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Simulation of Nanoceramic Composite Matrices with Reinforcements using Finite Element Method

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Abstract: In this project a finite element method has been used to simulate and study longitudinal and transverse deformation of Representative Volume Elements (RVE) of two ceramic matrices composites subjected to uniaxial tensile loading parallel to single nanotubes. Ceramic matrices firstly Alumina (AL_2O_3), secondly Silicon carbide (SiC), both reinforced by three types of single nanotubes reinforcements for each one, once Alumina, Carbon and Graphite respectively. Finite Element technique has been used to predict the damage and effective mechanical properties of nanotubes-based composites. The mechanical properties as stress–strain relation, Von-mies stress and strain, deformation, shear stress behaviour are estimated by using a 3-D nanoscale solid Representative Volume Element (RVE) and using input parameters (density, Modulus of Elasticity, Poisson's ratio) in software of ANSYS.

Keywords: Representative Volume Elements(RVE), Alumina (AL_2O_3), Silicon carbide.

I. INTRODUCTION

Composite materials (CM) consist of two or more materials to form a new material system with enhanced material properties; they combine on a microscopic scale to form a useful material. The main components of a structural composite are the discontinuous phase (reinforcements) and the continuous phase (matrix).The reinforcements are used to improved mechanical properties electrical properties, magnetic properties, thermal properties, etc[1]. Ceramic Matrix Composites (CMCs) differ with other classes of composite materials by most significant differences (metal and polymer matrix composites) is that for CMCs the matrix and reinforcements are composed of either the same or similar materials, and both are brittle. On the other hand, different in chemistry, their different processing routes produce a major difference in their flaws population and, consequently, their strengths. Many excellent properties, such as extremely high hardness, strength, high thermal and chemical stability, high corrosion resistance, and wear resistance. But with this properties have, low fracture toughness, crack growth resistance, hence high brittleness and lower reliability.

One way to overcome these drawbacks is preparation of composite materials, where the base ceramic matrix is reinforced by secondary phases. Also to shift a stress from matrix to reinforcements [2, 3]. The Present Project focus on Ceramic Composites by using three types of Nano reinforcements (Carbon – Alumina – Graphite) with a Ceramic matrix once contains Alumina (Al_2O_3) then contains Silicon Carbide (SiC). And their mechanical properties were analyses by using the finite element method to model longitudinal transverse deformation of representative volume elements (RVE). The ceramic matrix composites subjected to uniaxial loading parallel to fibers. The FE technique has been used to predict the damage in RVE by simulated mechanical properties behavior.

II.FE MODELING AND ANALYSIS

To obtain the analytical solution to solve any physical problem by a differentia equation , is known as classical approach .But this does not run for all physical problems because of difficulties in mathematically describing the physical problem . An alternative to the classical approach is a numerical method; they can be used to obtain an approximate solution when an analytical solution is not possible. Finite Element Method is one of several a numerical methods. Because of the high value of contrast in properties, large volume sizes must be investigated. The numerical simulations are performed using the finite element method. This means that it will be necessary to use more meshes with a huge amount of degrees of freedom to evaluate these properties. [4, 5]

The ANSYS has evolved into multipurpose design analysis software program, it is very exact and powerful easy tool to use. Each issue has new and enhanced capabilities that make the program more flexible, more usable, and faster. In this way, ANSYS helps engineers meet the pressures and demands of the modern product development environment. The procedure for ANSYS analysis consists of three main steps (Build the model, obtain the solution, Review the results)[6]. The present work is carried out taking the finite element method to simulate and study longitudinal and transverse deformation of representative volume elements (RVE) of two ceramic matrix composites. The matrices are subjected to uniaxial tensile loading parallel to single nanotubes. The dimension and properties of RVE as shown in table (1) and fig. (1).

