Development and characterization of polytetrafluoroethylene (PTFE) and expanded graphite nanocomposite

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Abstract : In this paper, mechanical properties of nanocomposite materials are studied. Composite material is a material consisting of two or more physically and chemically distinct phase, suitably arranged or distributed. A nanocomposite material usually has characteristics that are not depicted easily. The nanocomposite material used is polytetrafluoroethylene (PTFE) as matrix and expanded graphite as filler material. Digimat software is used to find out mechanical properties of the nanocomposite materials. Digimat-MF and Digimat-FE are complimentary tools used for nanocomposites modelling. Digimat-FE, based on direct nonlinear Finite Element Analysis (FEA), offers accurate predictions at the macroscopic and local microscopic scales. The mechanical behaviour of the composites such as elastic plastic and damage properties are calculated numerically with 3D representative volume element (RVE) models. In PTFE material the varying composition i.e. 0.15%, 0.25%, 0.35%, 0.45%, 0.5% etc. of expanded graphite is mixed. Mechanical properties such as Youngs modulus, Shear modulus, poisons ratio, density etc. are find by using digimat software.

***Keywords*-Polytetrafluoroethylene, Expanded graphite, Finite Element Analysis, Representative volume element.**

I. INTRODUCTION

Composite material is a material consisting of two or more physically and chemically distinct phase, suitably arranged or distributed.

1.1 Composite materials

Composite materials are engineered materials made from at least two or more constituent materials with significantly different physical or chemical properties. composites as multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, with different compositions, characteristics and sometimes in its form.

"The composite materials are heterogeneous structure consisting of two or more materials, which are in close contact with each other on a microscopic scale in the sense that whatever part of it will cause the same physical property. Generally, a composite material is composed of reinforcements (fibres, particles, flakes or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix holds the reinforcement, which improves the overall mechanical properties of the matrix. When designed properly, the composite material exhibits better strength" (Van Suchtelen ,1972).

1.2 Classification of composites

Composites material can be classified on the basis of the type of reinforcement which is responsible for the desired properties and high performance of the composites. Fig 1.1 shows the Classification of composites materials.

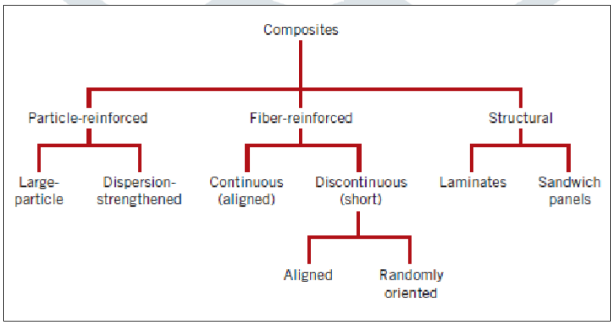


Fig 1.1 Classification of composites

In this paper, polytetrafluoroethylene (PTFE) and expanded graphite nanocomposite materials are used for carrying out analysis in DIGIMAT software. This material comes under the category of particle reinforced materials. Particulate-reinforced composite shown in Figure 1.2 uses the particles as the reinforcement material to increase the strength and hardness. The particles may be spherical, cubic, tetragonal, platelet, or of other regular or irregular shape or approximately equalized.

