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Finite Element Analysis of Temperature Distribution of Composites Reinforced by Nanopaper

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Abstract. The finite element software FLUENT was used to analyse the thermal property of the polymer composites reinforced by pulse bending nanopaper. The minimum temperatures increased during heating process under the same heating power. And the minimum temperatures increased when the heating power increased for the same heating time. The maximum, minimum and average temperatures of the pulse bending nanopaper enabled polymer composites is studied during the heating process when the thickness of nanopaper is 0.8mm. The heat source per unit volume of pulse bending nanopaper decreased when the thickness of pulse bending nanopaper increased from 0.4 mm to 1.2 mm.

1. Introduction

Although CNTs have excellent electrical, chemical, thermal and mechanical properties [1-4], it’s difficult for CNTs to disperse effectively in polymer matrix when CNTs are more than 10 wt.% for fabricating nanocomposites [5]. A new approach was developed by the authors to infiltrate a preformed nanotube network or nanotube mat (often called buckypaper) with resin to produce bulk polymeric nanocomposites with a uniform CNT dispersion, well-controlled nanostructures and high CNT loading capability [6]. The polymer composites reinforced by the nanopaper can be used to solve the heat problems associated with advanced electronic equipment [7].

2. Numerical model

The finite element software FLUENT was used to analysis the thermal property of the polymer composites reinforced by pulse bending nanopaper. Figure 1 shows the heating model of the polymer composites reinforced by pulse bending nanopaper.

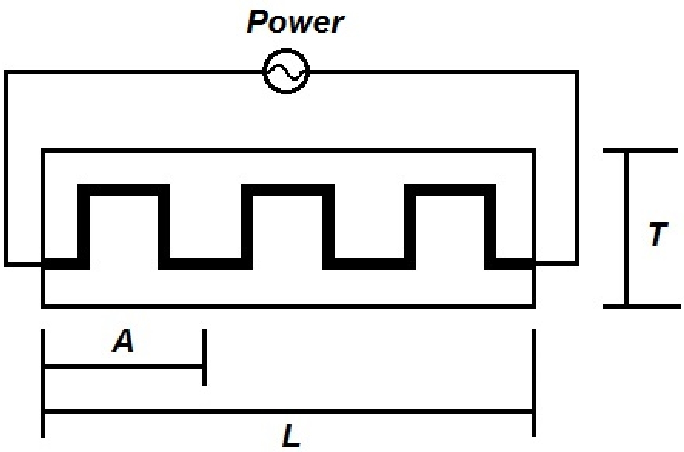

Fig. 1. Heating model of nanocomposites

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Within a certain range, the accuracy of calculation is directly proportional to the grid number, and the computation speed is inversely proportional to the grid number. When the computation accuracy is high and the calculation result is closer to reality, the number of grids needed is often high and the computation speed is very low. For a given computation model, how many grid numbers just match the computational requirements need to be studied, that is, grid independence verification.

The general method of grid independence verification is to select grid models with different density according to the size of the calculation model. Taking the specific calculation value as the evaluation index, this study is the temperature distribution in the whole heating device, and the evaluation index is chosen as the typical section average temperature. With the increase of grid number, when the average temperature change of typical section is less than 1%, it is considered that grid independence requirement is achieved.

Taking the heating power of carbon nanometers equal to 1W as an example, the average temperature of the cross section x=0 and the cross section z=0 under the steady state of the discrete grid density is calculated as a criterion for the convergence of the grid. The bending period is discrete with hexahedral structured grid. The minimum size of the grid is 0.1mm, 0.12mm, 0.16mm, 0.24mm and 0.4mm, and the number of the corresponding grids are 1858400, 1092420, 480480, 147420 and 36569, respectively.

Figure 2 shows the variation of the mean temperature of the cross section x=0 and the cross section z=0 with the number of discrete grids.

