point–bend loading, another load is pressed on a specimen at longitudinal direction which can prevent the crack extending K_I to break (Fig.1). When the crack extends to a certain length, the logitudinal load will produce a reverse moment. The length of the crack is longer, the moment is bigger. So the K_I value of the crack tip is reduced. Until the K_I value of the crack tip is smaller than the material's K_{IC} value, the crack stops extending.

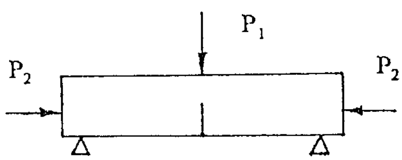


Fig.1 The principle schematic diagram of experiment apparatus

The advantages of the method is described as following:

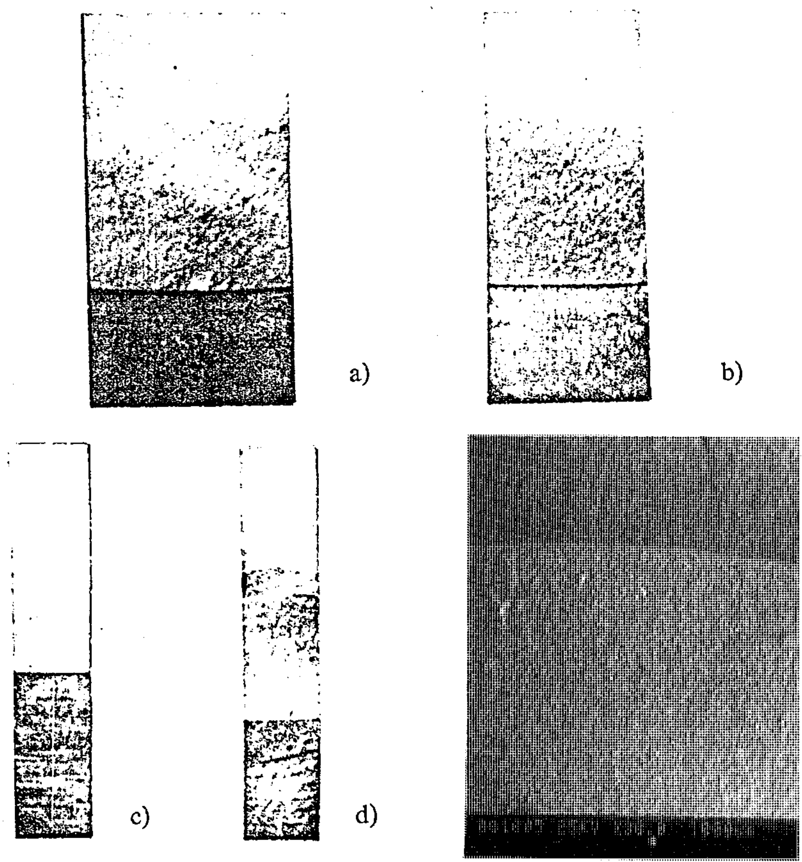
(1) when the crack length of specimen reaches a certain length, the crack doesn't extend no longer.

(2) After the crack length is stable, fatigue load can be applied continuously for about several hundred thousand cycles, and break of specimen never occurs. As a result, the front configuration of fatigue crack can be seen easily (referring to Fig.2). It is very convenient for measurement.

(3) Experiment apparatus is simple, its operation is convenient.

(4) Fatigue cycle number is finite till the crack growth stops. Ten thousand cycles are usually needed.

(5) The crack length can be controlled according to requirement by adjusting load P_2 (referring to Fig.1). Error of the length is very small.



a) b) c) d) e)

Fig.2 Photo of specimen's fracture appearance a)–d) Si_3N_4 specimens, e) W18Cr4V specimen, a), b), d), e) fracture appearance with fatigue pre–cracking. c) fracture appearance without fatigue pre–cracking. Width of the specimen a), b), c), d), e) is 5mm, 4mm, 2mm, 2mm, 3mm respectively.

3 SPECIMENS PREPARATION AND EXPERIMENT RESULTS

The ceramics used in this paper was ceramics Si_3N_4 consisting of Si_3N_4, additive, Al_2O_3, and Y_2O_3. The ceramics was pressed with pressure of 500 Kg/cm^2 firstly, with pressure of 200Kg/cm^2 at 1700℃ for half an hour secondly. Material parameters is listed in table 1, α stands for heat expansion coefficient. The size of three–point–bend specimens is listed in table 2, W stands for height, B stands for width, and S stands for span.

Table 1. Material parameters

material	σ_b(MPa)	α(1 / ℃)	$K_{IC}(MPa \cdot m^{\frac{1}{2}})$
Si_3N_4	500–600	2.5–3.10	4–5

Table 2. Size of three–point–bend specimens (S = 40mm)

test	1	2	3	4	5	6	7	8
W(mm)	9.52	9.847	9.873	9.54	10.0	9.96	10.0	9.967
B(mm)	2.1	2.1	2.047	2.072	4.14	4.1	4.98	4.86

Instron 1255 material test machine is used for fatigue and fracture test of specimens. Specimens whose number is from 5 to 8 contain fatigue crack. The number of fatigue cycles is listed in table 3.

Table 3. Number of fatigue cycles unit: ten thousand

test	5	6	7	8
N	57	66	40	36

Using the experiment data of specimens which hadn't got fatigue crack, K_{IC} values were measured and listed in table 4. From the specimens containing fatigue crack, K_{IC} values were also measured and listed in table 5. In table 4 and 5, P_f stands for break load, a for length of crack or notch.

Table 4.

test	1	2	3	4
P_f(N)	78	88	127	98
a(m)	.0041	.00428	.0043	.00424
$K_{IC}(MPa \cdot m^{\frac{1}{2}})$	4.3	3.7	5.7	4.69

Table 5.

test	5	6	7	8
P_f(N)	78.0	42.1	93.0	81.3
a(m)	.00704	.00769	.00742	.00714
$K_{IC}(MPa \cdot m^{\frac{1}{2}})$	4.5	3.5	5.6	4.39

Above K_{IC} values were calculated according to GB4161–84 and E399 and distinguished by Grubbs method. There were no suspicious data.

According to the data listed in Table 4, average value $\overline{K}_{IC} = 4.64 MPam^{\frac{1}{2}}$. On the basis of data listed in Table 5, average value $\overline{K}_{IC} = 4.54 MPam^{\frac{1}{2}}$ So above experiment results were considered closed in the scale of experiment error. In order to make a comparison, results of the same sort experiments using other brittle materials were listed in table 6 and discussed.

Table 6. Experiment results of K_{IC} value $(MPa \cdot m^{\frac{1}{2}})$

material	T8A	W18Cr4V	YG6	Glass
notch	37	28	18	1.3
fatigue crack	23	17	13	0.7

4 DISCUSSION AND CONCLUSION

The method used in this paper is widely suitable for brittle materials to produce fatigue crack. It is proved by lot of experiments that the method is effective and high precise.

The problem that the influence of pre–cracking on measurement of brittle materials' K_{IC} is a complicated one which demands further research. To some materials such as ceramics Si_3N_4, the influence is little. But to others such as T8A, glass, the influence is remarkable.

K_{IC} is an important material parameter, but isn't a criterion to decide that if it is necessary to use the specimens containing fatigue pre–cracking when K_{IC} value of material is measured.

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