International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 8, Issue 2 (August 2013), PP. 99-104

Study of Decomposing Polymer Matrix Composites at High Temperature Using FEA

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Abstract:- A three-dimensional model to describe the thermal behavior of polymer matrix composites (PMCs) in fire is developed and implemented into commercial finite element package ANSYS. The model is employed to predict the temperature and the internal pressure in one-sided heating tests for glass-talc/phenolic composites and it is validated by comparing the predicted results with the measured data. The effect of porosity and permeability on the temperature and the internal pressure is examined. In addition, an experimental technique based on Vacuum Assisted Resin Transfer Molding (VARTM) is developed to manufacture PMCs with inserted hypodermic needle for internal pressure measurement. One-sided heating tests are conducted on the glass/vinyl ester composites to measure the pressure at different locations through thickness during the decomposition process. The model is explored to simulate the heating process. Both predicted and measured results indicate that the range of the internal pressure peak in the designed test is around 1.1-1.3 atmosphere pressure.

Keywords:- Polymer-matrix composites (PMCs); Finite element analysis; Resin transfer molding (RTM) & (A4) is the model number used in ansys.

I. INTRODUCTION

Polymer matrix composites (PMCs) are widely used in a number of industrial and military areas, such as bridges, wind turbine blades, industrial vessels, and submarine structures. Advantages of PMCs include their high specific strength, long fatigue life, and excellent corrosion resistance. On the other hand, there are challenging issues for PMC application, including low rigidity, poor impact resistance, high cost, and difficulties in joining. In addition, one of the continuing concerns is the fire performance of PMCs. When the composites are exposed to fire, there is thermal conduction for heat transfer inside the composites at the beginning of the heating. As the temperature increases, the polymer matrix starts to decompose and gases are generated by the decomposition reaction. A porous network in the heated composites is formed with the continuing decomposition. Some gases carrying heat flow out of the composites and affect the temperature distribution by heat convection. Others are trapped inside the pores and impede the heat conduction because of their low thermal conductivity. Meanwhile, the gases held in the solid accumulate and build up the internal pressure which may contribute to the eventual failure through processes such as delamination. A description of this internal pressure is necessary for a better understanding of thermo-mechanical behavior of composites at high temperature. In addition, the experimental measurements of this pressure are needed to validate the existing models. Some models have been developed to consider the pressure effect on thermo- mechanical response of composites in fire. Henderson et al. presented a one- dimensional transient thermal model including the combined effects of thermo-chemical expansion and storage of the decomposition gases. The model was further developed in by relaxing the assumption of local thermal equilibrium existing between the solid matrix and decomposition gases within the porous network of the composites.

II. MODELING AND ANALYSIS USING ANSYS

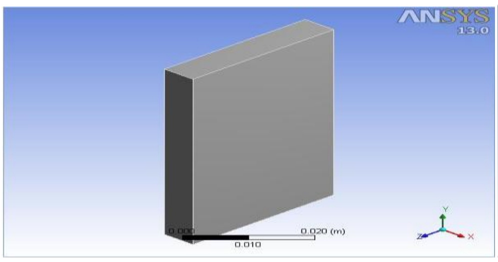

Fig.1 Generated model in ANSYS

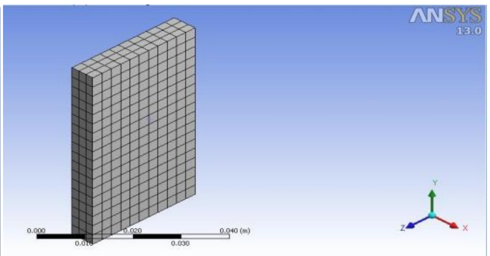

Fig.2 Meshed model

III. RESULTS & DISCUSSION

Model (A4) > Transient Thermal (A5) > Solution (A6) > Solution Information > Result Charts

Object Name	Temperature - Global Maximum	Temperature - Global Minimum
State	Solved	
Scope		
Scoping Method	Global Maximum	Global Minimum
Definition		
Type	Temperature	
Results		
Minimum	22. °C	
Maximum	22. °C	

