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Investigation on slag fiber characteristics: Mechanical property and anti-corrosion performance

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Abstract

Inorganic fiber shows good insulation performance in civil construction and industry insulation. In the present paper, tensile strength of slag fiber produced with molten blast furnace slag was investigated systematically with the Weibull distribution theory in comparison with glass and basalt fibers. It was found that the mean tensile strength reached 2578.60 MPa and the shape parameter m in Weibull distribution is 2.4494, which indicates a lower uniformity. Anti-corrosion performances were also studied by means of the mass and strength loss after acid and alkaline solution treatment. Furthermore, SEM and FTIR were used to analyze the structural characteristics of original and treated fibers. This work has proved that the H^+ and OH^- can both break the Si–O bond and then lead to the movement to high wavenumber for the bands of the symmetric stretching vibrations of $[SiO_4]$-tetrahedra. The anti-corrosion results indicated that slag fibers could not be used in acid environment, while its anti-alkali performance is relatively excellent compared with glass and basalt fibers.

Keywords: Slag fiber; Tensile strength; Weibull distribution; Acid treatment; Alkali treatment

1. Introduction

Nowadays, fibrous material plays an important role in civil engineering and building thermal insulation due to their serviceability, durability and fire resistance [1,2]. With anti-combustible property, inorganic silicate fiber materials show superiority compared with traditional organic foams. Slag fiber is one of the most potential inorganic fibers because of its low cost, simple producing process and possibilities for the creation of compound structures [3,4]. Attempts have been made to obtain this material with industrial slag [5], and a novel preparation method of slag fiber by direct injection with molten blast furnace slag was proposed by the present research group, which realizes both waste-heat recovery and resource recycling of hot slags [2,6]. Nevertheless, the study of long term use properties of this kind of fibrous materials is also necessary. When the slag fibers were used in equipment and pipeline insulation, the mechanical strength of slag fiber often provides structural intensity. What's more, as exposed materials, fibers inevitably suffer in the severe environment corrosion, especially in corrosive acid and alkaline conditions. It is therefore necessary to study the mechanical property and corrosion performance of slag fiber.

The previous studies were usually concentrated on the fabricated composite materials, in which slag fibers were generally covered with organic matrix [7–11]. Mechanical properties of the composite materials and filaments have also been researched [12–14], which declared that cement with short slag fibers would improve by about 30% in compression and wear resistance. However, the complete understanding of the mechanical property of slag fiber itself is still limited. As insulation materials, the mechanical property was often ignored. In fact, tensile strength of slag fiber is very important for its application of intensity. Weibull distribution, which has been successfully used in studying the defect of glass and basalt fiber, was also introduced to study the uniformity of slag fiber. In the past years, although some attempts have been made to study the corrosion resistance of slag fiber reinforced materials [15,16], where the resin usually plays a protective role by shielding the

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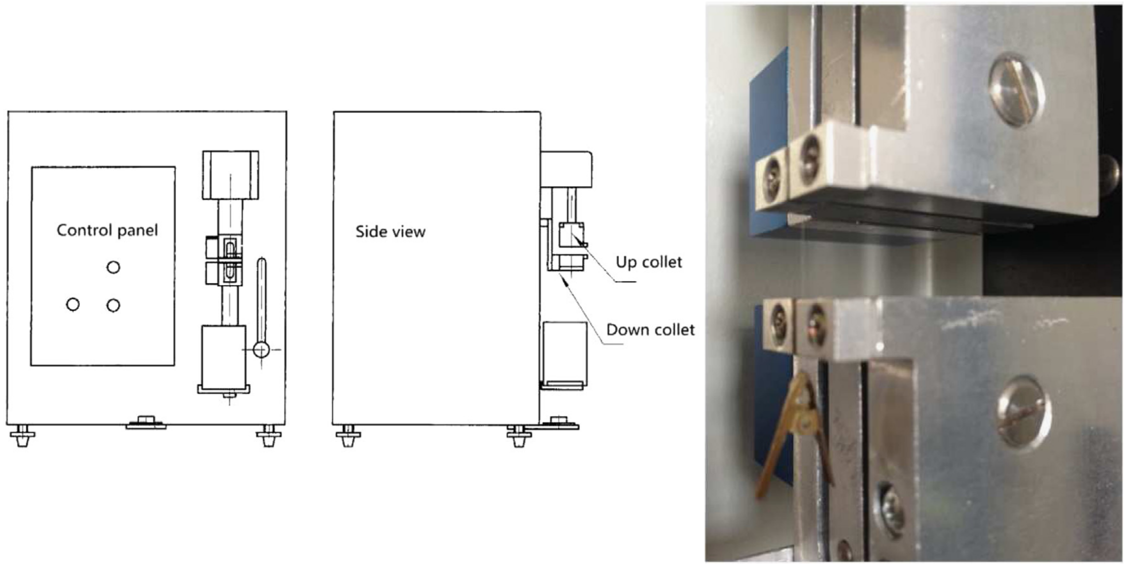

