IOP Conf. Series: Earth and Environmental Science **100** (2017) 012124 doi:10.1088/1755-1315/100/1/012124

Analysis on Electrically Resistive Heat Transfer of Composites Reinforced by Nanopaper

Aying Zhang[1] * and Zhenghong Li[2]

[1]Harbin University, Harbin 150086, People's Republic of China

[2]Harbin Institute of Technology, Center for Composite Materials and Structures, Harbin 150001, People's Republic of China

E-mail: zaying@sina.com

Abstract. The finite element software FLUENT was used to analyze how the heating power of the nanopaper affect the changes of the temperature with time and the heating rate during heating. Simulation results showed that the average temperature of the polymer composites reinforced by the bent nanopaper is increased with increasing heating power. The time reaching the stable state is longer with increasing heating power. For the composites with same heating power, the temperature difference between the maximum and minimum temperatures is increased with increasing heating time. For the composites under the same heating time, the temperature difference between the maximum and minimum temperatures is increased with increasing heating power.

1. Introduction

CNTs have been regarded as one of the most promising reinforcement materials or functional agents [1,2]. Carbon nanotube (CNT) nanopaper, 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 [3] investigated the effects of CNT diameter and length on the network formation of nanopapers by vacuum filtration and their thermal transport properties were thoroughly. The CNT architecture in nanopaper is found to be a key issue to affect the thermal conductivity of nanopapers. Gonnet et al [4] indicated that nanotube alignment has a measurable influence on the thermal conductivities of both nanopaper and nanocomposites, and the thermal conductivities were found to increase linearly with temperature for both nanopapers and composites. For the BP-reinforced composites, experimental results indicated an average 10 fold thermal conductivity improvement in comparison to the pure matrices. The temperature dependence of the thermal conductivity for both pristine BP and the laminates followed a quasi-linear relationship. Li et al [5] indicated that nanopaper/pCBT composites significantly improved thermal (70 W/mK) and electric conductivities (526 S/cm).

In this study, the thermal responses of the polymer composites reinforced by the flat and pulse bending nanopapers are systematically studied. The heating model of the polymer composite reinforced by flat and bent nanopaper is established to predict the thermal property of BP/composites. The finite element software FLUENT is used to analyze how the heating power affect the changes of the typical temperature with time and the heating rate of the composite materials during heating.

2. Numerical model

During the analysis, two different shapes of nanopaper were considered: flat and the bent; the heating powers were varied from 0.2, 0.3, 0.4, 0.6, 0.8, to 1W; the thermal conductivity of nanopaper and the polymer matrix was set to be 1.5 W/(m•K) and 0.20 W/(m•K). The natural convection heat transfer coefficient was set to be 10 W/(m^2•K). The ambient temperature was set to be 300 K. The specific heat capacity of nanopaper and the polymer matrix was set to be 800 J/(kg•K) and 1000 J/(kg•K).

Figures 1 show the mesh model of the polymer composite reinforced by the bent and flat nanopapers.

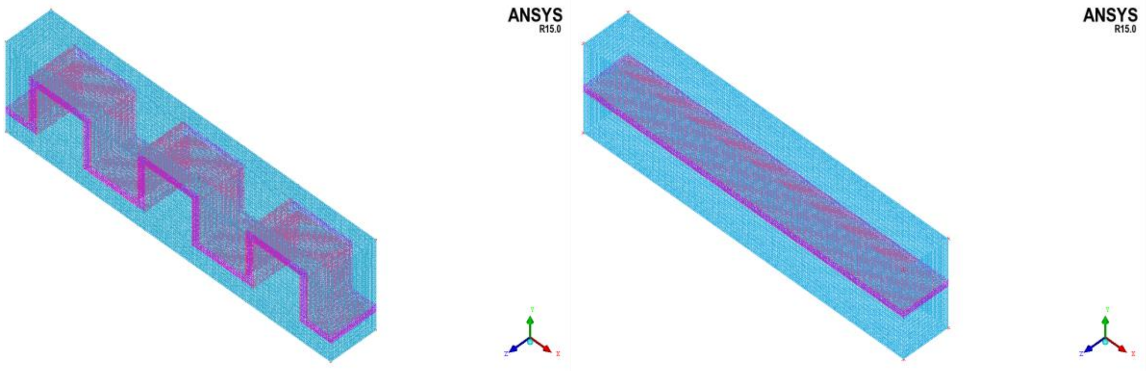

Figure 1 Mesh division model of the polymer composites reinforced by the bent and flat nanopaper

3. Results and discussion

As shown in Figure 2, the relationship of the average temperature with heating time for the polymer composites reinforced by the bent nanopaper was obtained as a function of heating power during heating until reaching the stable state.

