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The synergy effect in tribological performance of paper-based composites by MWCNT and GNPs

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ABSTRACT

In order to improve the tribological performance of paper-based composites, graphene nanoplatelets (GNPs) and multi-walled carbon nanotubes (MWCNT) were introduced as lubricating fillers by paper making technique. Results showed that the thermal conductivity and tensile strength of composites increased by 47% and 51% respectively after adding MWCNT and GNPs, which is beneficial to reduce the thermal damage of composites and improve the mechanical properties of composites. Furthermore, the wear rate of modified composites greatly dropped from $3.59 \times 10^{-14}\ m^3\ (N\ m)^{-1}$ to $1.24 \times 10^{-14}\ m^3\ (N\ m)^{-1}$. The higher specific surface area of GNPs and the rod-like structure of the MWCNT play a positive role on the improvement of the tribological performance by forming friction film on the worn surface.

1. Introduction

Paper-based composites are widely used in wet transmission and braking device, such as automatic transmission, torque manager, and synchronizer [1–3]. In order to ensure the torsional stability and braking safety of the transmission and braking device, they are usually required to possess moderate and stable friction coefficient, low wear rate, excellent thermal and mechanical properties [4,5]. The performance influencing factors of paper-based composites are complicated since they have a variety of components, involving reinforcements, binders and fillers [6–8]. Previous researches on improving the friction and wear properties of paper-based composites were mainly concentrated on the effects of reinforcements and binders [9–11], and the effect of fillers was rarely reported. It is worthy attempting to develop some novel fillers to modify tribological performance of the paper-based composites since they can effectively adjust the friction and wear performance by special microstructure or physical property [12–14].

One-dimensional carbon nanotube and two-dimensional graphene have been considered as good lubricant nanomaterials due to their large specific surface areas, high thermal conductivity and good thermal stability [15–17]. J Llorente et al. [18] found that the anti-wear performance of SiC-based composites was significantly improved by the addition of 20 vol % graphene nanoplatelets (GNPs). The excellent tribological performance was attributed to the formation of a lubricating and protective tribofilm. M. Kalin et al. [19] discovered that the tribological performance of the poly-ether-ether-ketone (PEEK) was enhanced after adding graphene and CNT. Lim et al. [20] found that the wear resistance of C/C composites was significantly increased with the content of CNTs ranging from 0 to 20 wt %. Golchin et al. [21] gave a conclusion that the friction and wear performance of the ultra-high molecular weight polyethylene could be significantly improved by introducing multi-walled carbon nanotube/graphene oxide. The above-mentioned discoveries demonstrate that the excellent wear and friction performance of composites can be achieved by introducing carbon nanotube and graphene. This is mainly attributed to the one-dimensional tubular structure and the two-dimensional layered structure. Unfortunately, little work has been reported about using carbon nanotube and graphene simultaneously to modify paper-based composites up to now.

In this work, carbon nanomaterials involving one-dimensional multi-walled carbon nanotubes (MWCNT) and two-dimensional graphene nanoplatelets (GNPs) were introduced into paper-based composites via paper making technique. Their thermal, mechanical and tribological properties were comparatively investigated with addition of carbon nanomaterials. The synergistic influence mechanism of GNPs and MWCNT in paper-based composites was discussed.

2. Experimental procedure

2.1. Materials preparation

The short fibers composed of carbon fibers (Jiyan high technology

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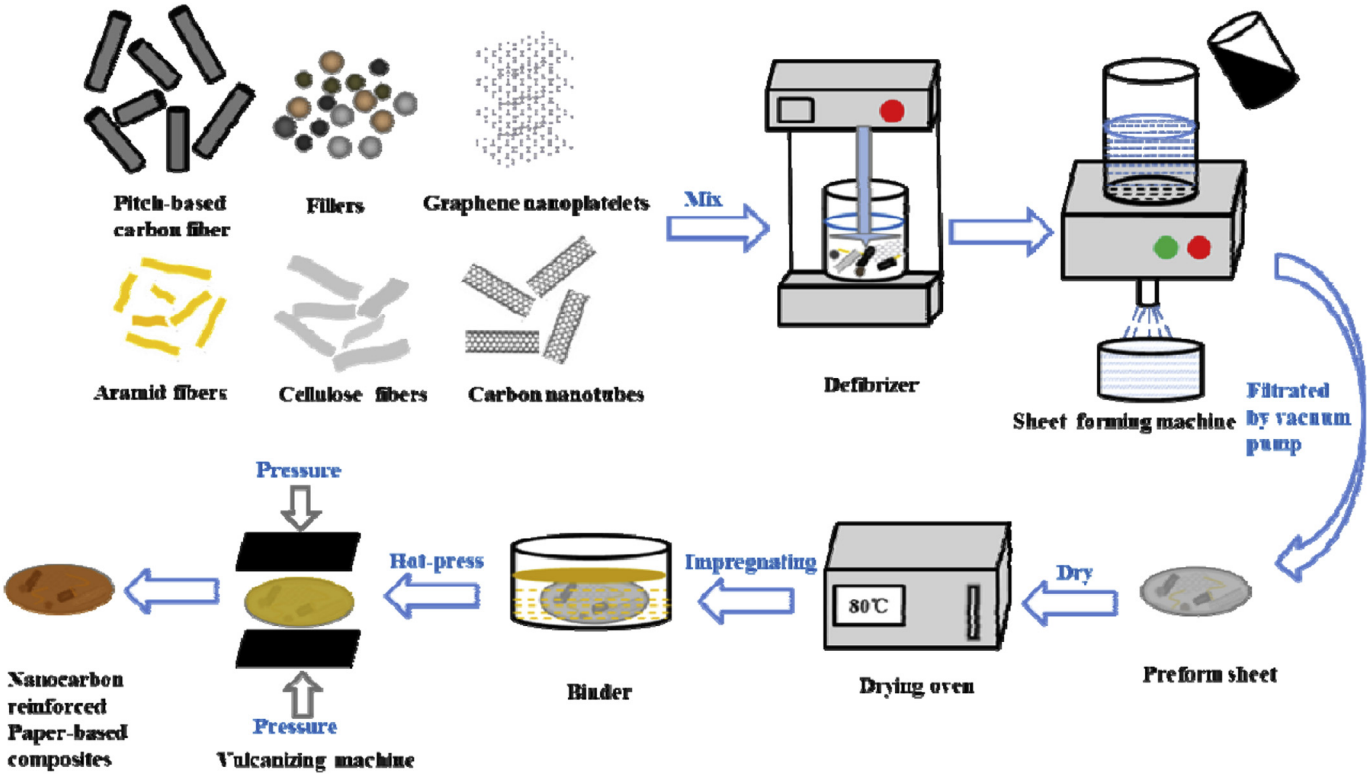

