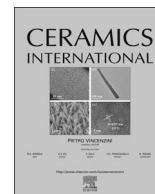




Contents lists available at ScienceDirect

Ceramics International

journal homepage: www.elsevier.com/locate/ceramint

Short communication

Effects of mechanical shock on thermal shock behavior of ceramics in quenching experiments

Haibo Kou^a, Weiguo Li^{a,*}, Xibei Zhang^b, Jiaying Shao^a, Xianhe Zhang^a, Peiji Geng^a, Yong Deng^a, Jianzuo Ma^a

^a State Key Laboratory of Coal Mine Disaster Dynamics and Control and College of Aerospace Engineering, Chongqing University, Chongqing 400030, China

^b Chongqing Nankai Secondary School, Chongqing 400030, China

ARTICLE INFO

Keywords:

Mechanical properties
Thermal shock resistance
ZrO₂
Thermal applications

ABSTRACT

Mechanical shock often exists in quenching experiments and service processes of ceramic materials. In this study, a series of experiments are designed and developed to study the effects of mechanical shock on thermal shock behavior of ceramic materials. It indicates that the pattern and length of cracks on specimens are significantly affected by mechanical shock in quenching experiments. Furthermore, the existence of mechanical shock will affect the stress field in ceramic specimens, and then the evaluation of thermal shock resistance by critical rupture temperature difference as well as service performance of ceramics can be easily affected by mechanical shock. This study provides suggestions that mechanical shock in quenching tests should be avoided or considered to shed light on the actual thermal shock resistance of ceramic materials.

1. Introduction

Ceramic materials have attracted growing attentions since 1950s owing to their high melting points, low densities, high stiffness, high hardness and good high-temperature stability [1–3]. However, they have terrible thermal shock resistance (TSR) due to their brittleness, and it's a main factor leading to their damages [4]. Quenching test is a frequently-used method to evaluate their TSR performance [5–7]. It has been reported that the results of quenching experiments of ceramic materials are obviously affected by the types and initial temperatures of cooling medium, geometry and surface treatment of specimens etc. [8–10]. Li [11] concluded that the pattern and number of cracks and the residual strength of ceramics differ significantly between lateral and longitudinal water entry postures. Water entry posture of specimens strongly affects the thermal shock behavior of ceramic materials.

In addition, there are usually mechanical shocks in quenching researches as well as the service processes of ceramics. When studying the TSR of ceramics by quenching experiment, specimens are usually maintained at target temperatures and then dropped into cooling mediums quickly to reduce exposing time in the air. However, in this process, mechanical shocks will be introduced. Moreover, as a part of the thermal protection system, ceramics always suffer from mechanical shocks because of the extremely large acceleration of hypersonic vehicles [12]. The mechanical shocks will affect the stress field in specimens when they are suffering from thermal shock, and then the

evaluation of thermal shock resistance by critical rupture temperature difference as well as service performance of ceramics can be easily affected by mechanical shock. However, few researchers have noticed this phenomenon and studied it. In this article, a series of experiments were designed and developed to study and evaluate the effects of mechanical shock on thermal shock behavior of ceramics.

2. Experiment procedures

2.1. Water quenching

In this study, specimens are made of ZrO₂ with dimensions of 4 mm*12 mm*68 mm and an average three-point bending strength of 515 MPa at room temperature. Density of the specimens is 6.60 g/cm³, typical grain size is ~10 μm, surface roughness is 1.5 μm.

As shown in Fig. 1, the specimen was pre-controlled to be longitudinal before heated by attaching to a molybdenum wire. And the molybdenum wire was tied up to a weight to make sure it is vertical. In this way, the specimen can drop freely into water with its long axes perpendicular to water surface. The distance from bottom of the specimen to water surface is 75 cm and from water surface to the weight is about 12 cm.

With other factors being the same, contrast experiments were designed to be Experiment 1 (with mechanical shock) and Experiment 2 (with mechanical shock absorber). As shown in

* Corresponding author.

E-mail address: wgli@cqu.edu.cn (W. Li).

<http://dx.doi.org/10.1016/j.ceramint.2016.10.021>

Received 3 October 2016; Accepted 4 October 2016

Available online xxx

0272-8842/ © 2016 Elsevier Ltd and Techna Group S.r.l. All rights reserved.

