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Letter

Thermal shock study of ceramic materials subjected to heating using a simple developed test method

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ABSTRACT

The research for the thermal shock resistance of ceramic materials during the ascending thermal shock has great significance. In this paper, a simple test method for the thermal shock testing of ceramic materials during heating is developed by refitting the quenching furnace. The method can control the target temperature of thermal shock and temperature distribution in the surface of materials better compared to the existing commonly used testing methods. During the testing, the specimen is designed to fall into a furnace chamber with a desired thermal shock temperature accurately and momentarily. The retained flexural strength of the specimen after thermal shocking is obtained. The results show that the thermal shock resistance of ceramic materials is very sensitive to the thermal shock temperature. The retained flexural strength of specimen without optical cracks on the surface can degrade seriously owing to the emergence of cracks in the interior of materials. The microstructure evolution in the interior of materials such as the phase transition has great effect on the thermal shock resistance of ceramic materials. This study will provide the technical reserves and theoretical bases for the research of the thermal shock resistance of ceramic materials under heating.

1. Introduction

Ceramic materials can be used in many high-temperature applications due to their high melting point, good chemical and physical stability. However, due to the inherently brittle behavior of ceramic materials, the thermal shock resistance (TSR) is very poor.

The TSR of ceramic materials is a major issue and an important performance index for high-temperature applications as the materials are susceptible to catastrophic failure under thermal stress owing to the temperature difference. The thermal shock can be divided into two kinds: thermal shock during cooling and thermal shock during heating. At present, most of the experimental reports are about the thermal shock under cooling. The commonly used method is the water quench testing [1–4], which is often performed by the quenching furnace. However, during the causative processes of ceramic materials used in high-temperature applications, thermal shock occurs mostly under heating conditions, and the intense ascending thermal shock would lead to the failure of materials [5–7]. Thus, it is very important and necessary to do the research for the TSR of materials during heating. The present testing methods for the thermal shock under heating mainly include electron beam heating [7,8], laser heating [9], oxy-acetylene heating [6], radiant heating [10], plasma arc heating [5], arc-heated wind tunnel [11], etc. At present, the commonly used methods are the electron beam heating, oxy-acetylene heating and plasma arc heating owing to their low cost and simplicity. When doing the testing using these methods, the central portion of the specimen is heated rapidly firstly, leading to the uneven temperature distribution in the surface of specimen, and the target temperature of thermal shock during heating is very difficult to be controlled. It can be observed that when determining the temperature in the surface of specimen the error will be very large. Currently, the used way of many testing methods to determine the TSR of materials is only to observe the changes in surface morphology of the specimen after thermal shocking, such as the cracks and erosion [5,6,8]. However, this cannot reveal the TSR of materials intuitively and comprehensively. As is well known, cracks will appear in the interior of the materials firstly which may lead to the serious degradation of the retained strength of the materials after thermal