Table.1 Global temperature results table

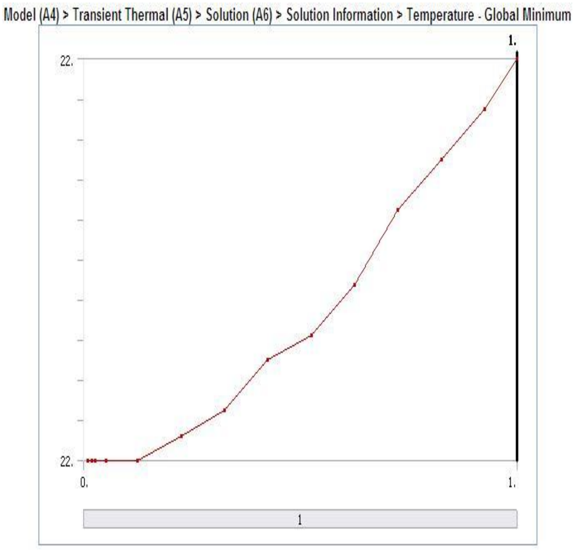

Fig.3 Global minimum temprature graph

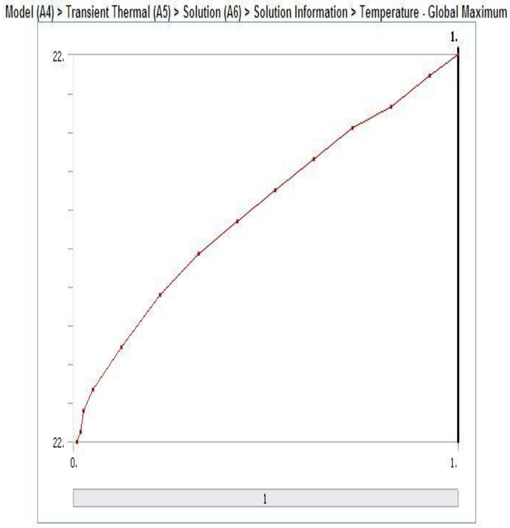

Fig.4 Global maximum temprature graph

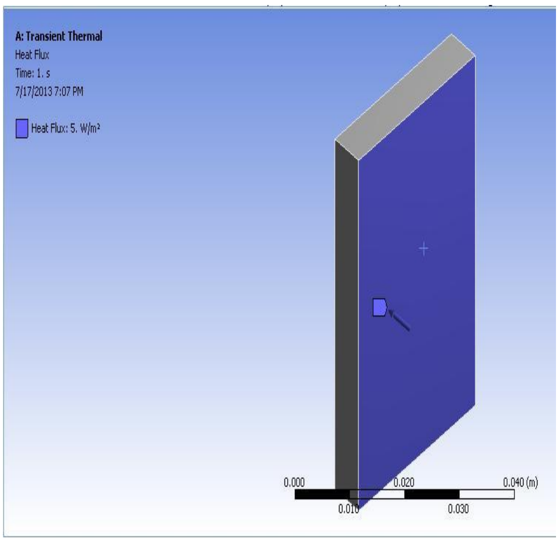

Fig.5 Transient Heat flux

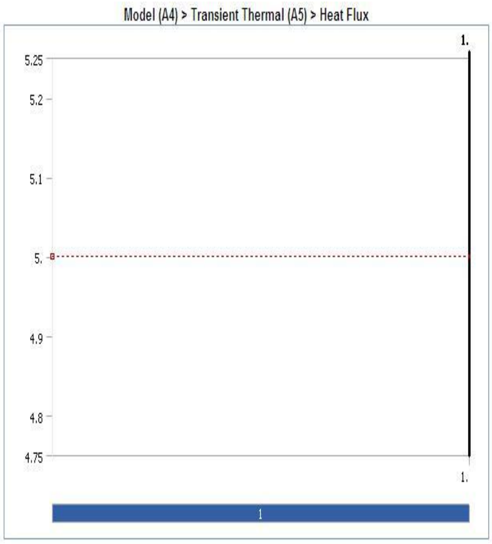

Fig.6 Transient Heat flux graph

Model (A4) > Transient Thermal (A5) > Solution (A6) > Results

Object Name	*Temperature*	*Total Heat Flux*	*Directional Heat Flux*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	22. °C	3.1217e-004 W/m²	-5.0275 W/m²
Maximum	22. °C	5.0275 W/m²	1.5993e-002 W/m²
Minimum Value Over Time			
Minimum	22. °C	1.835e-004 W/m²	-5.0566 W/m²
Maximum	22. °C	8.7239e-003 W/m²	-2.8511 W/m²
Maximum Value Over Time			
Minimum	22. °C	2.8521 W/m²	1.5993e-002 W/m²
Maximum	22. °C	5.0566 W/m²	0.4235 W/m²
Information			
Time	1. s		
Load Step	1		
Substep	14		
Iteration Number	14		
Integration Point Results			
Display Option		Averaged	