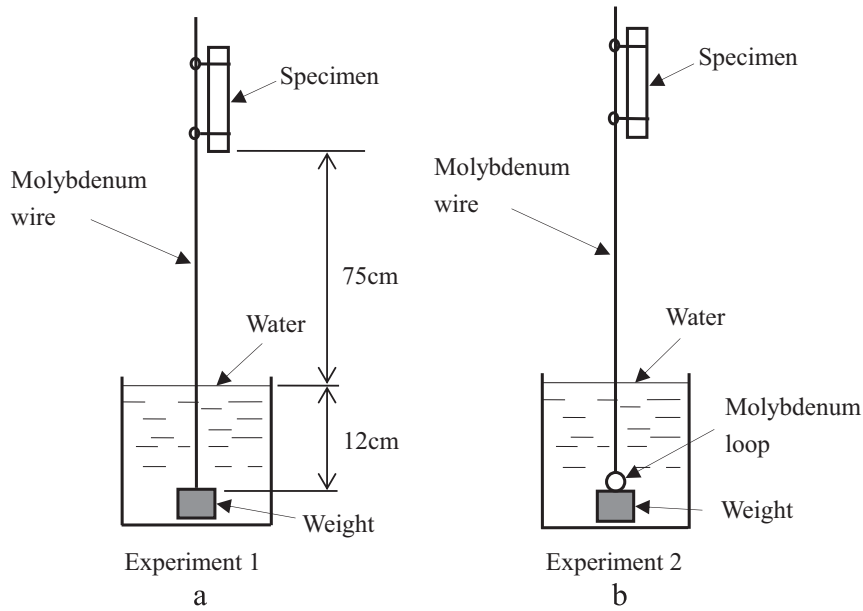


Fig. 1. Schematic of Experiment 1 and Experiment 2.

Experiment 1, the specimen would impact on the weight after dropping into water. And there would be a compressive stress parallel to the long axes of the specimen. However, in Experiment 2, the specimen would impact upon a molybdenum loop and the molybdenum loop would deform largely, leading to much longer impacting time and much smaller mechanical stress in specimen than Experiment 1.

Each specimen was heated to 405 °C and maintained at the temperature for 10 min. Then the specimen was dropped into water which was controlled to be a pre-set temperature (From 3 °C to boiling point) and quenched for about 30 s. After that, it was immersed into red penetration dye as a flaw-detecting agent for 15 min to reveal the cracks produced during water quenching. Then the specimen was washed and dried for 10 min at ambient temperature. After that, pictures of the quenched specimens were taken by a digital camera.

2.2. Measurement method of crack length

After taking photos of the water quenched specimens, crack length was measured by computer software. The method is shown as follows: 1. Sketch the contours of cracks; 2. Filter colour; 3. Measure crack length.

Original crack pattern of the quenched specimen is presented in Fig. 2a. The cracks were firstly sketched by *Photoshop* as in Fig. 2b. Then the sketched lines were disposed to be the same width by *Image Pro Plus* software, as shown in Fig. 2c. The white line is the disposed cracks and black part is the specimen. Next, the pixel length of the cracks can be calculated by pixel area dividing pixel width of the sketched lines. At last, the actual crack length can be figured out in accordance with the scale (Fig. 2d). The method to calculate it is:

$$L_c = \frac{A_p * L_a}{W_p * L_p} \quad (1)$$

where L_c is actual crack length. A_p and W_p are the pixel area and pixel width of the sketched line, respectively; L_p and L_a are pixel length and actual length of the specimen, respectively.

In this study, the total crack length within the first water entry part and latter water entry part are measured and compared quantitatively. The first water entry part is defined as the first quarter of the specimen entering water, and the latter water entry part is the end quarter.

3. Results and discussion

Fig. 3 shows the original crack pattern of the quenched specimens in Experiment 1 and Experiment 2 with water temperatures being 3 °C, 35 °C, 80 °C and 97 °C, respectively. It shows that specimens in Experiment 1 exhibited fewer cracks than Experiment 2. Besides, the crack density difference between first water entry part and latter water entry part in Experiment 1 is extremely distinct. Although crack density difference also arises in Experiment 2, it is obviously much smaller than Experiment 1.

To quantitatively evaluate the effects of mechanical shock on thermal shock behavior of ceramics, the total crack lengths within the first water entry part and latter water entry part of specimens in Experiment 1 and 2 are measured and compared, as shown in Fig. 4a and 4b respectively. We can see that, firstly, as shown in Fig. 4a, crack length of the first water entry part in Experiment 1 is markedly shorter than Experiment 2 and it is twice shorter at most water temperatures. Secondly, as shown in Fig. 4b, crack length of the latter water entry part in Experiment 1 is shorter than Experiment 2 at water temperatures lower than 50 °C. However, when water temperatures are higher than 50 °C, the difference of crack length between Experiment 1 and Experiment 2 is very small.

As mentioned in 2.1, specimens would impact on the weight after dropping into water in Experiment 1. A longitudinal compressive stress field was induced in the specimen due to the mechanical shock. And the compressive stress in the first water entry part was much larger than it in the latter water entry part. In accordance with the superposition principle, the compressive stress would relieve the tensile stress induced by thermal shock. Moreover, the tensile stress is relieved more

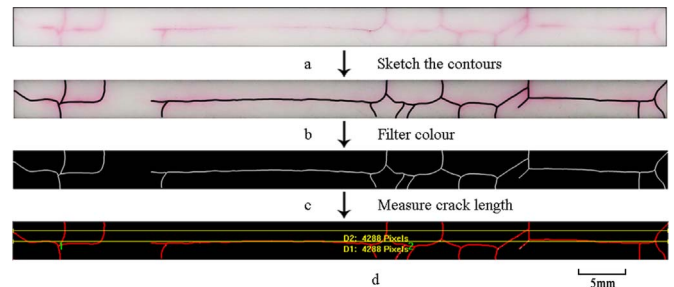


Fig. 2. Measurement method of crack length.

Download English Version:

<https://daneshyari.com/en/article/5439243>

Download Persian Version:

<https://daneshyari.com/article/5439243>

[Daneshyari.com](https://daneshyari.com)