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Measurement of tensile strength of nuclear graphite based on ring compression test

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Abstract： Nuclear graphite is a type of quasi-brittle material, in which the ratio of the tensile strength to the compressive strength is higher than that of ceramic and hard rock materials. In this case, it is difficult to achieve a perfect splitting mode when the Brazilian splitting test is used to measure the tensile strength of such materials, leading to significant errors in the measurement. In this study, a ring compression test for measuring the tensile strength of the nuclear graphite material was proposed, and related principles and experimental verification were presented. The results showed that a regular tensile failure mode can be achieved using ring compression tests, and the tensile strength of nuclear graphite can be accurately measured. Furthermore, it was found that the accuracy obtained from the ring compression test was much better than that of the Brazilian splitting test.

Keywords: Nuclear graphite; Tensile strength; Brazilian splitting test; Ring-shaped specimen

1. Introduction

Tensile strength is an important indicator for evaluating the mechanical performance of materials, especially for brittle materials. Accurate measurement of the tensile strength of materials is of great importance for the design and analysis of structural safety. For ductile materials, the tensile strength is usually measured using the direct tensile tests. In this case, first, the target material should be processed into a standard tensile specimen, i.e., specimen of a dog-bone shape. The dog-bone specimen is then mounted in an appropriate fixture and stretched until the specimen fails [1]. However, the manufacture of the standard brittle specimen for the direct tensile test is not easy. In addition, uncertain factors such as damage and eccentric loading during the direct tensile test easily lead to unexpected failure or deviation. Therefore, the tensile strength of brittle materials, such as rock and ceramic materials, is usually measured using some indirect methods such as the disc splitting method, i.e., the Brazilian splitting test [2-4]. Theoretical analysis and experimental results show that certain conditions are necessary for the use of the Brazilian splitting test for measuring the tensile strength of materials. First, the tensile strength of the materials should be far lower than its compressive strength because for a disc specimen under compression loading, the stress state along the loading axis is bidirectional, rather than the uniaxially tensile state, and the tensile stress is less than its compressive stress (e.g., the tensile stress at the centre of the disc specimen is only 1/3 of the compressive stress at this position [5]). Therefore, a crack can initiate at the centre section and propagate along the loading axis of this specimen only if the tensile strength of the material is far lower than its compressive strength, and the specimen splits along the axis while the other regions remain intact. Second, the Brazilian splitting test requires a small deformation at the contact area with crosshead during the test because the stress analytical solution to the Brazilian splitting test model is established based on the assumption of concentrated loading on the disc specimen. The stress distribution will greatly deviate from the theoretical solution if a large deformation occurs at the contact area of the specimen.