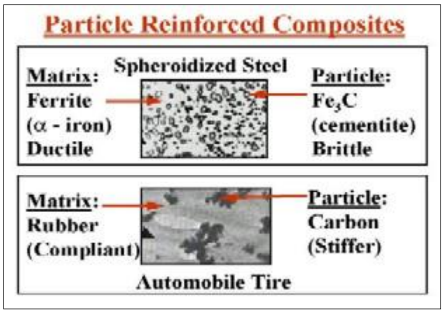


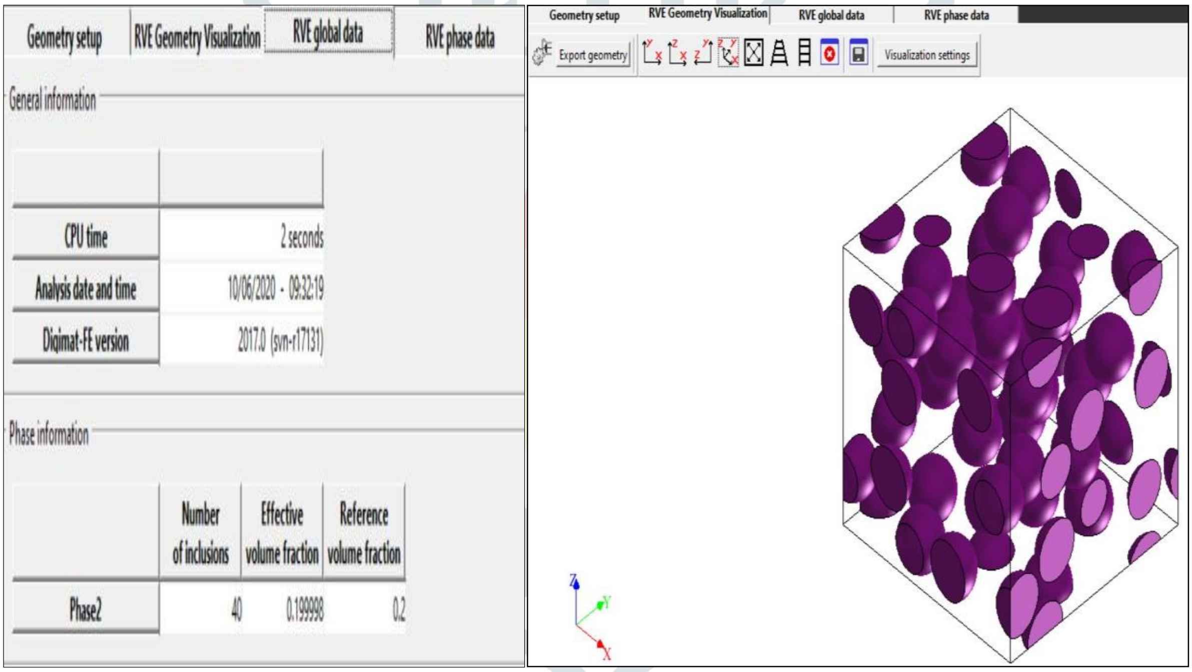
Fig 1.2 Particle reinforced composites

1.3 DIGIMAT software:

Digimat software is used to find out mechanical properties of the nanocomposite materials. In PTFE material the varying composition i.e. 0.15%, 0.25%, 0.35%, 0.45%, 0.5% etc. of expanded graphite is mixed. Mechanical properties such as Youngs modulus, Shear modulus, poisons ratio, density etc. are find by using digimat software.

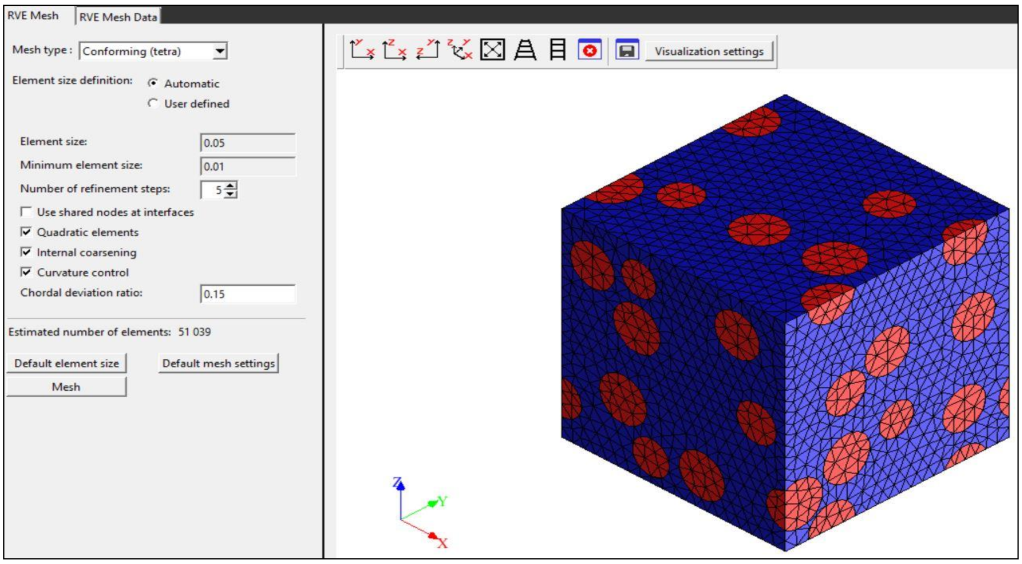
II. MODELLING:

Digimat-FE is used to generate very realistic RVE microstructure geometries, which can be exported in step or formats. Digimat-FE is interfaced for the semi-automatic meshing of the RVE microstructure geometry as well as the definition of materials, load and boundary conditions. Figure 2.1 shows an FE mesh of a polymer matrix filled with coated, spherical inclusions with and without clustering.



