Study of Thermal Behaviour of Thermoset Polymer Matrix Filled with Micro and Nanoparticles

Bénédicte Reine[1], Jérémy Di-Tomaso[2], Gilles Dusserre[1], Philippe Olivier[1]

1. Institut Clément Ader, IUT Paul Sabatier – Dépt. GMP, 133C avenue de Rangueil, BP 67701, 31077 Toulouse Cedex 4, France;

2. Rescoll, Société de Recherche, 8 allée Geoffroy Saint-Hilaire, CS 30021, F-33615 Pessac Cedex, France.

SUMMARY

New researches aim for thermal behaviour improvement of onboard equipments which are in contact with electrical components. The first step of this research is to improve the thermal conductivity of a thermoset matrix filled with micro and nanoparticles. We will try various kind of fillers in order to determine the best particules volume fraction to introduce on the matrix to get the desired thermal conductivity. Experimental results will be compared to an analytical reference model (Hamilton Crosser model [1]) and a numerical model developed with COMSOL Multiphysics.

Keywords: thermal conductivity, effective properties, microparticles, random dispersion

COMPUTATIONAL METHODS

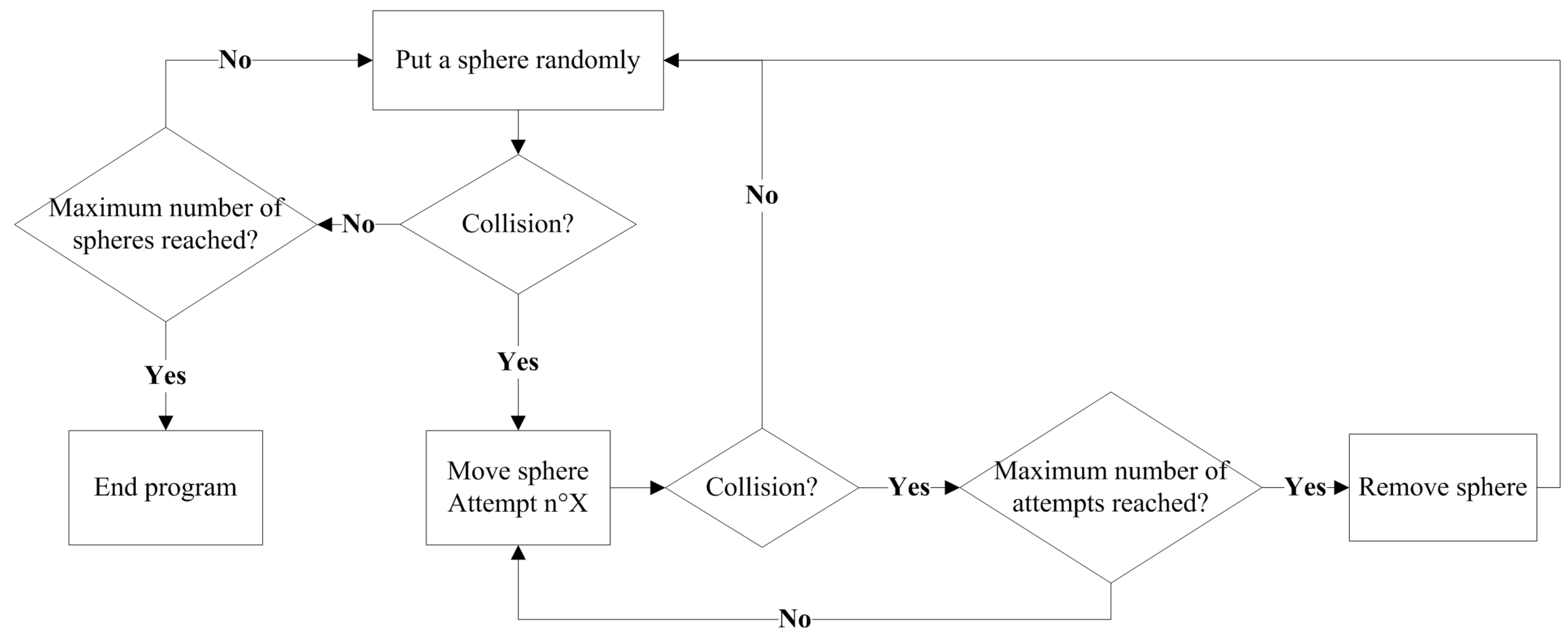

Figure 1. Automatic generation of CAO

Problem	• 3D model • Stationary study
Geometry	• Spheres R = 3 µm • v_p fixed
Behaviour	• Physics used Heat transfer in solids • Fourier's law $\phi_S = \lambda_h \overrightarrow{grad\,T}$
Boundary conditions	• T_0 = 293.15 K • $\Phi_S = 2.10^5$ W/m²
Solver	• Tetrahedral elements • Direct Solver