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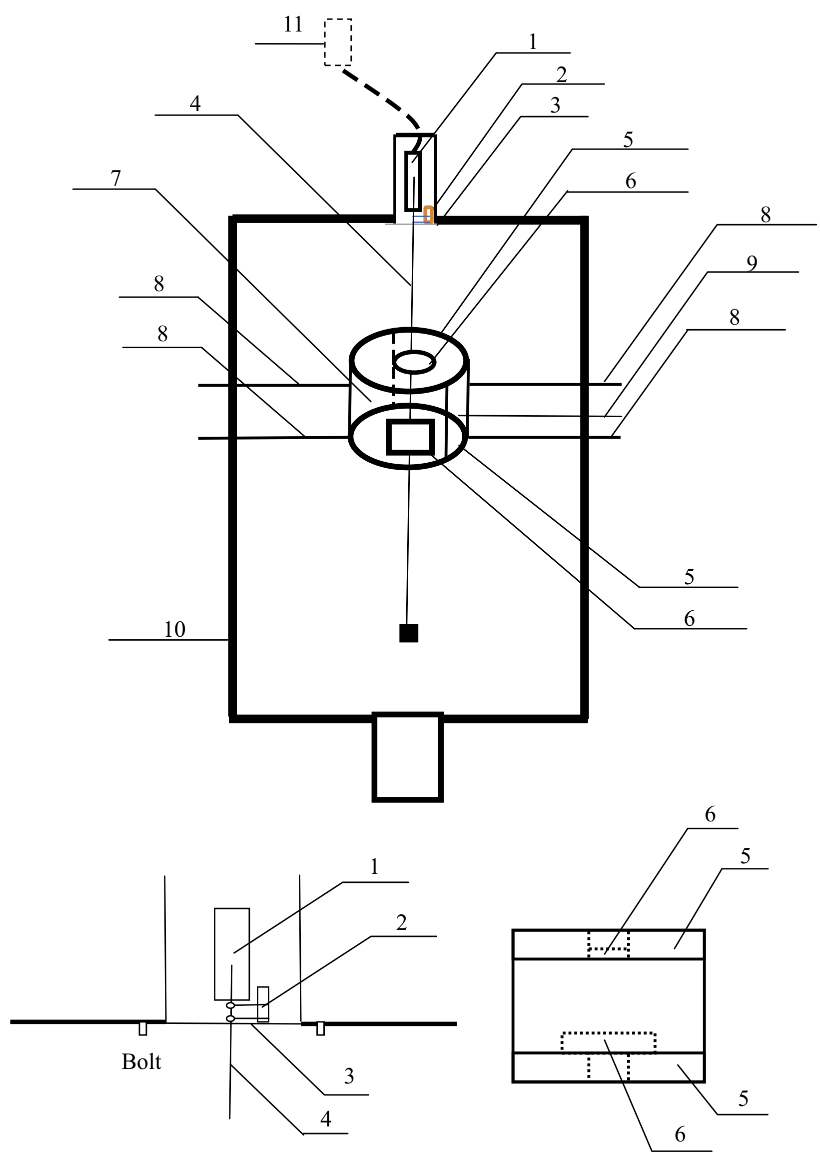
shocking. The microstructure evolution in the interior of the materials such as the phase transition may also affect the TSR of materials. Yet the researchers have not paid enough attention to that.

The aim of this paper is introducing a simple test method for the thermal shock testing of ceramic materials during heating. The principle of the method is designing a specimen under low temperature to fall into a thermal environment under a higher temperature automatically and momentarily. The temperature of the thermal environment can be controlled precisely and easily. Therefore, when using the method the target temperature of thermal shock can be controlled accurately. Meanwhile the surfaces of specimen in the thermal environment can be heated evenly, leading to the more evenly distributed of the temperature in the surface of specimen. During the ascending thermal shock testing, the ZrO_2(3Y) was used. The retained flexure strength of the specimen after thermal shocking was obtained. The microstructure evolution in the interior of materials was discussed in detail.

2. Experimental

The test equipment used in the proposed method (as shown in Fig. 1) includes the traditional quenching furnace (Fangrui Technology Co., Ltd., Changchun, China) and some auxiliary systems. The heating of the furnace chamber of quenching furnace is used the induction heating which can be controlled precisely and easily. The temperature of furnace chamber is measured using a thermocouple. The operating principle of the furnace is as follows: (1) fix the test specimen in the furnace chamber; (2) heat the specimen to a desired temperature and hold for 15 min; (3) fall the specimen into the water bath automatically and momentarily. In the method, the quenching furnace is refitted to fulfill the ascending thermal shock. The test specimen is placed and fixed using a sample holder (a molybdenum wire and two bolts) in a notch at the top of furnace which is used for the installation of pressure bar. The rear end of the pressure bar is unscrewed, leaving the front end. With the help of



1. Pressure bar; 2. Specimen; 3. Fixture (Molybdenum wire); 4. Guiding system (Molybdenum wire); 5. Graphite plate; 6. Carbon fiber felt; 7. Furnace chamber; 8. Heating device (Induction heating); 9. Thermocouple; 10. Quenching furnace; 11. Inflatable devices

8, 9 and 11 are connected to the controlled system; 10 is connected to the vacuum pump and cooling device

Fig. 1. Schematic of the refiting quenching furnace.