Materials and Design 32 (2011) 4180–4186

Contents lists available at ScienceDirect

Materials and Design

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

Strengthening of basalt fibers with nano-SiO_2–epoxy composite coating

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ARTICLE INFO

Article history:
Received 5 February 2011
Accepted 21 April 2011
Available online 29 April 2011

Keywords:
A. Basalt fibers
C. Coatings
D. Bonding

ABSTRACT

Coatings, which were made from pure epoxy and SiO_2 nanoparticle modified epoxy composite, respectively, were applied onto the basalt fiber rovings. The SiO_2 nanoparticles were synthesized using a sol–gel method and modified using coupling agent. Fourier transform infrared spectroscopy (FT-IR) and Differential Scanning Calorimetry (DSC) analyses indicated the formation of modified SiO_2 nanoparticles. The SiO_2 nanoparticle–epoxy composite coating gave rise to a significant increase in the tensile strength of the basalt fibers as compared with the pure epoxy coating, and also the coating endowed the basalt fiber with a promising interfacial property in the basalt fiber reinforced resin matrix composite. The coating modification was an effective way in improving the mechanical properties of basalt fibers and the properties of basalt fiber/epoxy resin composites.

1. Introduction

High performance filaments, such as carbon fiber and glass fiber, are frequently used as the reinforcement of composites. Basalt fiber is one of them and its chemical composition is shown in Table 1. In general, it has high strength, excellent fiber/resin adhesion and ability to be easily processed using conventional processes and equipment [1]. In addition, basalt fibers do not contain any other additives in a single producing process, which makes them have an additional advantage in terms of cost. As is known, the basalt fiber has a higher tensile strength than the E-glass fiber and its strain to failure is larger than the carbon fiber. Furthermore, the basalt fiber has high chemical stability and sound mechanical properties as well as being non-toxic and non-combustible [2]. For these reasons, the basalt fibers could be widely applied to many fields, such as corrosion resistance stuff in the chemical industry [3], wear and friction stuff in the automobile industry [4], target area of anti-low velocity impact [5], reinforcing material in construction [6], and high temperature-insulation of automobile catalysts [7]. Moreover, they have advantages over the glass and asbestos fibers in terms of environmental cleanness [8]. Apart from these, the basalt fibers could be made into various products, such as mat, fabric, and strip. Therefore, the basalt fiber is a new generation fiber with high performance and has received enormous attention in many countries [9–12].

However, there is a problem concerning these fibers in that the measured strengths are significantly lower than their theoretical values. The strength of the materials is influenced by the presence of surface and internal defects that are created during manufacturing and handling. The tensile strength of virgin basalt fibers varies in the range of 2–4 GPa, depending on drawing conditions. Just like other materials, basalt fibers also have surface defects, which make their measured mechanical properties remarkably lower than the maximum theoretical values. Therefore, a thin film of sizing consisting of coupling agents (film former and other constituents) is normally applied onto basalt fibers immediately after drawn from melt. The sizing aims to promote the fiber–matrix adhesion through the coupling effect as well as to avoid damage during handling. It can also effectively reduce the stress concentration at the surface flaws by blunting the crack tips [13], providing a useful healing effect and thereby enhancing the strength of the fibers. Applications of various polymeric coatings as sizing or part of sizing have been reported [14]. When an epoxy-based sizing was used, the distribution of the defects on the fiber surface became narrower than that without sizing (coating). The properties of basalt fibers without sizing treatment are poor and they cannot be used in the manufacturing process. In recent studies, the idea of nano-material reinforced polymer coatings on basalt fibers has been explored. When a polymer coating containing 5 wt.% nanoparticles was applied onto the surface of basalt fibers, a significant improvement in the tensile strength of the fibers was noted [15]. The improvement in fiber tensile strength is attributed to the nanoparticles in polymer coating, which act as the "padding" at the defect tips on the fiber surface and in turn delay the crack opening. Fig. 1 sheds insight into the crack healing effect of nanoparticle reinforcements in the coating.

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doi:10.1016/j.matdes.2011.04.041