Fig. 1. Diagrammatic sketch and collets of the YG004 fiber tensile strength tester.

fibers from the corrosive environment [17,18], little attention was paid to slag filaments' resistance behaviors themselves. Wei et al. [19] suggested that both acid and alkaline solutions were aggressive to the surface of glass fiber, and they attributed the corrosion to the breaking of Si–O bonds in the network by hydrogen or hydroxyl ions. However, this study of corrosion behavior was still limited because the comparison was not systematic and microstructures of silica tetrahedrons were not discussed.

In reality, glass fiber and basalt fiber, as inorganic silicate fibers drawn from hole-board and applied widely in industry, were often compared with slag fiber. Produced from glass balls and natural basalts, preparation method and raw materials of glass and basalt fibers are different from slag fibers. However, systematic contrastive study among the three kinds of inorganic fibers has not been conducted yet. Thus, in order to make better understanding of slag fiber properties, this paper firstly studied the mean tensile strength of single slag monofilament with the Weibull distribution theory. Then, an environmental resistance analysis was carried out based on FTIR analysis, and the corrosion mechanism was thus explored.

2. Experimental procedure

In this research, slag fiber (produced by Huaxing Environmental Materials Corporation, Shanxi, China) produced by direct injection and centrifugal method (Junkers Method) from molten blast furnace slag was used. To compare and analyze the mechanism of their mechanical performance, E-glass fiber (produced by Jinwu Glass Fiber Corporation, Hebei, China) and basalt fiber (produced by Sichuan Dianshi Corporation, Sichuan, China) were also employed in the experiment. Mean diameters of fibers were measured with an optical microscope (GX41 by Olympus Inc., Japan).

Firstly, 100 repeated tensile tests have been carried out to determine the mean tensile strength for each kind of fiber. Then, fibers were immersed into 2 mol/L acid and alkaline solutions to study the environmental resistance performance. After the treatments, SEM and FTIR were used to research the corrosion principles.

The mechanical performance tests were carried out by fiber tensile strength tester (YG-004, manufactured by Changzhou Inc., Shanghai, China) as shown in Fig. 1. During the measurement, distance between two collets was 10 mm and stretching speed was 10 mm/min, while the force down rate was 10%. The collets were innovated by adding thin rubber film to increase the friction. All the measurements were undertaken with the environment humidity of 55% and 25 °C. For each kind of fiber, 100 specimens were tested and the mean value was obtained as the measurement result.

In the environmental resistance tests, solutions of 2 mol/L HCL and 2 mol/L NaOH were used to simulate the acid and alkaline environment. All the glass and basalt fibers were pretreated in acetone for 3 h to get rid of the size agents on the surface. Water-bath heating at 90 °C was applied to accelerate the reaction rate in the treatment. All the fibers were washed before the treatment by immersing in deionized water for 8 h to remove the residual after each processing. Mass loss of fibers was measured using electronic scales AL104 with an accuracy of 0.0001 g manufactured by METTLER TOLEDO, Switzerland. Micro-morphologies before and after treatment were characterized by a Hitachi S4800 scanning electron microscope (SEM). FTIR spectra were obtained with TENSOR 27, manufactured by Bruker, Germany.

3. Results and discussion

3.1. Essential properties of fibers

Main chemical compositions are shown in Table 1, which were measured by an X fluorescence spectrometer (XRF). As only physical change occurs, the compositions did not change during the production process. From Table 1, it can be seen