TABLE1: RVE DIMENSIONS

RVE characteristics (Nanotubes)		
Matrix Dimensions	**Reinforcement Dimensions**	**Tension Force**
L=30 (nm) W=30 (nm) H=30 (nm)	R1=3 (nm) R2=2 (nm) H=30 (nm)	100 (nN)

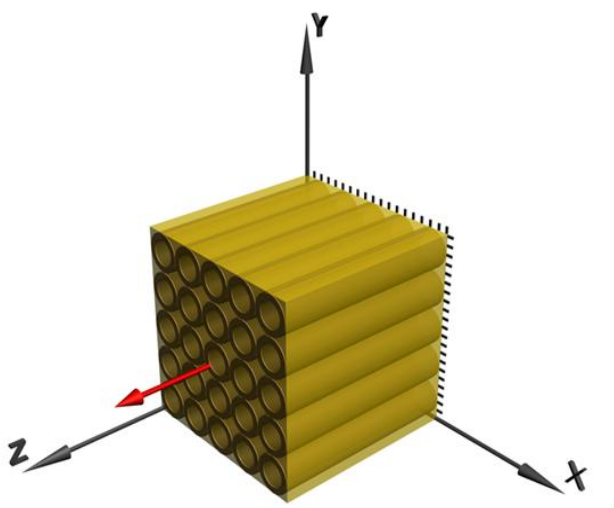

Fig.1. Nano composite RVE with Tension Force.

The material properties are assumed to simulate a sample, firstly has been dealing with Alumina matrix from first group of Alumina is 96.5% purity and Alumina of reinforcement from second group is 99.5% purity with their properties and physical properties of RVE as input parameters liked Yong's modulus, Poisson's ratio, density are listed in table (2) Are varied in simulation to check the change in length of the sample, Von mises stress and strain also relation between stress–strain are found. The procedures are repeated with Carbon and Graphite reinforcements based Alumina matrix.

TABLE2: ALUMINA IPUT

Property	Alumina matrix	Alumina reinf.	Carbon reinf.	Graphite reinf.
Density (ρ)	3710 kg/m³	3900 kg/m³	1300 kg/m³	1800 kg/m³
Modulus of Elasticity (E)	375 GPa	390 GPa	21 GPa	10 GPa
Poisson's Ratio (v)	0.25	0.24	0.2	0.2

Silicon Carbide matrix and reinforcements properties are listed in table (3) used with same previous procedures. After completing the simulation of two matrices the better process is used.

TABLE3: SILICON CARBIDE IPUT

Property	Silicon carbide	Alumina reinf.	Carbon reinf.	Graphite reinf.
Density (ρ)	2800 kg/m³	3900 kg/m³	1300 kg/m³	1800 kg/m³
Modulus of Elasticity (E)	280 GPa	390 GPa	21 GPa	10 GPa
Poisson's Ratio (v)	0.2	0.24	0.2	0.2

3. SIMULATION BY ANSYS

A. Alumina-Alumina reinforcement

In case of Alumina-Alumina reinforcement, tensile load of 100 nN is applied on RVE sample to calculate deformation in 3-D and 2-D, and deformation with Z-axis and the length of deformation of shape in this direction is checked. The properties of the Alumina matrix and Alumina reinforcement materials are taken from table (2). Performance is evaluated for Von mises stress, length of deformation, shear stress on Y-plan and the shear stress length. Stress-strain relation is developed for the condition chosen.

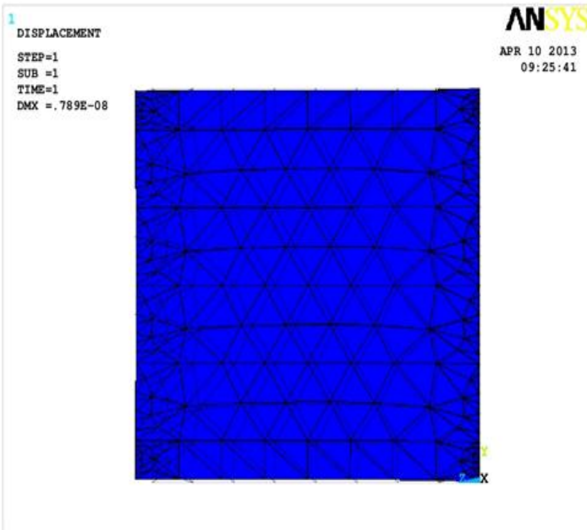

Fig.2. Deformation in 2-D.