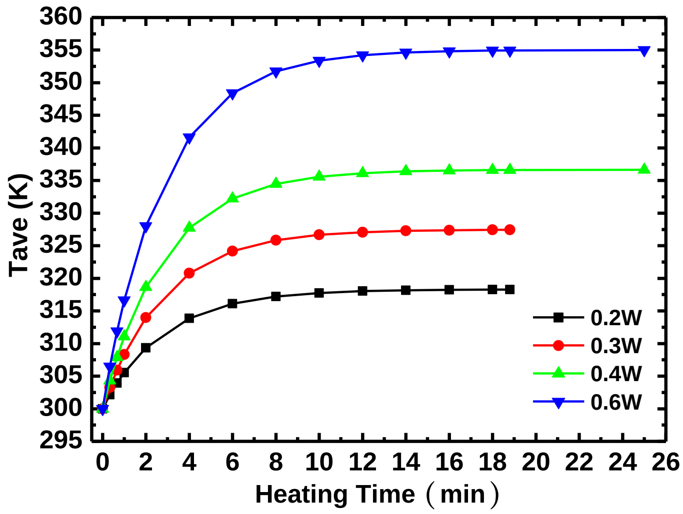

Figure 2 Curve of average temperature of composites reinforced by the bent nanopaper versus time along the section z=0 under different heating power

As shown in Figure 2, at the same heating power, the average temperature is increased with increasing the heating time, and for the same heating time, the average temperature is increased with increasing the heating power. Figure 2 also shows that the time reaching a stable state is much longer with increasing the heating power. Because the larger the unit volume of the nanopaper sheets is, the higher the temperature of the nanopaper sheets is when the heating power is increased. It means that the heat transfer rate is less than the increase rate of heat production, which results in the increase of the heating time of the composites before reaching the stable state. When the heating power is 0.6 W, it takes over 20 minutes to reach the stable state.

Figures 3 show the maximum and minimum temperatures of the polymer composites reinforced by the bent nanopaper along the section z=0 with four different levels of heating powers plotted against heating time. For the composites with same heating power, the maximum and minimum temperatures are increased with increasing heating time. For the same heating time, the maximum and minimum temperatures are increased with increasing heating power.

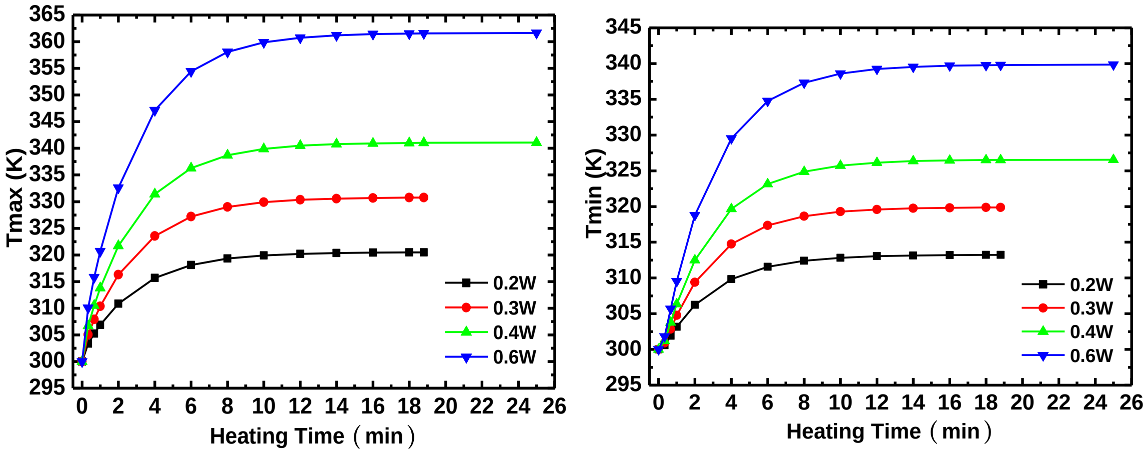

Figure 3 Curve of maximum and minimum temperature of composites reinforced by the bent nanopaper versus time along the section z=0 under different heating power