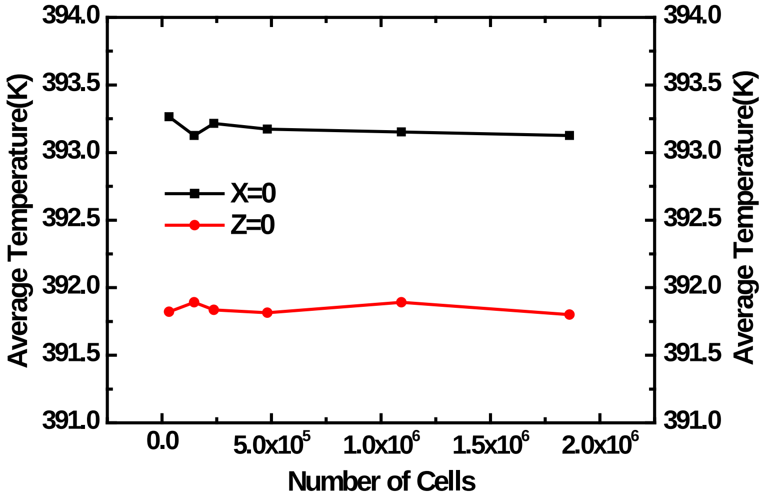

Fig. 2. Verification of grid independence

As shown in figure 2, the bending period is discrete about 480 thousand grid, and the average temperature value and minimum grid size of typical cross section x=0 and z=0 are 0.12mm, the number of mesh is about 1 million 90 thousand, the minimum grid size is 0.1mm and the average temperature of the cross section is about 1 million 860 thousand when the mesh size is about 1 million 860 thousand. The total number of 480 thousand grids is within 1%, and the grid scheme with the smallest grid size of 0.16mm can satisfy the result independent of the number of grids. Therefore, the latter analysis and computation will be discretized according to the grid density.

3. Results and discussion

Figures 3 show the minimum temperatures of the pulse bending nanopaper enabled polymer composites under different heating powers during the heating process. The minimum temperatures increased during heating process under the same heating power. And the minimum temperatures increased when the heating power increased for the same heating time.

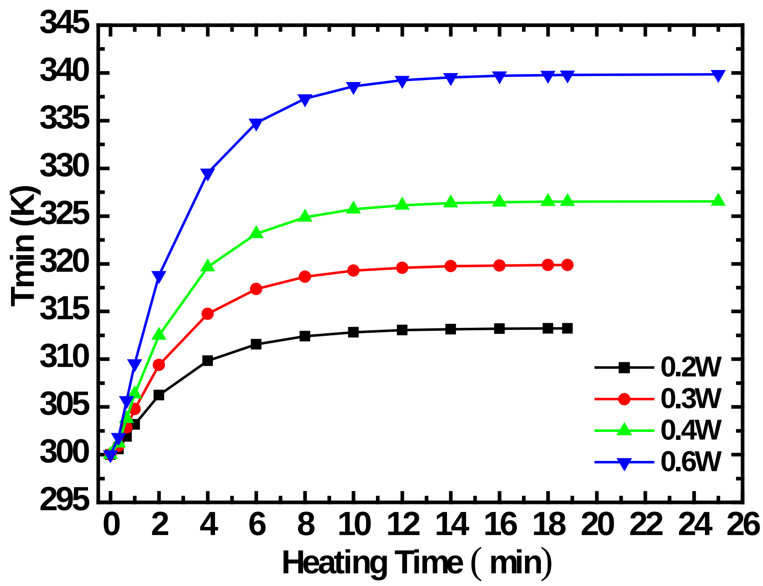

Fig. 3. Curve of the minimum temperature of the pulse bending nanopaper enabled polymer composites under different heating powers during the heating process

Table 1 show the maximum, minimum and average temperatures of the pulse bending nanopaper enabled polymer composites during the heating process when the thickness of nanopaper are 0.8mm.

Table 1 Typical temperature of composites reinforced with pulse bending nanopaper versus time along the section z=0

Time/s	Tmax/K	Tmin/K	Tave/K
0	300	300	300
20	305.04	300.90	303.24
40	307.89	302.84	305.93
60	310.35	304.77	308.31
120	316.28	309.38	313.99
240	323.54	314.74	320.80
360	327.19	317.35	324.17
480	329.00	318.64	325.84
600	329.90	319.28	326.67
720	330.35	319.59	327.08
840	330.57	319.75	327.28
960	330.68	319.82	327.38
1080	330.74	319.86	327.43
1200	330.76	319.88	327.46
1320	330.78	319.89	327.47
1440	330.78	319.90	327.48

Table 2 shows the heat source per unit volume of pulse bending nanopaper of different thickness. As shown in Table 2, the heat source per unit volume of pulse bending nanopaper decreased when the thickness of pulse bending nanopaper increased from 0.4 mm to 1.2 mm.

Table 2 The heat source per unit volume of pulse bending nanopaper of different thickness

Thickness of nanopaper (mm)	0.4	0.8	1.2
the heat source per unit volume (W/m^3)	2155172	1116071	771605

4. Summary

The finite element software FLUENT was used to analyse the thermal property of the polymer composites reinforced by pulse bending nanopaper. The minimum temperatures increased during heating process under the same heating power. And the minimum temperatures increased when the heating power increased for the same heating time.

The maximum, minimum and average temperatures of the pulse bending nanopaper enabled polymer composites is studied during the heating process when the thickness of nanopaper is 0.8mm. The heat source per unit volume of pulse bending nanopaper decreased when the thickness of pulse bending nanopaper increased from 0.4 mm to 1.2 mm.

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