2.1 Geometry generation of PTFE & EG nanocomposite materials

In this geometry generation representative volume element geometry visualization in xyz directions. analysis of number of inclusions is 40 & effective volume fraction is 0.2 also indicates the analysis date and time. Geometry generation is finally completed then automatic RVE mesh generate and complete the digimat-FE solver model shown in following figure 2.2 Development of RVE-embedded solid elements model for predicting effective elastic constants of inclusion-matrix reinforced composite. Unlike the traditional finite element (FE) modelling, the matrix and filler material can be meshed separately and independently due to the implementation of the embedded element technique, which enables the ease of RVE meshing without strictly satisfying the mesh conformity at the interfaces.



2.2 representative volume elements mesh data

III. ANALYSIS:

"A three-dimensional (3D) representative volume element (RVE) model was developed for analysing effective mechanical behaviour of fiber-reinforced ceramic matrix composites with imperfect interfaces. In the model, the fiber is assumed to be perfectly elastic until its tensile strength, and the ceramic material is modelled by an elasto-plastic Drucker-Prager constitutive law. The RVE model is then used to study the elastic properties and the tensile strength of composites with imperfect interfaces and validated through experiments" (Wu-Gui Jiang).

Wu-Gui Jiang has carried out experiments numerically by using Mori-Tanaka's method and periodic boundry condition in Abaqus software.

In this paper the therotical experiments are performed by using Digimat FE and the comparison with Digimat MF software. In order to validate the proposed model, the experimental data are compared with model for material properties of PTFE with expanded graphite nanocomposite in the DIGIMAT software. 3D RVE's generated by Digimat FE and the comparison with Digimat MF. As mentioned before, Digimat MF performs a mean field homogenization of multi-phase materials, so that it can be treated as a material with one set of parameters. Digimat FE is a software program that creates a 3D RVE structure.

3.1 Properties of pure PTFE

This research work is expected to understand the development and characterization of PTFE-Expanded Graphite based composite material for tribological aspects.

Table 3.1 introduces the PTFE properties in general.

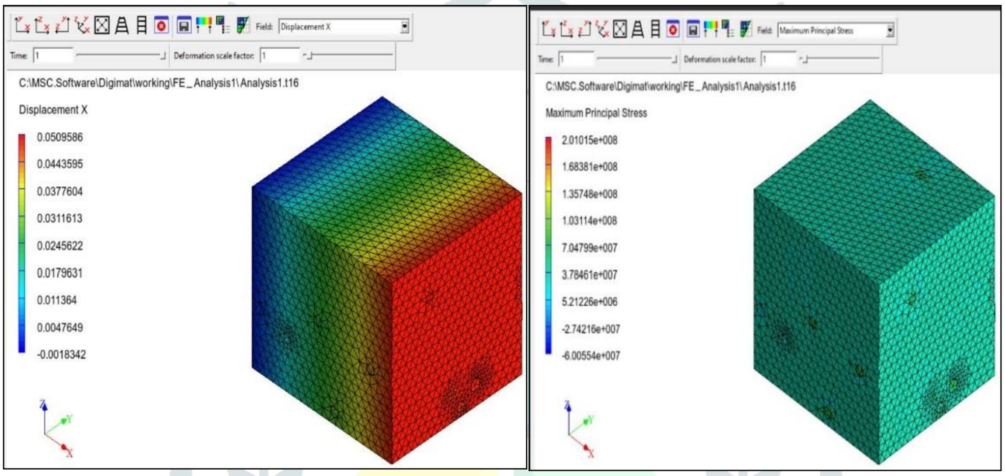
Table 3.1 PTFE properties (From Wikipedia, the free encyclopaedia)

Property	Value
Density	2200 kg/m^3
Glass temperature	114.85 °C (238.73 °F; 388.00 K)
Melting point	326.85 °C (620.33 °F; 600.00 K)
Thermal expansion	112–125×10^{-6} K^{-1}
Thermal diffusivity	0.124 mm^2/s
Young's modulus	0.5 Gpa
Yield strength	23 MPa
Bulk resistivity	10^{18} Ω·cm
Coefficient of friction	0.05–0.10
Poisson ratio	0.42
Dielectric constant	ε = 2.1, tan(δ) < 5×10^{-4}
Dielectric constant (60 Hz)	ε = 2.1, tan(δ) < 2×10^{-4}