Table 1 and 3summarizes the results from Figures 3.

Table 1 Typical temperature of composites reinforced by the bent nanopaper versus time under heating power of 0.2 and 0.3W along the section z=0

Time/s	0.2w			0.3w		
	T_{max}/K	T_{min}/K	T_{ave}/K	T_{max}/K	T_{min}/K	T_{ave}/K
0	300	300	300	300	300	300
60	306.89	303.17	305.54	310.35	304.77	308.31
120	310.84	306.24	309.32	316.28	309.38	313.99
240	315.68	309.82	313.85	323.54	314.74	320.80
360	318.11	311.55	316.10	327.19	317.35	324.17
480	319.32	312.41	317.21	329.00	318.64	325.84
600	319.92	312.83	317.76	329.90	319.28	326.67
720	320.21	313.05	318.03	330.35	319.59	327.08
840	320.36	313.15	318.17	330.57	319.75	327.28
960	320.43	313.20	318.24	330.68	319.82	327.38
1080	320.47	313.22	318.27	330.74	319.86	327.43
1128	320.48	313.23	318.28	330.75	319.87	327.45

Table 2 Typical temperature of composites reinforced by the bent nanopaper versus time under heating power of 0.4 and 0.6W along the section z=0

Time/s	0.4w			0.6w		
	T_{max}/K	T_{min}/K	$T_{av}e$/K	T_{max}/K	T_{min}/K	T_{ave}/K
0	300	300	300	300	300	300
60	313.80	306.36	311.09	320.70	309.55	316.65
120	321.72	312.51	318.67	332.59	318.78	328.02
240	331.41	319.67	327.75	347.13	329.52	341.64
360	336.27	323.15	332.24	354.43	334.75	348.39

480	338.69	324.87	334.47	358.06	337.32	351.74
720	340.49	326.14	336.13	360.76	339.23	354.22
840	340.78	326.35	336.40	361.20	339.54	354.62
1080	341.00	326.50	336.60	361.53	339.77	354.93
1128	341.02	326.51	336.61	361.56	339.79	354.95
1500	341.07	326.55	336.66	361.63	339.84	355.02

For the composites with same heating power, the temperature difference between the maximum and minimum temperatures is increased with increasing heating time. For the composites under the same heating time, the temperature difference between the maximum and minimum temperatures is increased with increasing heating power.

4. Conclusions

FLUENT was used to analyze how the bending shapes affect the changes of the temperature with time and the heating rate during heating. The average temperature of the polymer composites reinforced by the bent nanopaper is increased with increasing heating power. The time reaching the stable state is longer with increasing heating power. For the composites with same heating power, the temperature difference between the maximum and minimum temperatures is increased with increasing heating time. For the composites under the same heating time, the temperature difference between the maximum and minimum temperatures is increased with increasing heating power.

Acknowledgement

This work was financially supported by Heilongjiang Postdoctoral Scientific Research Developmental Fund (Grant No. LBH-Q16141).

References

[1] Thostenson E T, Ren Z F, Chou T W 2001 *Composites Science & Technology* vol 61 p1899-1912
[2] Lau K T, Hui D 2002 *Composites: Part B* vol vol vol 263-277
[3] Chen H Y, Chen M H, et al. 2012 *The Journal of Physical Chemistry C* vol 116 p 3903-3909
[4] Gonnet P, Liang Z, et al 2006 *Current Applied Physics* vol 6 p 119-122
[5] Li Z R, Downes R, Liang Z Y 2015 *Macromolecular Chemistry & Physics* vol 216 p 292-300