Table.2 Transient thermal results

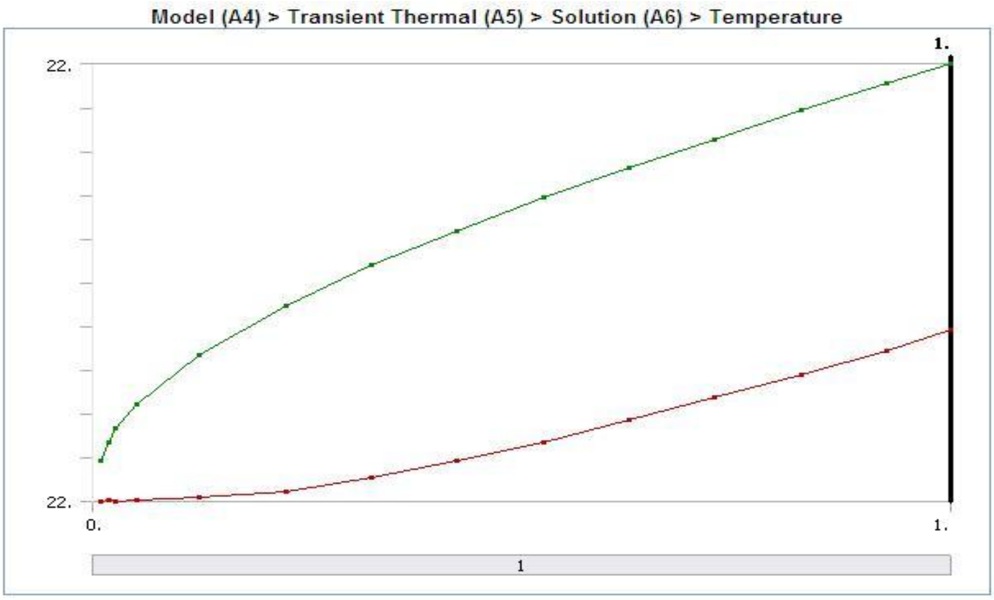

Fig.7 Transient thermal graph

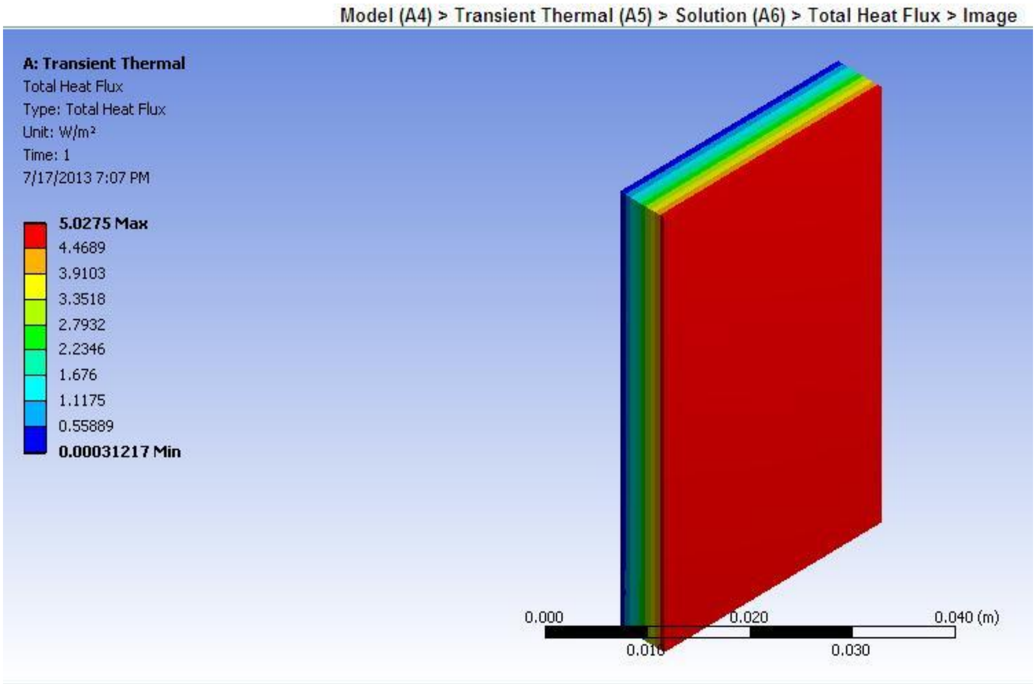

Fig.8 Transient thermal total heat flux

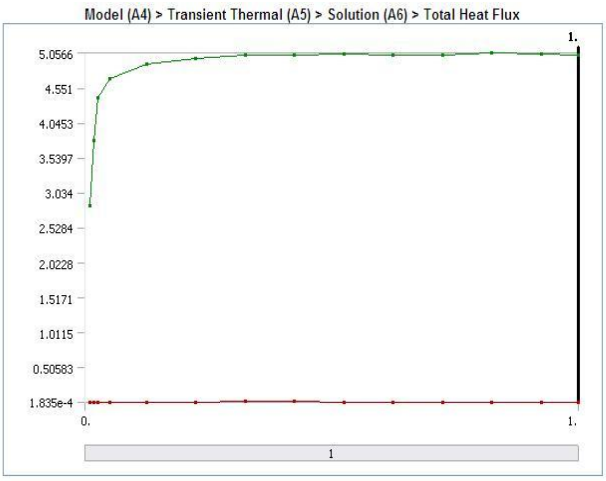

Fig.9 Transient thermal total heat flux graph

Model (A4) > Transient Thermal (A5) > Solution (A6) > Total Heat Flux

Time [s]	Minimum [W/m²]	Maximum [W/m²]
1.e-002	5.1008e-004	2.8521
1.8229e-002	5.0526e-004	3.7884
2.6459e-002	2.2137e-004	4.4035
5.1147e-002	1.835e-004	4.6762
0.12521	2.7039e-003	4.8943
0.22521	3.6273e-003	4.9714
0.32521	8.6354e-003	5.0291
0.42521	8.7239e-003	5.0292
0.52521	3.2536e-003	5.0395
0.62521	9.4071e-004	5.0288
0.72521	8.4801e-004	5.0178
0.82521	1.0917e-003	5.0566
0.92521	2.0504e-004	5.0484
1.	3.1217e-004	5.0275

