Thermal Balancing and Thermodynamic Analysis of Nanopaper Enabled Composite Materials

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Abstract: The finite element software FLUENT was used to study the thermal balance and thermodynamic analysis of composites reinforced by pulse bending and flat nanopaper during the heating process. At the initial stage of heating, the heating energy is mainly used to increase the internal energy value of the polymer matrix and the nanopaper, and because the mass and heat capacity of the polymer matrix are greater than the nanopaper, the heat absorption of the polymer matrix is more than that of the nanopaper. With the increase of the heating time, the increase of the external surface temperature makes the convection heat dissipation increase, so the proportion of convection heat dissipation increases gradually. As the heating time prolongs, the heating rate of the polymer matrix and the nanopaper decreases and the heat absorption of the material decreases. Therefore, the endothermic ratio of polymer matrix and nanopaper decreases.

1. Introduction

The research shows that the in-plane thermal conductivity of buckypaper with CNTs aligned in the plane could be higher than 300 W/mK [1], and the thermal conductivity along the thickness direction was in a range of 1-20 W/mK [2-4] varied for the different preparation methods. Carbon nanotube (CNT) buckypaper, which has large specific surface area and tunable network structures, shows great potential in the application of heat dissipation for high power electronic devices.

Chen et al [5] investigated the effects of CNT diameter and length on the network formation of buckypapers by vacuum filtration and their thermal transport properties were thoroughly. The CNT architecture in buckypaper is found to be a key issue to affect the thermal conductivity of buckypapers. Gonnet et al [2] indicated that nanotube alignment had a measurable influence on the thermal conductivities of both buckypaper and nanocomposites, and the thermal conductivities were found to increase linearly with temperature for both buckypapers and composites.

The finite element software FLUENT was used to study the thermal balance and thermodynamic analysis of composites reinforced by pulse bending and flat nanopaper during the heating process.

2. Numerical model

The finite element software FLUENT was used to study the thermal balance and thermodynamic analysis of composites reinforced by pulse bending and flat nanopaper during the heating process. Figure 1 shows the heating model of the polymer composite reinforced by pulse bending and flat nanopaper.

As shown in Figure 1, the length (L) and the thickness (T) of the heating model are 36 mm and 10 mm respectively, and the width (w) is 5 mm. The thicknesses of the nanopaper are 0.4 mm. For the heating model of pulse bending nanopaper, the bending height (h) and bending period (A) of pulse bending nanopaper are 6 mm and 12 mm. The heating powers are 0.3 W.

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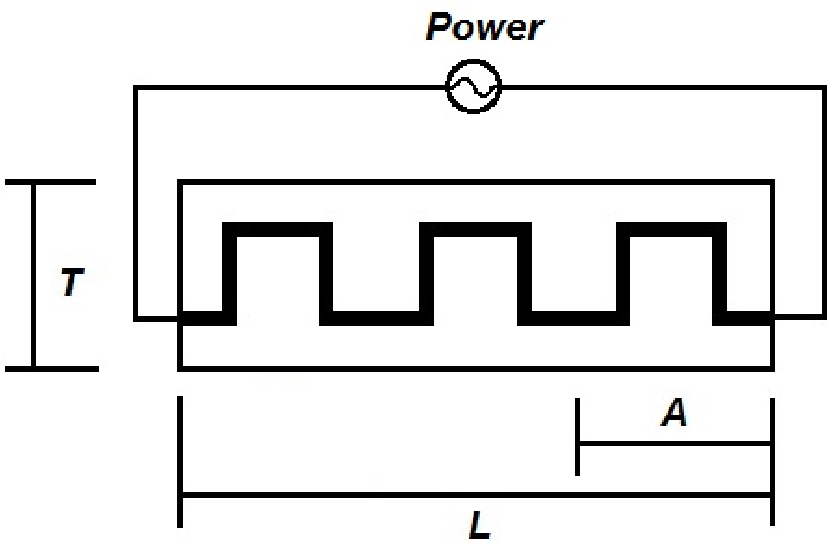
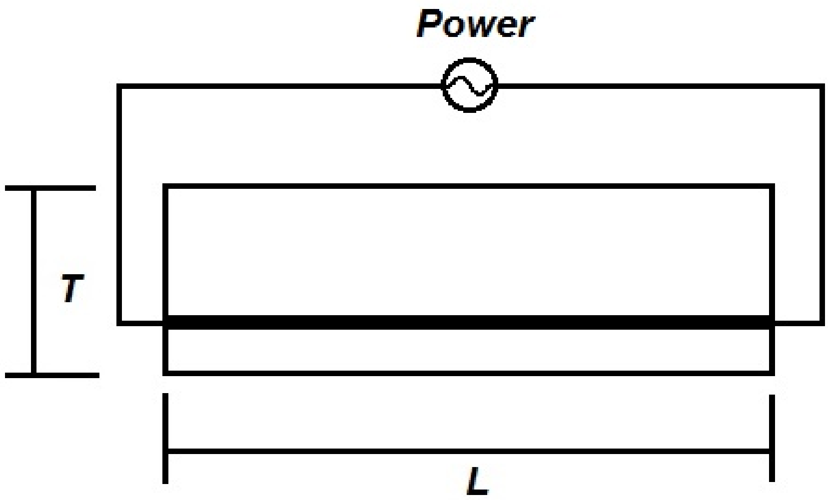


(a) Pulse bending



(b) Flat

Fig. 1. Sketch diagram of heating experimental device

3. Results and discussion

Figures 2 shows that the ratio of the amount heat consumption to the total heat consumption Q*total* vary with the heating time under the shape of pulse bending and flat nanopaper. The thermal conductivity of nanopaper was set to be 1.5 W/(m•K). The thermal conductivity of the polymer matrix was set to be 0.2 W/(m•K).