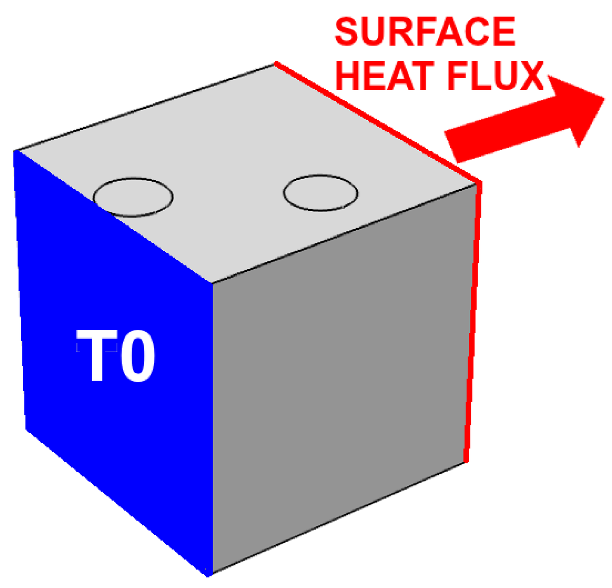

Figure 2. Boundary conditions

SENSITIVITY STUDY

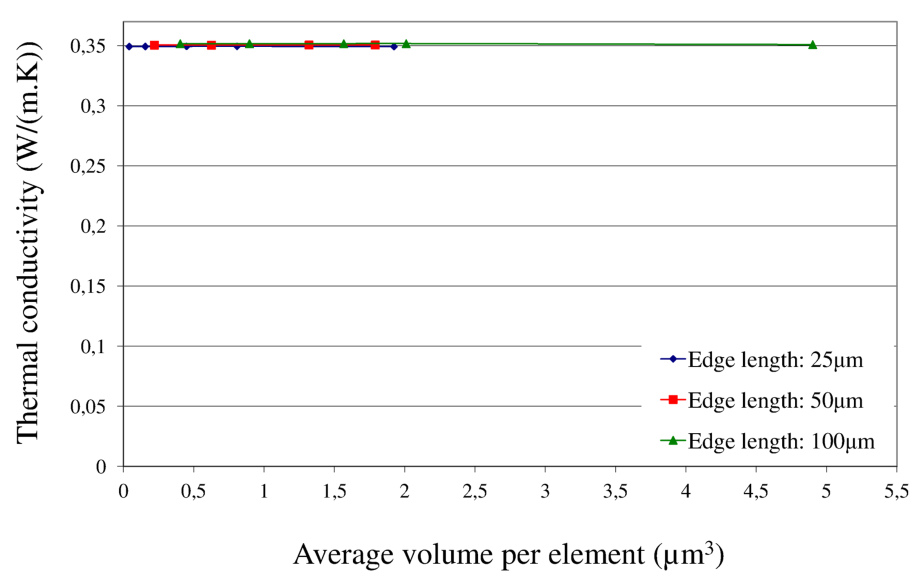

Figure 3. Choice of mesh size – R = 3 µm, L = 25 µm

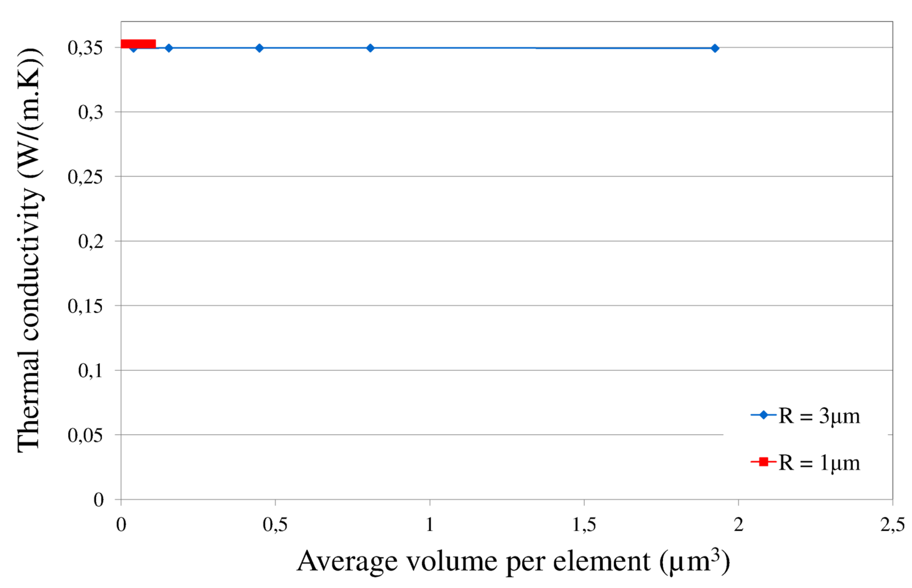

Figure 4. Choice of particules size – v_p = 3%, L = 25 µm

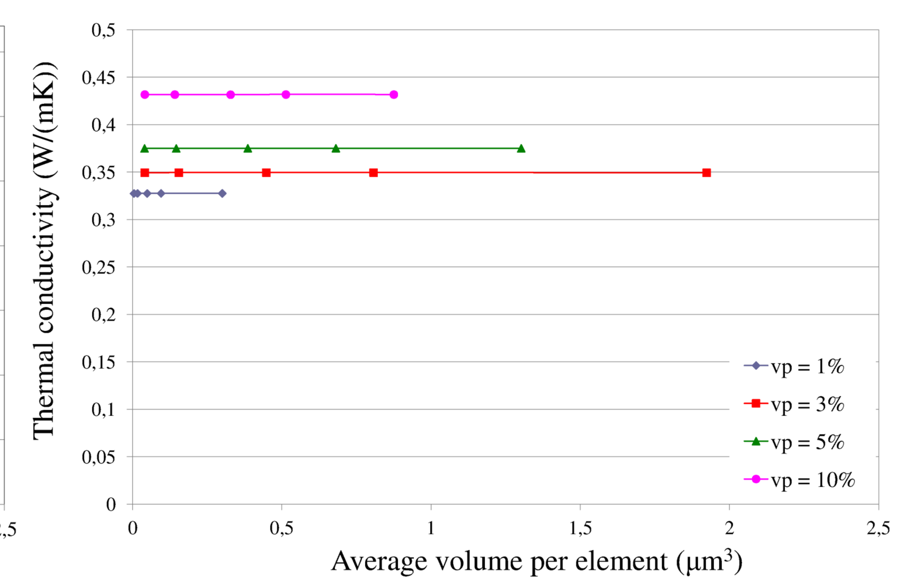

Figure 5. Verification of v_p influence on thermal conductivity – R = 3 µm, L = 25 µm

λ* : thermal conductivity

COMPARISON SIMULATIONS VS EXPERIMENT

Experimental thermal conductivity ➡ $\lambda = a.C_p.\rho$

Analytical reference model [1] ➡ $\lambda_c = \lambda_m \left[\frac{\lambda_p + (n-1)\lambda_m - (n-1)v_p(\lambda_m - \lambda_p)}{\lambda_p + (n-1)\lambda_m + v_p(\lambda_m - \lambda_p)} \right]$

v_p (%)	Hamilton model (W/(m.K))	Experiment (W/(m.K))	COMSOL (W/(m.K))
0	0.207	0.207 (0.017)	0.207
3	N.D.	N.D.	0.226
5	0.240	0.270 (0.026)	0.242
10	0.276	N.D.	0.286
15	0.316	0.380 (0.004)	N.D.