Table.3 Transient thermal total heat flux results

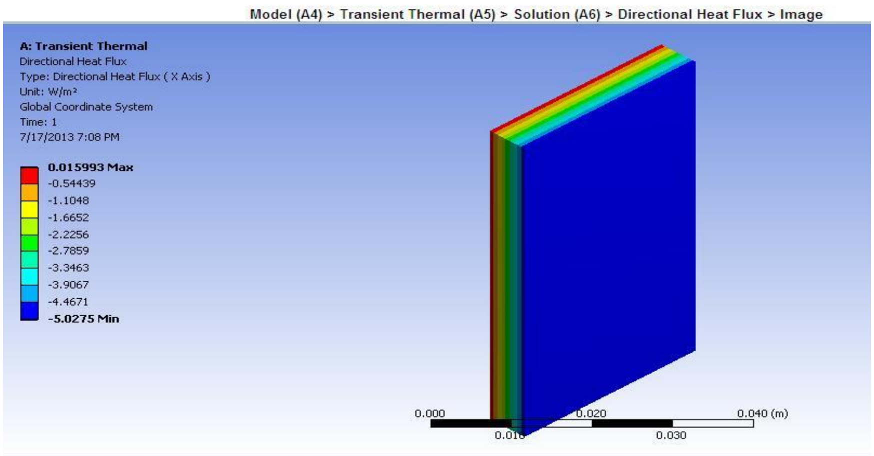

Fig.10 Directional heat flux

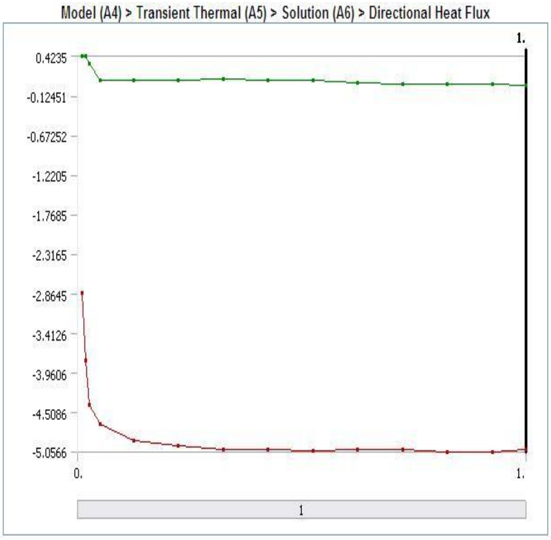

Fig.11 Directional heat flux graph

Model (A4) > Transient Thermal (A5) > Solution (A6) > Directional Heat Flux

Time [s]	Minimum [W/m²]	Maximum [W/m²]
1.e-002	-2.8511	0.41956
1.8229e-002	-3.7878	0.4235
2.6459e-002	-4.4032	0.32359
5.1147e-002	-4.6761	8.6421e-002
0.12521	-4.8943	8.2935e-002
0.22521	-4.9713	9.229e-002
0.32521	-5.0289	0.10555
0.42521	-5.0291	8.3812e-002
0.52521	-5.0394	8.7376e-002
0.62521	-5.0288	5.8677e-002
0.72521	-5.0178	4.1436e-002
0.82521	-5.0566	3.3788e-002
0.92521	-5.0484	2.8001e-002
1.	-5.0275	1.5993e-002

Table.4 Directional heat flux results

IV. CONCLUSION

A three-dimensional model to describe the thermal behavior of composites in fire was developed and implemented into the finite element commercial software ANSYS by user subroutine UMATHT. The model was used to simulate the one-sided heating tests conducted for glass-talc/phenolic composites by the overlaid element technique. The predicted temperatures and pressures at different locations were compared to the calculated results and measured data from and it is found they have good agreement. The effect of porosity and permeability on thermal response of composites was studied by comparing the temperature, pressure, decomposition factor, and mass flux calculated from the model using different sets of property inputs. Temperature is insensitive to permeability; however, permeability has a strong influence on pressure. The peak of pressure increases by about three times with permeability reduced by one order of magnitude. The influence of porosity on both temperature and pressure is apparent. Smaller porosity facilitates the heat transfer through composites. In order to investigate the internal pressure of glass/vinyl ester composites and overcome the leakage issue of previous experimental technique for pressure measurement, a manufacturing procedure based on VARTM was proposed and executed to make the glass/vinyl ester composite panel with inserted hypodermic needle. The one-sided heating tests for the sample with inserted needle were set up to measure the internal pressure at mid-surface and the location of one quarter thickness from the exposed surface. In addition, the