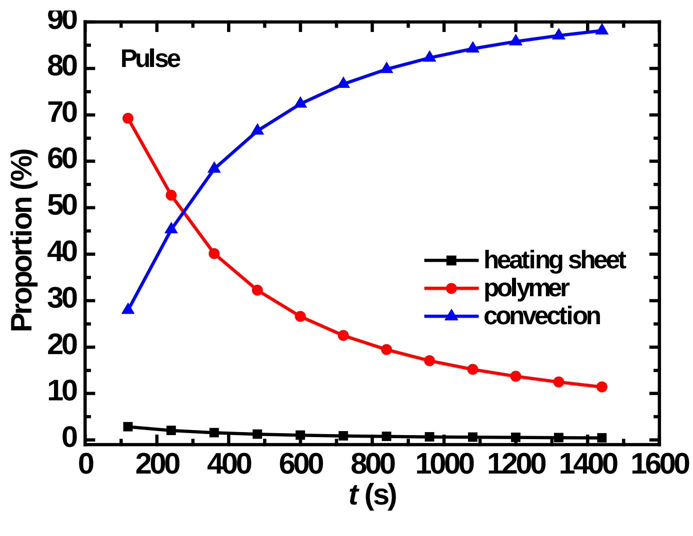
As shown in Figures 2, at the initial stage of heating, the heating energy is mainly used to increase the internal energy value of the polymer matrix and the nanopaper, and because the mass and heat capacity of the polymer matrix are greater than the nanopaper, the heat absorption of the polymer matrix is more than that of the nanopaper. With the increase of the heating time, the increase of the external surface temperature makes the convection heat dissipation increase, so the proportion of convection heat dissipation increases gradually. As the heating time prolongs, the heating rate of the polymer matrix and the nanopaper decreases and the heat absorption of the material decreases. Therefore, the endothermic ratio of polymer matrix and nanopaper decreases.

Table 1 shows typical temperature of composites reinforced with pulse bending nanopaper versus time under the heating power of 0.3 W.

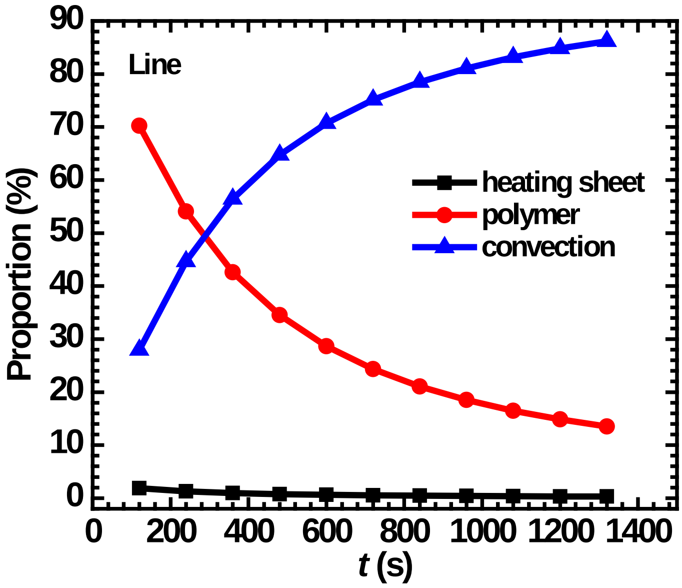
Table 1 Typical temperature of composites reinforced with pulse bending nanopaper versus time

Time/s	Tmax/K	Tmin/K	Tave/K
0	300	300	300
20	305.0	300.9	303.2
40	307.9	302.8	305.9
60	310.4	304.8	308.3
120	316.3	309.4	314.0
240	323.5	314.7	320.8
360	327.2	317.4	324.2
480	329.0	318.6	325.8
600	329.9	319.3	326.7
720	330.4	319.6	327.1
840	330.6	319.8	327.3
960	330.7	319.8	327.4
1080	330.7	319.9	327.4
1128	330.8	319.9	327.4

As shown in Table 1, the typical temperature of composites reinforced with pulse bending nanopaper increase during the heating process.



(a) pulse bending



(b) flat

Fig. 2. The curve of proportion of heat flow versus time

4. Summary

The finite element software FLUENT was used to study the thermal balance and thermodynamic analysis of composites reinforced by pulse bending and flat nanopaper during the heating process. At the initial stage of heating, the heating energy is mainly used to increase the internal energy value of the polymer matrix and the nanopaper, and because the mass and heat capacity of the polymer matrix are greater than the nanopaper, the heat absorption of the polymer matrix is more than that of the nanopaper. With the increase of the heating time, the increase of the external surface temperature makes the convection heat dissipation increase, so the proportion of convection heat dissipation increases gradually. As the heating time prolongs, the heating rate of the polymer matrix and the nanopaper decreases and the heat absorption of the material decreases. Therefore, the endothermic ratio of polymer matrix and nanopaper decreases.

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