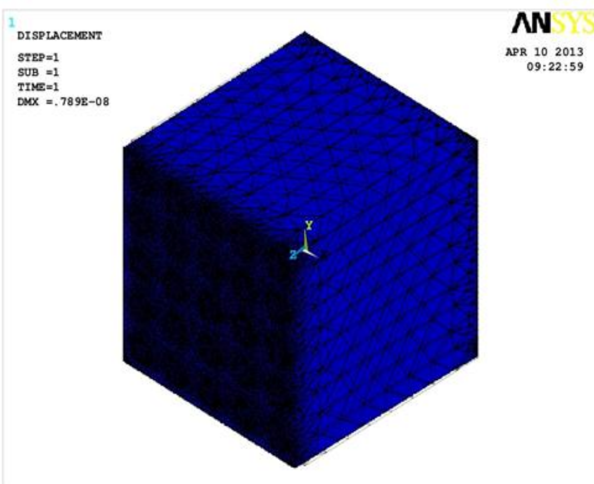

Fig. 3. Deformation in 3-D.

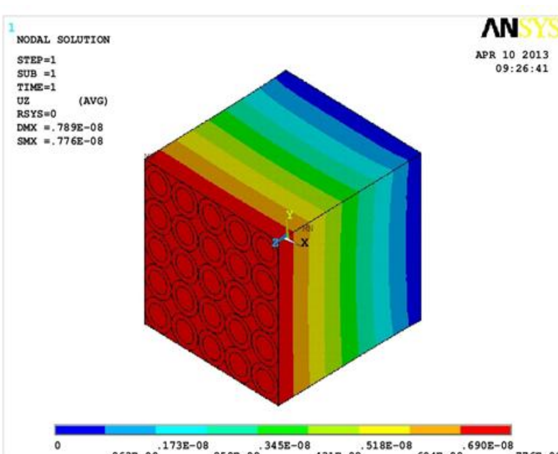

Fig.4. Deformation shape.

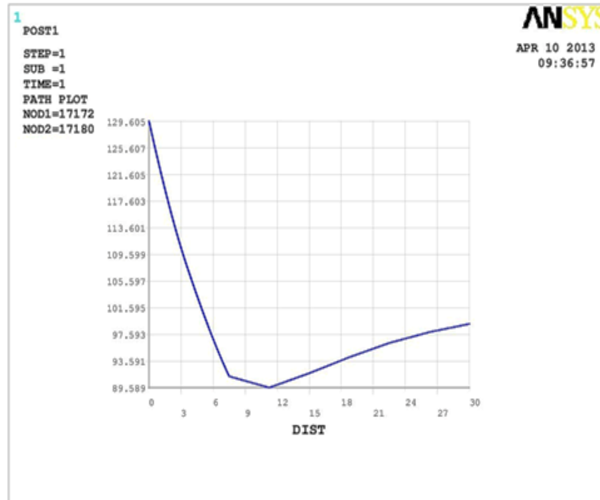

Fig.5. Alumina-Alumina (von-mises stress).

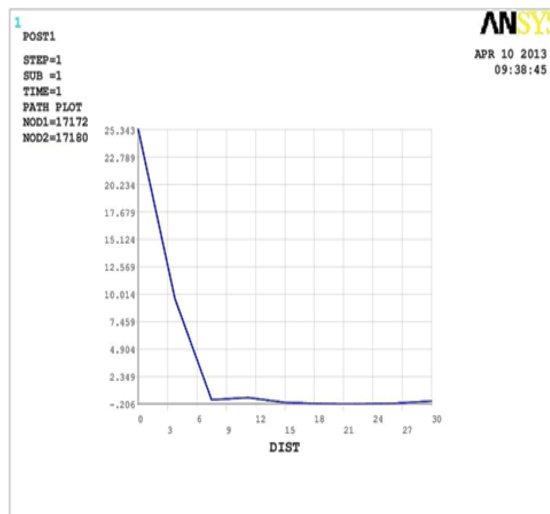

Fig.6. Alumina-Alumina (shear stress).

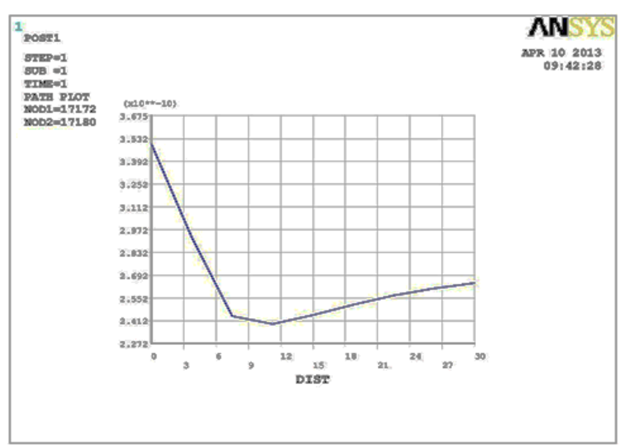

Fig.7. Alumina-Alumina (von-mises strain).

