IMPROVING MECHANICAL PROPERTIES OF COMPOSITES BY NANOPARTICLES USING A THREE DIMENSIONAL MODEL

A.R.Shahmohamadi[1], M.Salehi[1], M. Sadighi[1] and S.Saber-Samandari[2]
[1]Mechanical Engineering Department,Amirkabir University of Technology, Tehran, Iran
[2]New Technologies Research Centre, Amirkabir University of Technology, Tehran, Iran

1. Introduction

Improving the properties of composites is highly regarded by researchers due to the increasing use of composites. By adding a small amount of nanoclay to the matrix, its mechanical properties such as elastic modulus can be substantially increased [1]. In this paper, the elastic modulus of polymer based composite that is reinforced by nanoparticles is investigated with numerical method. A three dimensional Representative Volume Element (RVE) is used. The RVE comprises of nanoclay, interphase and a polymeric matrix (i.e. epoxy resin), with random distribution of nanoclaysis created.

2. Finite element modeling

To build RVE, a commercial finite element package, has been used. Random distribution of particles makes the model closer to reality.

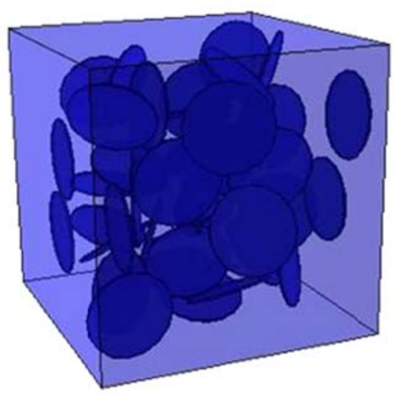

figure 1. The generated RVE used in this study

Saber-Samandari [2] reported interphase thickness equal to 0.5 and achieved its properties while the properties of the matrix and Nanoclay are known. Because of the random distribution of the particles, we cannot rely on the results of a model and modeling must be repeated until the average of results does not change anymore. Heydari Meybodi [3] showed that after 15 times, the average of results remains constant. The nanoclay, matrix and interphase is assumed in the form of isotropic and linear Elastic material. Matrix properties and particles are taken from previous works. Saber-Samandari (2007) presented Equation 1 to get the interphase module.

$$E_i(r) = E_m \times \frac{r_i}{r} + \left[\frac{r_i - r}{r_i - r_f}\right]^{n/2} \times \left[E_c - E_m \times \frac{r_i}{r_f}\right] \quad (1)$$

Where E_i, E_c and E_m indicate the elastic modulus of the interphase region, nanoclay and matrix, respectively and "r" is considered as the coordinate in the direction of the nanoclay length and 'n' is a dimensionless coefficient that is called the interfacial enhancement index and equal to 40 [2].

Heydari Meybodi [3] and M-l Chan [4] obtained elastic modulus of nanoclay composite experimentally. The FE analysis is done completely for each of 3, 5 and 7 weight fraction of the nanoclay. The contact between the interphase and matrix in one hand, and the nanoclay and interphase in the other hand is assumed to be perfect and there is not any debounding. The strain is applied to one side of element. The models are mashed using 4_node linear tetrahedron shaped elements (C3D4).

3. Results

The present results show higher values than the experimental results. When interphase is not included, this difference is even higher and it shows that interphase increases the accuracy of the analysis (see Table1). In addition, as amount of nanoclay increases, the difference between the two sets of results also increases. So that for 3% wt and 7% wt, respectively, there are 8% and 13% difference.

percentage of nanoclay (%wt.)	Elastic Modulus (MPa)				
	Experiment [3]	FEM without interphase	Error	FEM with interphase	Error
3	7186.1	7428.5	3.3%	7256.64	1%
5	7241.6	7842.41	8.3%	7567.61	4.5%
7	6885.5	8523.42	23.7%	8142.45	18.2%

Table 1.Results for case1

5. Conclusion

In the present study, the elastic modulus of nanoclay composite was investigated by finite element method .All of analysis was conducted with and without interphase.With regard to interphase, the results are closer to realty.The results of 3D-RVE and 2D-RVE were compered. The 3D model showed better results than 2D. Since the optimum amount of nanoclay reported is less than 5%, and the present study shows smaller difference up to 5%wt., consequently this model can be used to determine elastic modulus or other properties of nanoclay composite

6. References

[1] P.Kumar, and J.Srinavas (2014). Numerical Evaluation of Effective Elastic Properties of CNT-Reinforced Polymers for Interphase Effect, *J.Computational Materials Science*,**88**, 139–144.

[2] S.Saber-Samandary and AfaghiA.Khatabi (2007), Evaluation of Elastic Modulus of Polymer Matrix Nanocomposites,J. *polymer composites*,**28**, 405-411.

[3] M.Heydary-Meybodi, and S.Saber-Samandary (2015), A New Approach for Prediction of Elastic Modulus of Polymer/nanoclay Composites by Considering Interfacial Debonding: Experimental and Numerical Investigations, J.*Composites Science and Technology*,117,379-385.

[4] M.I.Chan and K.Lau, (2011). Mechanism of Reinforcement in a Nanoclay/polymer Composite, *J.Composites: Part B*, **42**,1708-1712.