# Interpretation of Fracture Behavior of a Grinding Wheel Material by a Crack-Body Model

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## 1. Introduction

A grinding wheel which consists of grain phase embbeded in a bonding material is one of the porous composite materials. This material whose constituent elements distribute at random is macroscopically isotropic-homogeneous but microscopically inhomogeneous. In our previous study, a model for the microstructure of a grinding wheel was proposed and better quantitative estimation value of the elastic constants was obtained. Since the mechanical properties of such inhomogeneous material have a scattering nature in itself, the statistical estimation ( mean value, dispersion ) may be desired for the industrial purposes. Our model combined Monte-Carlo Method with the Finite Element Method is also provided with such characteristic. The authors proposed recently other improved models concerning the influence of the configuration of the pore. These models, however, may not be directly applicably to the fracture problem, because the appropriate fracture criterion is not yet obtained in our experiment. In this paper, an attempt is made to show the fracture behavior of grinding wheel by a crack-body model.

## 2. Crack-body model and the fracture toughness.

### 2.1 Crack-body model.

In this model, pores of the grinding wheel are replaced by cracks, regardless of the pore configuration, and the equivalent crack length is assumed to be the sum of the length of a pore and microcracks in the grain or bonding materials (see Fig.1 ). Furthermore, following assumptions are made.

1. The material is idealized to be isotropic-homogeneous body and analyzed as two dimensional structure.
2. Although many cracks are distributed in the constituent material, they do not interfere with each other, and of these randomly oriented cracks only the maximum length of a crack which is perpendicular to the direction of loading is considered ( see Fig.1 ).

### 2.2 Fracture toughness.

Fracture toughness $K_{IC}$ is defined as the critical value of stress intensity factor $K_I$. In this test, bending, tension and bursting test methods were employed to unify the same stress mode of $K_I$ type. To obtain the value of $K_{IC}$ for each stress mode, the specimens with artificially manufactured sharp slit of length a were prepared. $K_I$ values and test piece configurations for each mode are shown in Fig.2. Specimen used is the vitrified grinding wheel with different volume fraction and dimension. Test results of bending are shown in Fig.3.

## 3. Discussion.

Fig.4 shows the maximum stress of bending versus structure for the non-slit specimen. Fig.5 shows that the equivalent crack length is approximately proportional to the grain size under the constant grade. On the other hand, the crack length remains constant irrespective of the change of grade under constant grain size, as shown in Fig.6. These experimental results indicate the validity of the assumption of the equivalent crack length.

## 4 Prediction of bursting speed.

The fact that $K_{IC}$ values obtained by different test methods agree with each other indicates the independence of the test methods. Hence, by determining the $K_{IC}$ value by one or two methods, fracture strength for other test method can be predicted without experiment. For example, the bursting speed of normal grinding wheel can be predicted by using the $K_{IC}$ values of bending and tension. The experimental value agrees fairly well with calculated value by the method mentioned above. Results are tabulated in Table.

## Reference

H.Miyamoto et al, I. C. M. Proc., vol. IV, pp484 1972.

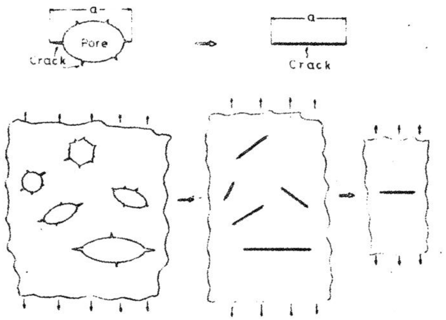
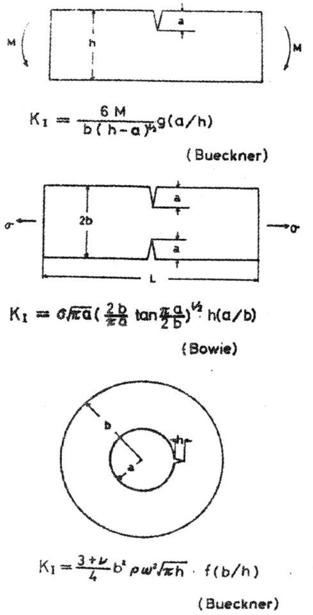


Fig.1 Schematic model of the material.



$$K_I = \frac{6M}{b(h-a)^{3/2}} g(a/h)$$

(Bueckner)

$$K_I = \sigma\sqrt{\pi a}\left(\frac{2b}{\pi a}\tan\frac{\pi a}{2b}\right)^{1/2} h(a/b)$$

(Bowie)

$$K_I = \frac{3+\nu}{4} b^2 \rho\omega^2\sqrt{\pi h} \cdot f(b/h)$$

(Bueckner)

Fig.2 $K_I$ value and test piece configuration.

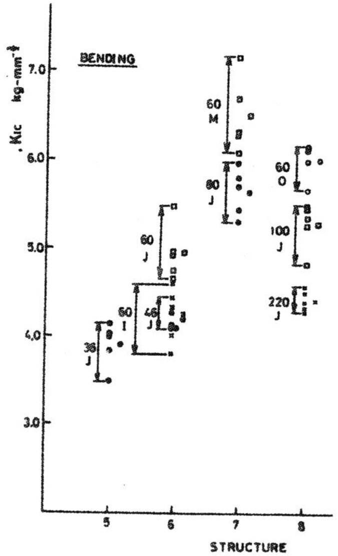


Fig.3 Relation of $K_I$ value vs. structure.

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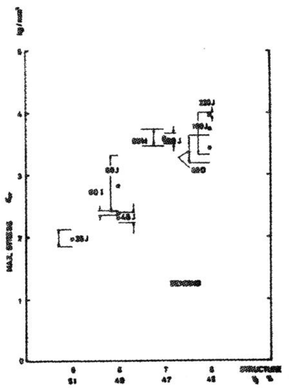

Fig.4 Relation of max. stress vs. structure ( bending ).

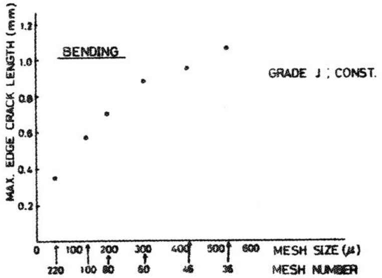

Fig.5 Predicted internal crack length vs. grain size.

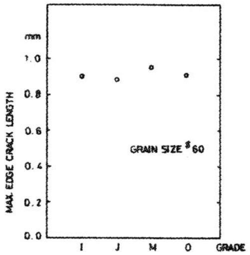

Fig.6 Predicted internal crack length vs. grade.

| Mesh Number | Grade | Estimated Bursting Speed<br>by Bending<br>$n_c$ (r.p.m) | <br>by Tension<br>$n_c$ (r.p.m) | Experimental Results<br>$n_c$ (r.p.m) |
|---|---|---|---|---|
| 36 | J | 5.61 X10³ | 5.25 X10³ | 5.41 X10³ |
| 46 | J | 6.10 | 4.66 | 5.83 |
| 60 | J | 6.81 | 6.32 | 6.31 |
| 60 | O | 7.45 | 6.17 | 6.26 |
| 80 | J | 7.97 | 6.32 | 6.79 |
| 220 | J | 8.27 | 7.98 | 7.03 |

Table Predicted bursting speed and experimental results.