Bend Deformation Behavior of Silicon Carbide Reticulated Porous Ceramics

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Abstract

The deformation behavior under three-point bend test was found to depend on the loading uniformity and the macrostructure for SiC reticulated porous ceramics (RPCs). However, this dependence of loading uniformity is alleviated by improved macrostructure with fewer flaws and clogged pores. Even, this dependence becomes less important as the struts become thicker and stronger. The bend result of RPCs with highly uniform macrostructure is in excellent agreement with the GA (Gibson and Ashby) model, but the one with un-uniform macrostructure deviates from the GA model, suggesting that the macrostructure plays an important role in deformation behavior of RPCs under bend.

Keywords: Porous ceramics, Ceramic foam, Silicon carbide, Microstructure, Mechanical property.

1. Introduction

Reticulated porous ceramics (RPCs) are known to have a wide variety of applications such as molten metal filters, diesel engine exhaust filters, catalyst supports, gas-burner media, energy-absorbing materials, preforms for metal-ceramic composites, sensors, biomedical implants and structural microwave absorber and so on, owing to the unique open-cell network structure [1]. Due to the superior mechanical properties, excellent thermal-shock resistance, high thermal conductivity and good chemical stability at high temperature, silicon carbide (SiC) has been regarded as one of the best filter materials suitable for severe environmental applications.

The most-popular method of producing RPCs is to coat the open-cell polymer sponge with a ceramic slurry, followed by burn-out of sponge skeleton and sintering of the ceramic. However, the RPCs produced by this method usually show poor mechanical properties, due to the hollow struts and other processing-related flaws. Though the most applications of RPCs are not fully structural, the mechanical properties are crucial to guarantee the reliability of RPCs in applications, e.g. molten metal filters, diesel particulate emission filters, etc. Recently, we developed an improved approach to enhance mechanical strength and reliability of SiC RPCs by uniformly recoating the reticulated performs with a thin slurry to increase strut thickness and remove crack defects in the struts. The compressive deformation behavior of RPCs has been studies intensively. Unfortunately, the work concerning bending deformation behavior is lacked. Therefore, the work will report the deformation behavior of SiC RPCs under three-point bend test. The effects of the load uniformity and macrostructure on the deformation behavior are studied.

2. Experimental and Results

As described in aour previous paper, SiC RPCs used for the present study were fabricated by the traditional and innovative polymeric sponge method [2]. Compared with the traditional method, leads to an improvement in the uniformity and integrity of the macrostructure of SiC RPCs, e.g. thicker struts, fewer clogged pores (double arrows) and fewer crack flaws (single arrows) in the struts, as shown in Fig. 1.

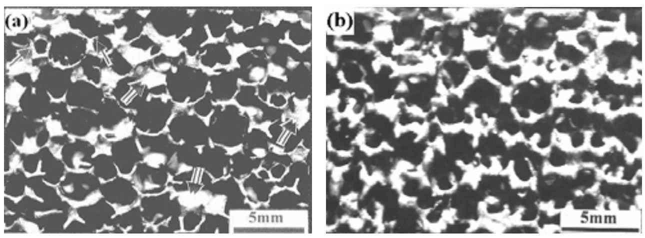

Fig. 1. Typical structure of SiC RPCs fabricated by (a) traditional and (b) innovative methods.

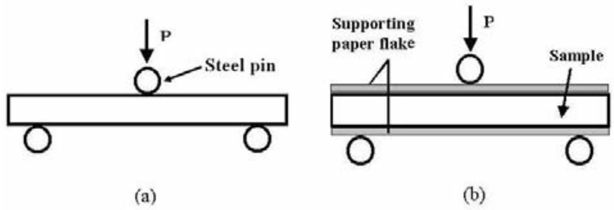

Fig. 2. Schematic of the three-point bend test (a) Without and (b) with a compliant paper pad.

As is chematically shown in Fig. 2, figure 3 gives typical bending load-displacement curves of SiC RPCs prepared by the traditional method without and with a compliant paper pad. In the absence of a paper pad, the curve shows more complicated shapes (extremely irregular serration) than the case under compression, this is due to the fact that the three-point loading is more un-uniform than the compressive loading because of the much smaller contacting area. In contrast, the use of the paper pad makes the bend deformation behavior of RPCs similar to that of dense ceramics, despite the macrostructural un-uniformity. This indicates that the loading uniformity plays a crucial role in the bend fracture behavior of RPCs.

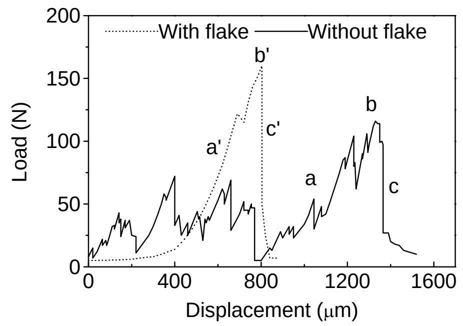

Fig. 3. Bend load-displacement curves of SiC RPCs prepared by traditional method without and with a paper pad.

As shown in Fig. 4, it is interesting to see that due to the more uniform macrostructure and stronger struts, the deformation behavior is greatly improved. The variation in the load with displacement is significantly reduced, compared to that of those with un-uniform macrostructure (Fig. 3). Moreover, this variation becomes as the relative density increases, because the probability of the breakage of the local struts is largely reduced.

As shown in Fig. 5, the density exponents are determined to be 2.40 and 1.55 for SiC RPCs prepared by the traditional and innovative methods by the linear regression, respectively. This suggests that the density exponent value of the materials prepared by the innovative method is in excellent agreement with the prediction (1.5) of the simple open-cell model developed by Gibson and Ashby [3], in which the bend strength versus relative density can be described by the equation $\sigma_{ff}/\sigma_{sf} = C(\rho_b/\rho_s)^{1.5}$, where σ_{sf} is the strength of the cell struts. But the value for those prepared by the traditional method deviates significantly from the prediction of the model. This discrepancy is mainly attributed to the un-uniformity in the macrostructure.

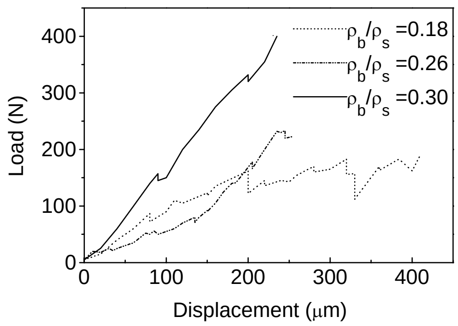

Fig. 4. Bending load-displacement curves of SiC RPCs prepared by innovative method without a paper pad.

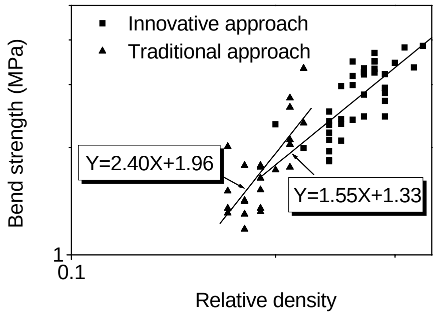

Fig. 5. Bend strength as a function of relative density for SiC RPCs without a paper pad.

3. Summary

The bending deformation behavior of SiC RPCs strongly depends on the loading uniformity and the macrostructure. The uniform loading leads to a significant transition in the load-displacement curve of SiC RPCs from the complex saw-tooth shape to the one similar to dense ceramics, However, this dependence of loading uniformity is alleviated by improved macrostructure with high uniformity, less flaws and stronger struts.

4. References

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