three-dimensional model was employed to analyze the heating tests for glass/vinyl ester composites with measured temperatures on the exposed and unexposed surfaces as thermal boundary condition. The predicted pressures can capture the trend of the measured pressure history curves and both the measured and predicted results indicate a pressure peak in the range of 1.1-1.3 atmosphere pressure for glass/vinyl ester systems in the conducted heating tests. The good match between the predicted results and measured data for two different material systems validates the generality of the model.

REFERENCES

[1]. Brown, J.R. and Z. Mathys, *Reinforcement and Matrix Effects on the Combustion Properties of Glass Reinforced Polymer Composites*. Composites Part A: Applied Science and Manufacturing, 1997. 28(7): p. 675-681.

[2]. Sorathia, U., et al., *Fire Safety of Marine Composites*, in *45th International SAMPE Symposium and Exhibition*. 2000, SAMPE, Covina, CA, United States: Long Beach, CA, USA. p. II/-.

[3]. Lyon, R.E., et al., *Fire-Resistant Aluminosilicate Composites.* Fire and Materials, 1997. 21(2): p. 67-73.

[4]. Sastri, S.B., J.P. Armistead, and T.M. Keller, *Phthalonitrile-Carbon Fiber Composites.* Polymer Composites, 1996. 17(6): p. 816-822.

[5]. Sorathia, U. and C. Beck, *Fire Protection of Glass/Vinyl Ester Composites for Structural Applications*, in *41st International SAMPE Symposium and Exhibition*. 1996, SAMPE, Covina, CA, United States: Anaheim, CA, USA. p. 687-697.

[6]. Brown, J.R., et al., *Fire-Retardant Performance of Some Surface Coatings for Naval Ship Interior Applications.* Fire and Materials, 1995. 19(3): p. 109-118.

[7]. Ohlemiller, T., T. Cleary, and J. Shields, *Effect of Ignition Conditions on Upward Flame Spread on a*

Composite Material in a Corner Configuration, in *41st International SAMPE Symposium and Exhibition*. 1996, SAMPE, Covina, CA, United States: Anaheim, CA, USA. p. 734-747.

[8]. Henderson, J.B., et al., *Characterization of the High-Temperature Behaviour of a Glass-Filled Polymer Composite*. Composites, 1987. 18(3): p. 205-215.

[9]. Henderson, J.B. and M.R. Tant, *Measurement of Thermal and Kinetic Propertiesof a Glass-filled Polymer Composite to High Temperatures*, in *9th EuropeanConference on Thermophysical Properties*. 1986: Manchester, UK. p. 17-28.