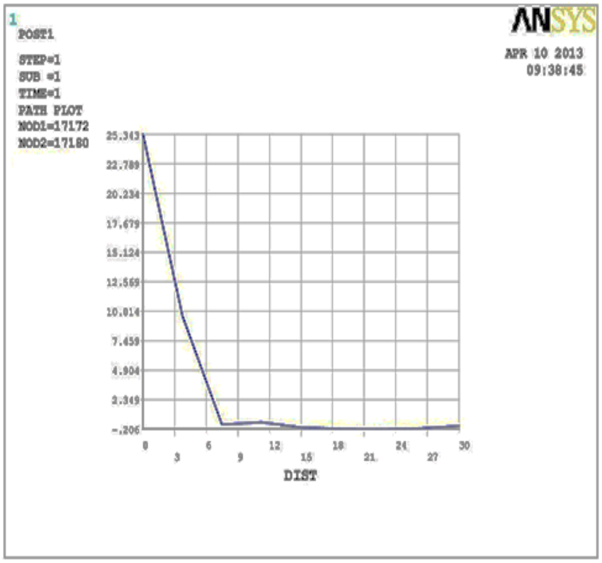

Fig.8. Alumina-Alumina (shear strain).

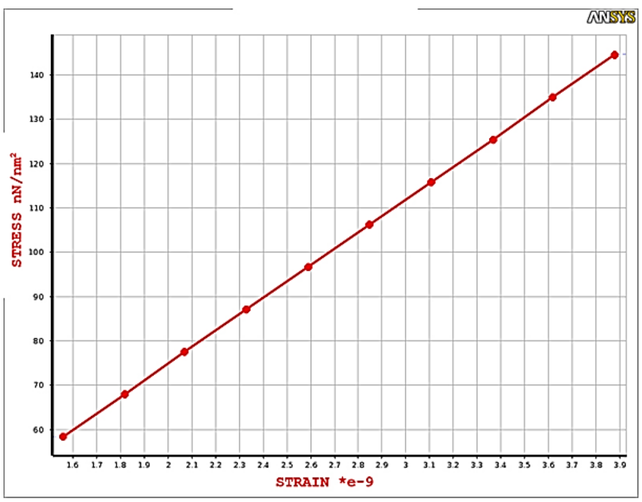

Fig.9. Alumina-Alumina (relation between stress-strain.

The procedures are repeated with Carbon and Graphite reinforcements based Alumina matrix. Also same previous procedures are repeated with Silicon Carbide matrix and reinforcements properties are listed in table (3) used to completing of simulation.

IV. RESULT AND DISCUSSION

A. Results of matrices

The results were analysed for Alumina matrix and three reinforcements (Alumina, Carbon, Graphite) with input physical properties (density, Modulus of Elasticity, Poisson's ratio) and are listed in table (4).Also the results of Silicon Carbide matrix and three reinforcements (Alumina, Carbon, Graphite) with same input physical properties are listed in table (5).

TABLE4: RESULT OF ALUMINA MATRIX

Mechanical properties	Alumina-Alumina	Alumina-Carbon	Alumina-Graphite
Maximum deformation (nm)	0.776E-08	0.160E-07	0.190 E-07
Maximum stress (nN/nm^2	144.62	320.082	345.879
Maximum strain	0.388E-09	0.434E-08	0.901 E-08
Maximum shear stress (nN/nm^2)	40.6501	81.6218	100.672
Maximum shear strain	0.271E-09	0.397E-08	0.900 E-08

TABLE5: RESULTS SILICON CARBIDE MATRIX

Mechanical properties	Silicon Carbon-Alumina	Silicon Carbon-Carbon	Silicon Carbon-Graphite
Maximum deformation (nm)	0.913E-08	0.204E-07	0.236E-07
Maximum stress (nN/nm^2)	147.007	308.806	341.276
Maximum strain	0.450E-08	0.434E-08	0.901E-08
Maximum shear stress (nN/nm^2)	37.5162	73.138	95.4554
Maximum shear strain	0.269E-09	0.377E-08	0.879E-08

B. Discussion of results

The solid model and free mesh of ANSYS was used to simulate RVE sample, deformation values of Alumina matrix reinforced by Alumina nano-tubes were less than Graphite and carbon. But the stress results of alumina matrix with Graphite can resist more load than carbon reinforcement, but both resist loading much more than that of the alumina reinforcement. The maximum strain results with Alumina matrix are shown in table

(4) Carbon and Graphite have elongation more than that of Alumina.