Dielectric strength (1 MHz)	60 MV/m
Magnetic susceptibility (SI, 22 °C)	-10.28×10^{-6}

3.2 Finite element analysis

The mechanical properties of PTFE & wt.% EG nanoparticles in adding PTFE matrix composites material are find out different mechanical material properties in DIGIMAT-MF software such as 0.15% to 0.5% of expanded graphite adding in PTFE matrix then improve material properties such as Youngs modulus, shear modulus, possion's ratio & also find out value of densities of materials. In PTFE matrix increasing nanoparticle of expanded graphite also increases Youngs modulus & shear modulus. Owing to honeycomb structure, low cost, high aspect ratio, and specific surface area, EG is widely used as reinforcement into the polymer matrix. Its addition to the polymer matrix increases the thermal, mechanical and electrical properties significantly. Unfortunately, despite many advantages, EG particle has not yet been tried as filler to the polymer matrix for tribological applications. In view of this, this work aims to produce PTFE & EG nanocomposites by exploiting properties of PTFE and EG. we report here that homogeneous PTFE & EG nanocomposites could be prepared using a simple method, i.e. by dispersing commercial EG powder in the PTFE matrix via solvent suspension method, followed by cold pressing, and then sintering. These nanocomposites show dramatic increase in mechanical properties of materials for the nanocomposites containing 0.1 to 0.5wt.% EG. Fig.3.1 shows Principal stresses developed in model.



3.1 Principal stresses developed in model

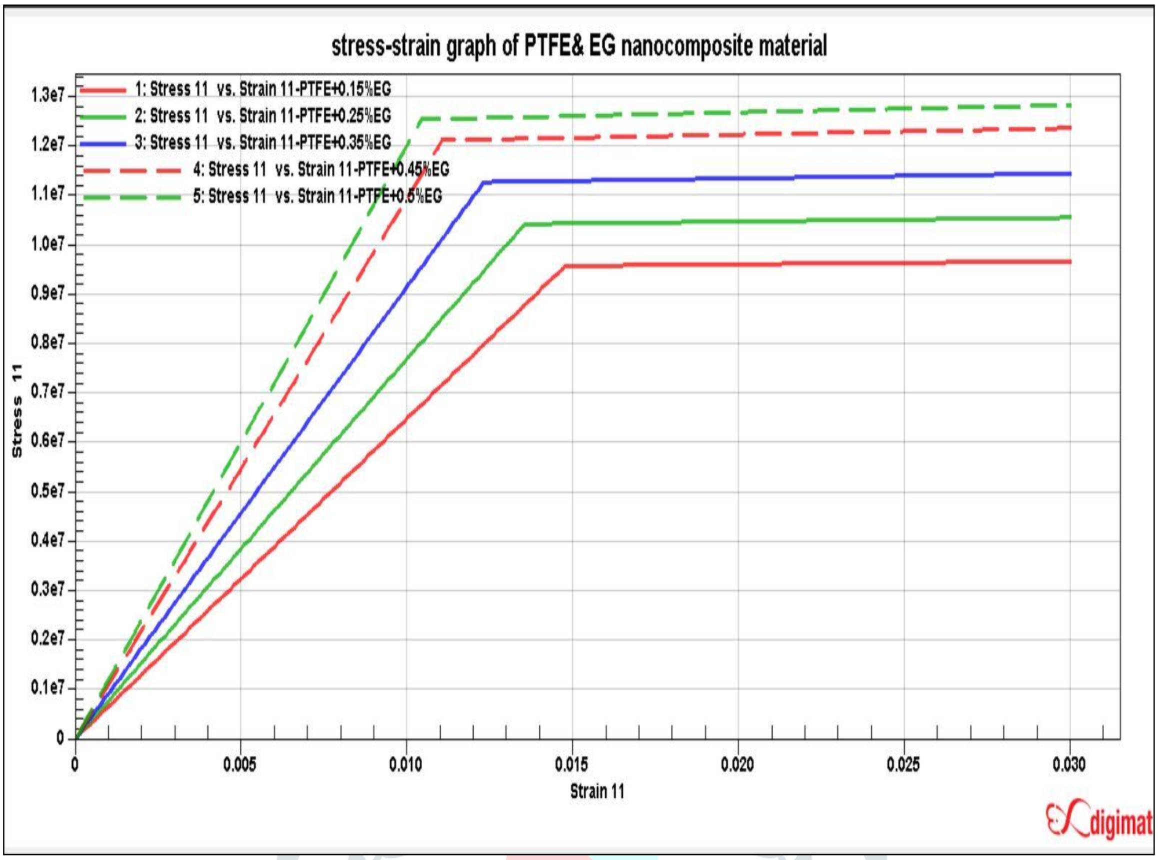
IV. RESULTS AND DISCUSSION:

The data are presented in table 4.1.as expected some density of composite are lower than that of pure PTFE because the matrix is much denser than nanoparticles. Table 4.1. shows composition (wt.%) of PTFE-based composites.

Table 4.1. Composition (wt.%) of PTFE-based composites (Digimat-MF software)

Designation	Nanocomposites materials	Youngs Modulus (Gpa)	Shear Modulus (Gpa)	Poisson Ratio	Density mg/mm^2
0	Pure PTFE	5E+008	1.7123E+008	0.46	2200
1	PTFE+0.15%EG	6.4822E+008	2.3074E+008	0.40	2183.5
2	PTFE+0.25%EG	7.6978E+008	2.7625E+008	0.39	2172.5
3	PTFE+0.35%EG	9.1615E+008	3.3181E+008	0.38	2161.5
4	PTFE+0.45%EG	1.0938E+009	3.9915E+008	0.37	2150.5
5	PTFE+0.5%EG	1.1998E+009	4.4018E+008	0.36	2145

In this adding nanofiller of expanded graphite in polytetrafluoroethylene matrix increases mechanical properties of materials such as Young's modulus, shear modulus as shown in graph 4.2 The addition of 0.5wt.% EG in the PTFE matrix decreases the density of materials & increases the elastic modulus of materials. Stress & strain graph of PTFE & EG nanoparticle in digimat software is shown below.



4.2 Stress & strain graph of PTFE & EG nanoparticle in digimat software

V. CONCLUSION

In this paper, the research work aims to produce PTFE & EG nanocomposites model by digimat software. Analysis is also carried out in same software to find out mechanical properties. The mechanical properties of the nanocomposites are compared and the results are obtained.

With the increase in the percentage of expanded graphite in the pure PTFE the young's modulus of nanocomposite material increases upto 0.5% of expanded graphite. Beyond 0.5% of expanded graphite in the pure PTFE nanocomposite properties changes to brittle material.

In order to validate the proposed model, the experimental data has been compared with model for material properties of nanocomposite it can see from that results from the present model show a good agreement with theoretical results.

REFERENCES

1. R.K.Goyal, "The wear & friction Behavior of Novel Polytetrafluoroethylene / Expanded Graphite Nanocomposites For tribology Application." Journal of tribology, April-2014.
2. Wang Y. and Yan F., "Tribological Properties of Transfer Films of PTFE Based Composites." Wear, 261(11–12), pp. 1359–1366,2006.
3. Y.J. Shi, X. Feng, H.Y. Wang, C. Liu, X.H. Lu "Effects of filler crystal structure and shape on the tribological properties of PTFE composites." Tribology International 40 (2007) 1195–1203
4. Jacob Fish, David Jal, "Generating a statically equivalent RVE with discrete defects." Composite structures,53(2016)791-803
5. J. R.Vail, Krick, B. A. Marchman, K. R. and Sawyer W. G., "PTFE Fiber Reinforced PEEK Composites." Wear, 270(11–12), pp. 737–741,2011.
6. Wu-Gui Jiang "Homogenized Finite Element Analysis on Effective Elastoplastic Mechanical Behaviors of Composite with Imperfect Interfaces" International Journal of Molecular Sciences 15 (2014) 23389-23407
7. A. Chennakesava Reddy "Characterization of Mechanical Behavior of Nylon/Teflon Nano Particulate Composites" International Journal of Advanced Research, Volume 3, Issue 5,(2015) 1241-1246
8. Costas Soutis & Aidah Jumahata "Tensile properties of nanosilica/epoxy nanocomposites" Procedia Engineering 41 (2012) 1634 – 1640