Table1. λ* values for Hamilton model , experiment (standard deviation) and COMSOL simulations (N.D.: No Data)

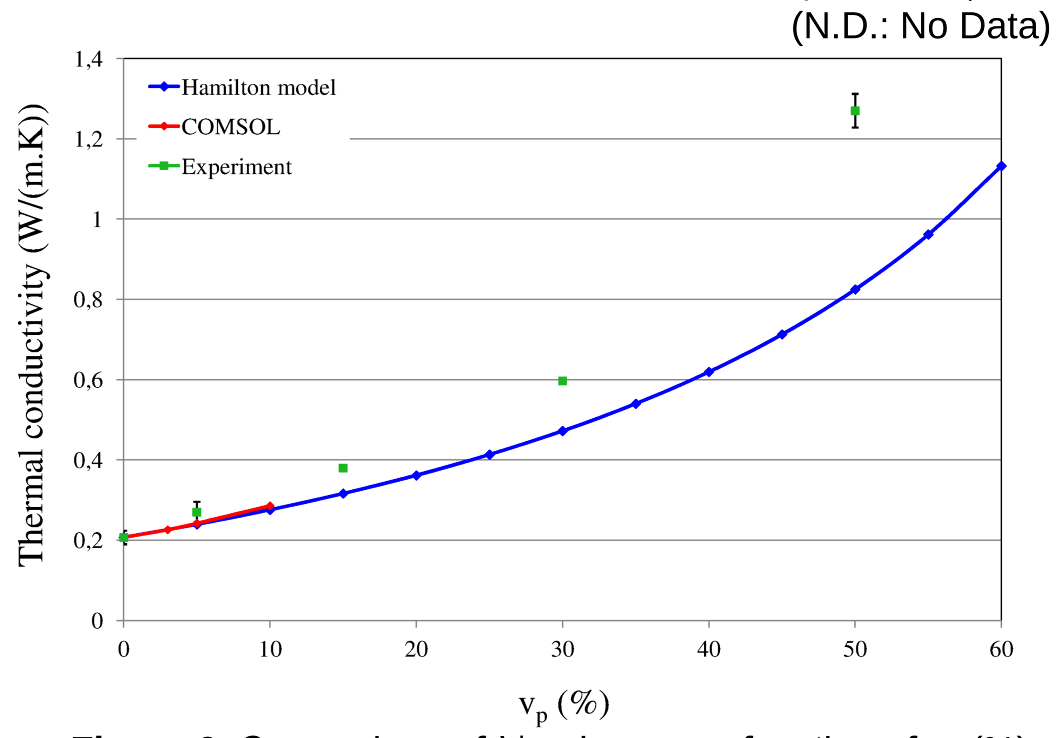

Figure 6. Comparison of λ* values as a function of v_p (%)

Samples:

- Pellets Φ 10 mm x 3 mm
- Epoxy system LY 556 + D230 (Hunstman) *λ_m = 0.207 W/(m.K)*
- Aluminium powder Z600 (Toyal) *λ_p = 237 W/(m.K)*

Nanoflash® measurement (diffusivity measurement)

