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The influence of ultra-fine glass fibers on the mechanical and anticorrosion properties of epoxy coatings

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ABSTRACT

The effects of different contents of ultra-fine glass fiber on mechanical and anticorrosion properties of epoxy coatings have been investigated. The FTIR and SEM have been used to analyze the surface nature and microstructure of the coatings. Electrochemical impedance spectroscopy (EIS) and a salt spray test have also been used to characterize the contents of ultra-fine glass fibers on the impedance of the coatings. When 10%, 20%, 30% of ultra-fine glass fibers are added to the coatings, their hardness and adhesion increases by 67%, 67%, 200% and 21.6%, 39%, 40%, respectively, compared with the properties of the pure coating. But the anticorrosion properties of the coatings containing high ultra-fine glass fiber content decreased with respect to the pure coatings properties.

1. Introduction

The protection of ocean facilities, such as ports, bridges, is a systematic engineering and it includes many fields and factors. Corrosion occurs most seriously in the marine splash zone. This area always encounters the varying conditions of wet and dry environments and erosion by sea water. In order to protect the facilities, anticorrosion coatings, especially heavy duty anticorrosion coatings, must be used due to their favorable adhesion, long-acting and good anticorrosion properties. Epoxy resins have many excellent properties, such as high Young's modulus, tensile strength, thermal stability, as well as excellent adhesion to various substrates and good environmental resistance [1]. As a result, they are widely used in heavy duty anticorrosion coatings. However, the major disadvantages of pure epoxy resins are their brittleness and low fracture toughness [2].

Glass fibers have a higher modulus, higher toughness, lighter weight than traditional materials, so that they are widely used in many reinforcement situations, such as in polymer-fiber composites, ceramic-fiber composites and concrete-fiber composites [3–5]. Many researchers [6–16] have studied the influence of polymer–glass fiber composites where some glass fibers are used as the reinforcing materials. Glass fibers whose surface has been modified by first using a coupling agent and then mixing with the polymer can improve the composite impact resistance [17,18] and shear strength.

Previous studies have mainly focused on continuous glass fibers [19–21] or short glass fibers, their diameters lying between 14 and 19 μm and with a length between several millimeters to several meters. They are difficult to apply in a coating directly because of their length. In order to solve this question, ultra-fine glass fibers can be added to the coatings to take the place of the long or short glass fiber in the coating. They have smaller diameters and length, are dispersed in the resin more easily and are easily applied than traditional long or short glass fibers. The ultra-fine glass fiber has lower price than whisker and so they can be used widely in coating industry. Research about the use of ultra-fine glass fibers in paints has not previously been reported. In the work reported in this paper we have studied coatings containing ultra fine glass fibers and their influence on the coating anticorrosion properties and mechanical properties. At the same time, the effect of adding some content of zinc powder in the coating as an anticorrosion pigment [22–27] to protect the iron substrate has also been investigated.

2. Experimental

2.1. Sample preparation

Fig. 1 shows an SEM micrograph of the zinc powder (Jiangsu Kechuang Metal Materials Co., Ltd., China) and of the ultra-fine glass fibers (Tianjin Junsheng Architecture Material Company, China). It can be seen from the Fig. 1 that the ultra-fine glass fibers were mostly of length 50–80 μm, with diameters 10 μm and the diameters of zinc powder was between 2 and 5 μm. Fig. 2 shows the result from XRD spectroscopy of the zinc powder and the ultra-fine glass fibers. It can be seen from the Fig. 2 that the ultra fine glass fiber is amorphous.

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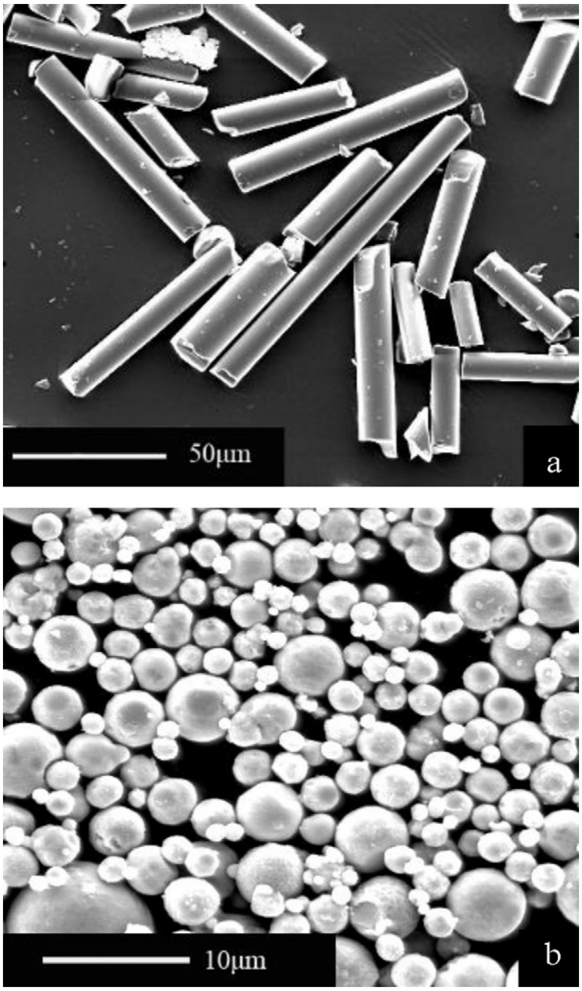


Fig. 1. (a) SEM micrograph of short ultra-fine glass fiber (b) SEM micrograph of Zn powder.