In spite of the stress and strain in Alumina matrix with Graphite and Carbon more than with Alumina, we noted the relation between stress-strain were similar because the linear and uniform deformation in representative volume element model. The comparison between stress-strain curves of Alumina matrix with original stress-strain curve as shown in figure (10) we observe the curve of Alumina in figure (9) take straight line after yield point, in other word it is not passed in plastic region due to the brittleness property of ceramic materials, also the deformation in RVE is linear and uniform.

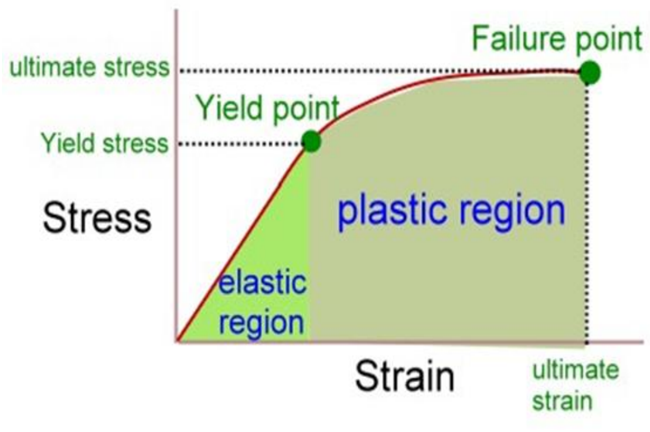

Fig. 10: stress-strain curve

The results of Silicon Carbide matrix with Graphite can resist the loading more than carbon reinforcement are shown in table (5), but both resist loading much more than the alumina reinforcement. The values of stress and strain in Silicon Carbide matrix with Graphite and Carbon more than Alumina reinforcement, but the relation of stress-strain were similar due to the linear and uniform deformation in representative volume and the brittleness materials take straight line after yield point.

V. CONCLUSIONS

The present work studied the behavior of two types of advanced ceramics Al_2O_3, SiC as matrices under tensile force with three types of reinforcements Alumina, Carbon and Graphite. To predict the damage and effective mechanical properties of nanotubes-based composites, are evaluated by using a 3-D nanoscale solid representative volume element (RVE) and using the finite element method (FEM). Due to small size, low density and good electrical and thermal conductivity of nanotubes has been studied as reinforcements.The main aim of using nanotubes is to shift stress from matrix to reinforcement and to improve mechanical properties, thermal performance and electrical characteristics, magnetic performance of ceramic composite. The Alumina- Alumina composite deformation less than Alumina-Carbon and Alumina-Graphite composite, but both possess elongation more than Alumina-Alumina before collapsing. The stress conditions are better for Graphite and Carbon reinforcement than Alumina. In other words, Graphite resist tensile load more than Carbon, Graphite and Carbon showed much better results than Alumina for shear stress and shear strain. Alumina reinforced by Graphite is more usable for applications with tensile forces. Regard behavior of Silicon Carbide matrix and three types of single-wall nanotubes with same tensile load and input parameters, the results roughly similar to the values of Alumina matrix with same types of reinforcements.

VI. REFERENCES

1. Bryan Harris, 1999, Engineering composite materials, The Institute of Materials, P(1-16, 99-101), London.
2. Johann Cho1,2, Aldo R Boccaccini1*, Milo SP Shaffer,Ceramic matrix composite containing carbon nanotubes, P(1-6), Imperial College London.
3. Amit K. Shrestha, 2006,Synthesis and characterization of ceramic composite, P(1-46), University of Wisconsin-Stout .Menomonie.
4. T. Kanit , et al, 2003, Determination of the size of the representative volume element for random composites: statistical and numerical approach, p(48-77), France.
5. Chennkesava R. Alavala,2012,finite element method, P(1-17), New Delhi.
6. ANSYS Users Manual, Revision 12.0, 2013.

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