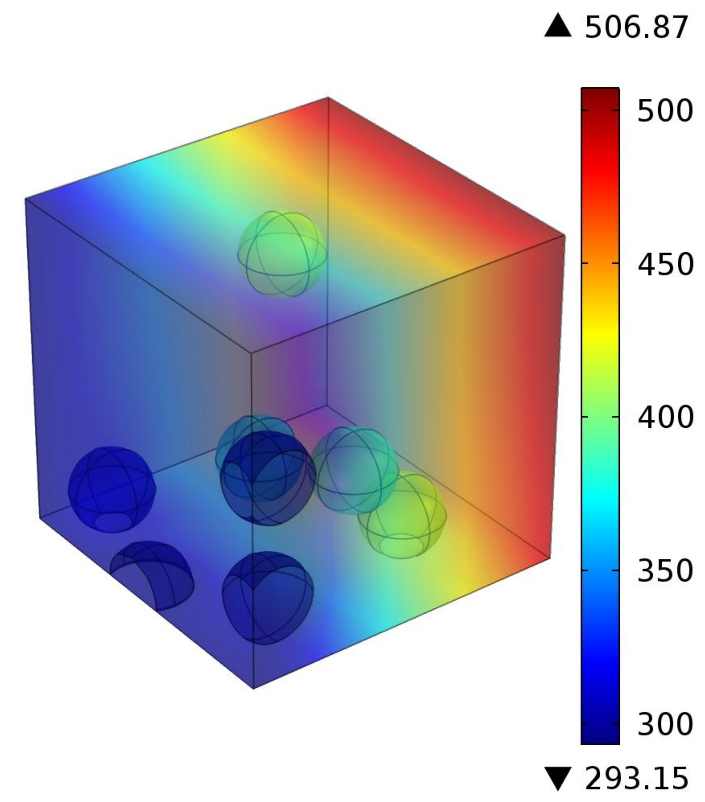

Figure 7. Temperature distribution (K) v_p = 5%, R = 3 µm

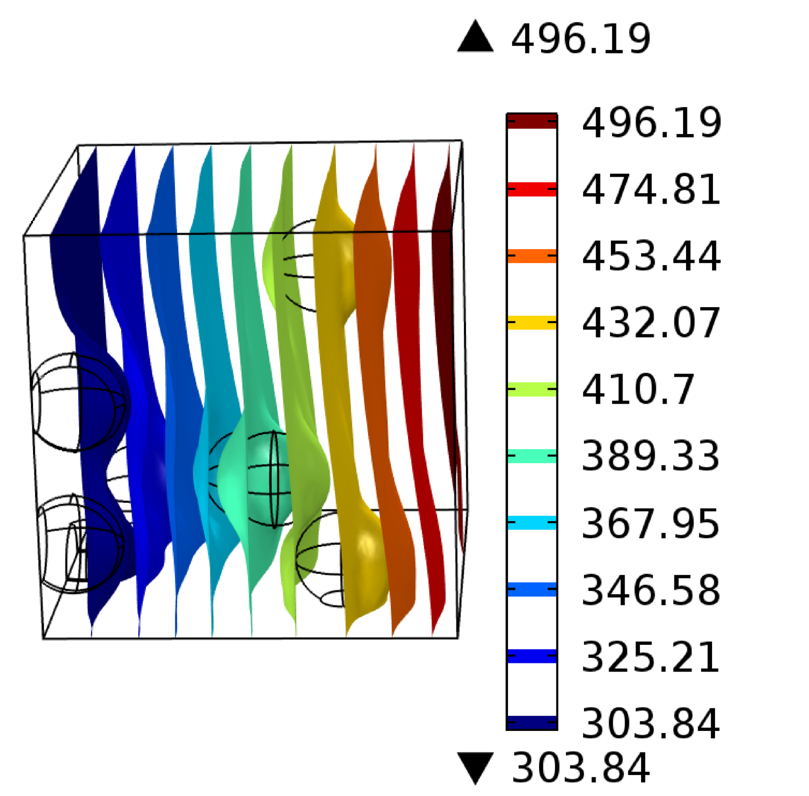

Figure 8. Isothermal contours (K) for v_p = 5%, R = 3 µm

CONCLUSION

- Numerical modelling limited to a maximum particles volume fraction (v_{pMAXI}) of 15%.
- Good correlation between Hamilton model and COMSOL simulation.
- More experiments with other types of fillers are in progress → Development of a new Java® program for other shapes of particles

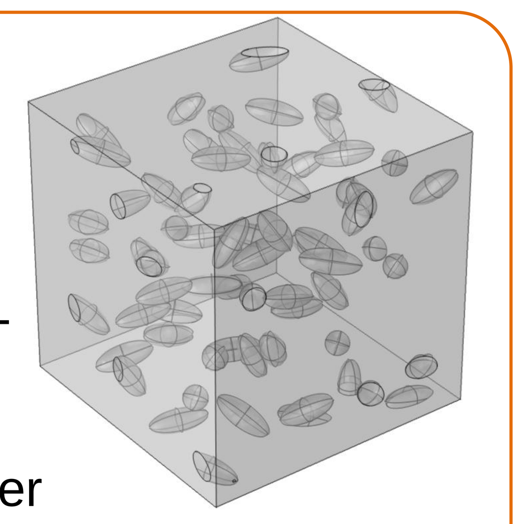

Figure 7. Random dispersion of ellipsoidal particles

REFERENCES

[1] R.L. Hamilton and O.K. Crosser, Thermal conductivity of heterogeneous two-component systems, Industrial & Engineering Chemistry Fundamentals, 1(3), pp. 187-191 (1962)

ACKNOWLEDGEMENT

This work was a part of THEOREM project leaded by THALES Systèmes Aéroportés, within the framework of the call for projects FUI 2010 funded by OSEO.