Table 1
The coatings containing different ultra-fine glass fiber content used in the experiments.

Coating number	Zn (%)	Ultra-fine glass fiber (%)
1#	9	0
2#	9	10
3#	9	20
4#	9	30

Table 2
Mechanical properties of the four coatings.

Mechanical properties	1#	2#	3#	**4#**
Hardness (H)	3	5	5	9
Flexibility (mm)	1	1	1	1
Impact resistance (kg cm)	120	120	120	120
Adhesion (MPa)	5.1	6.2	7.1	7.2

The ultra-fine glass fibers were treated with a 4 mass% KH-570 (Fig. 3) (γ-methacryloxypropyl trimethoxy silane) silane coupling agent (Nanjing Shuguang Chemical Group Co., Ltd., China) ethanol solution, and dried in an oven at 80 °C for 10 h. The product was screened before use. The diglycidyl ether of bisphenol A resin, E-44 (epoxy equivalent 212–243 g/equiv, Jiangsu San-Mu Group. Co., Ltd., China) and diglycidyl ether of bisphenol F resin, DER 354(epoxy equivalent 167–174 g/equiv, DOW. Co., Ltd., US) blended in a mass ratio of 85: 15 was selected as the matrix. The curing agent was

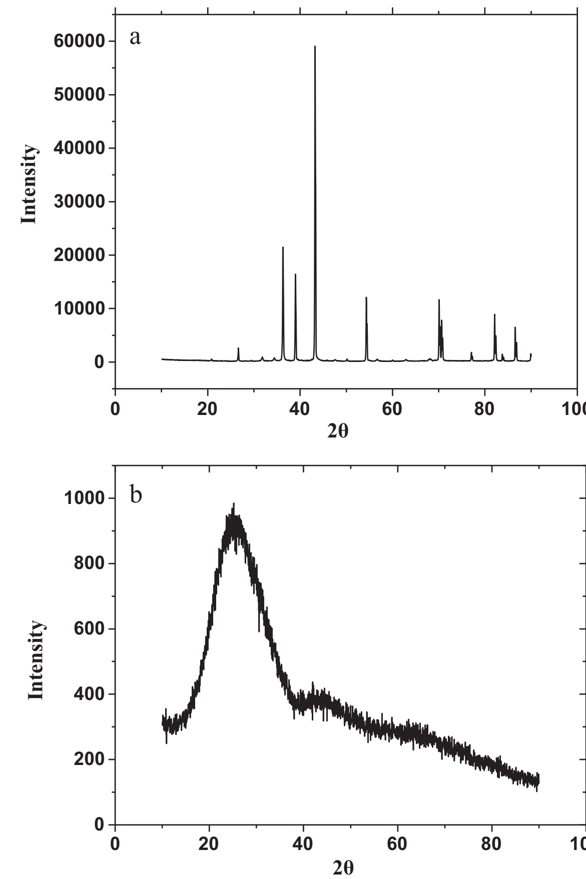


Fig. 2. (a) XRD pattern of Zn powder, (b) XRD pattern of ultra-fine glass fibers.

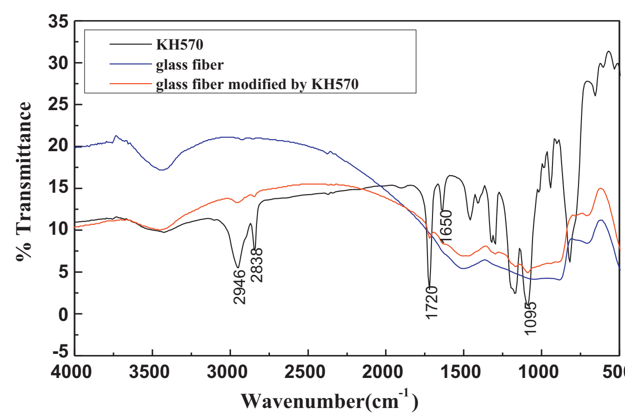
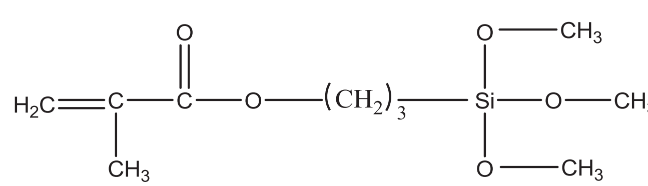


Fig. 3. FTIR of ultra-fine glass fibers, modified ultra-fine glass fibers and KH-570 coupling agent.



KH-570 (γ-methacryloxypropyl trimethoxy silane)

Fig. 4. The structure of the KH-570 coupling agent.