Fig. 1. The schematic of overall fabrication process for paper-based composites reinforced by MWCNT and GNPs.

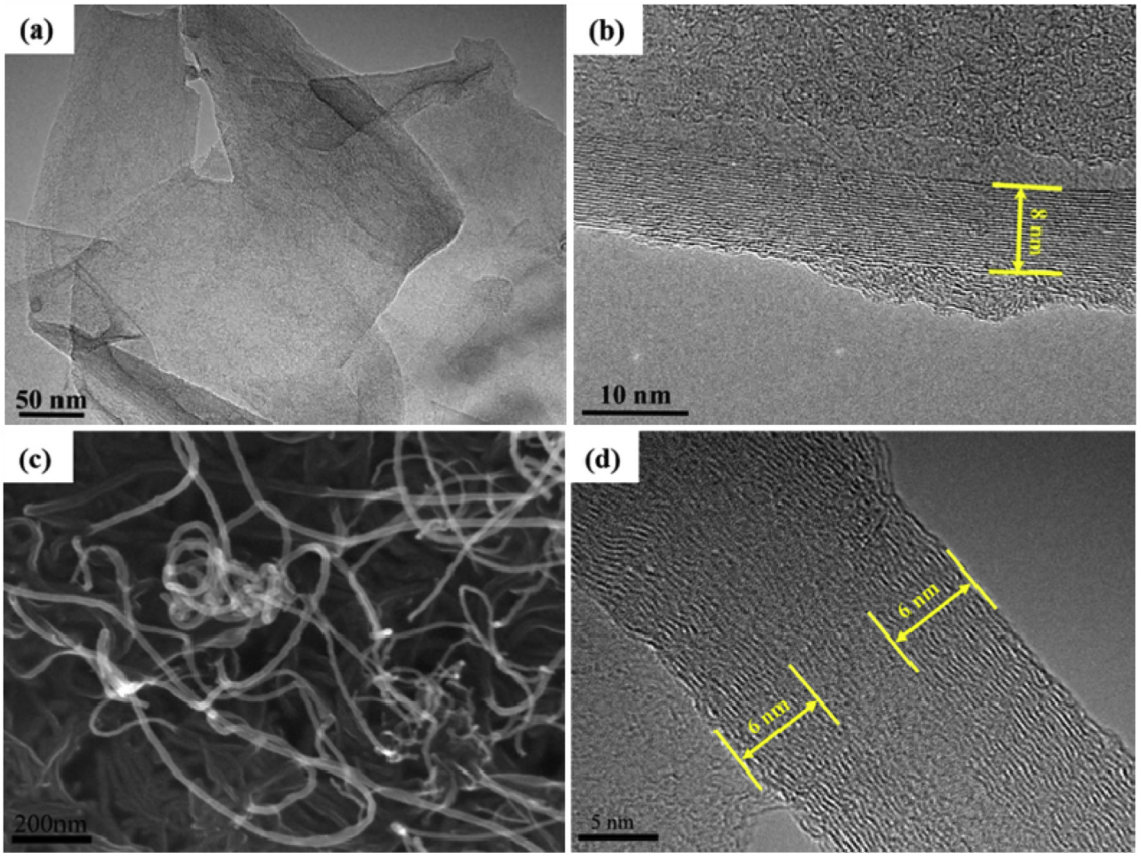

Fig. 2. TEM image (a) and (b) of GNPs, SEM image (c) and TEM image (d) of MWCNT.