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The Optimum Design of Particulate in Composite Sheets Using Finite Element Method

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Abstract

Composite sheets are relatively new materials used in different applications of sheet metals forming as it has better mechanical properties than the other employed engineering materials. Scientists of materials engineering try to connect between industrial applications and the characteristics of composite sheets to solve many of the industrial problems which have occurred. In addition, the composites sheets are used in complex designs for mechanical parts which used in space shuttles and submarines. In this study, an Sic particulate – reinforced composite sheet was numerically simulated using finite element method to show the effect of silicon carbide particles arrangements on the design of Sic – reinforced epoxy composite sheet.

Keywords: Composite Sheets, Arrangements of Sic Particles, Optimum Design, FEM.

1. Introduction

A modern engineering use is composite sheet, which improves mechanical properties by incorporating a new material into the sheet matrix. Many factors participate in composite sheet such as reinforcement materials types, reinforcement shapes, reinforcement size, reinforcement orientation…etc.

Engineering material researchers discovers a new industrial application via reinforcing epoxy matrix with metals due to add a new mechanical property comparing with basic materials.

The influence of particle dimension ratio on the mechanical properties was experimentally investigated. They concluded that the modulus of elasticity decreases due to increase particle ratio, in addition, the yield stress deceases with increasing particle dimension ratio [1]. In 2008, the impact of interface adhesion between powders, powder size, and applied load on mechanical properties were studied to show the effect of some parameters on mechanical properties. They used three powder sizes (12, 25, 50nm) inside matrix. They noted that an increase in the volume fraction of reinforcing composite sheet causes an increase in the modulus of elasticity. [2].

They effect of particles position in matrix was numerically studied using finite element method software and comparing with experimental results. He used different volume fractions and particle sizes for two types of reinforcements such as sphere, ellipse and fiber [3]. In 2017, they investigated and modeled of composite frame using FEM to show the effect of size and direction of reinforcing, shapes, distribution. They concluded that the stress decreases due to increase the size of powder, in addition, the highest stress for all shape happens when direction 45° for powder.[4]. In 2022, the impact of particle geometry in the mechanical properties was numerical investigated, they used three different types of particle shapes. They found that the sphere particles reinforcing composite had improved the mechanical properties of composite materials [5].

The impact of strain path with thermal forming on the deformation of sheet metal was theoretically investigated using plastic deformation formulas. They pointed that the deformation strain of AA6061 sheet improved due to combined influences of changing forming path and increasing temperatures [6]. The impact of particle geometry inside polymer matrix on mechanical properties was numerically considered using finite element method. They used six geometry types to show which one of particle geometry is more effect on mechanical characteristic. Also, they used different volume fraction for each geometry type of glass reinforcing inside nylon matrix. They found that the triangle particles gave highest effective stress than all types of particles geometry [7]. They numerically modeled of polymer composite material using finite element method. Also, they used different particles size to show the effect of particle size on mechanical properties of composite materials, in addition, the effect of particles distribution was investigated using different arrangement. They noted that the square arrangement has highest effective stress than all arrangement [8].

They studied the influence of seed reinforcing size on the mechanical properties of composite materials experimentally. They found that the mechanical properties changed due to change of seed particle size [9]. Two types of reinforcing geometries for composite sheets were numerically investigated using finite element method software to show the effective mechanical properties for reinforcing composite sheet. They used two different shapes for reinforcing in composite sheet: fiber and particulate. They found that the fiber composite sheet has a higher effective stress than the particle composite sheet, and the effective circle fiber composite sheet increase than square fiber composite sheet [10].

The object of this study is to determine the best arrangement of silicon carbide particles in epoxy matrix from the point of view of strength and displacement.

2. Mechanical Characteristics of Materials

The mechanical characteristics of materials were determined from tensile testing ASTM D 638 that will be used in simulation of composite sheet as properties. The composite sheet used in this research containing silicon carbide SiC as reinforcing materials, and epoxy as matrix materials. Table 1 displays all mechanical characteristics for materials using in composite sheet which will use in FEM software as input.

Table (1) Mechanical characteristics for all materials

Type of materials	Proof stress (MPa)	Tensile stress (MPa)	Modules of elasticity (GPa)	Poisson's Ratio
Epoxy matrix	12	33	3.8	0.3
SiC	112	345	250	0.23

3. Numerical Model

The silicon carbide particles reinforcing composite sheet was numerically simulated via finite element software with using different design depend on number and distribution of particles to show the impact of these factor on mechanical characteristic, finally will be select the best design of composite sheet depend on no. of particles and mechanical properties.

3.1. Composite Sheet Model

There are two stresses: major stress σ_1 and minor stress σ_2 are used in composite sheet under condition of plane stress condition, and these stresses represent the effective stresses in the composite sheet. The von mises stress represent the effective stress in composite sheet instead of two stresses in composite sheet as shown in equation (1).

$$S' = \left[(S_1)^2 + (S_2)^2 - S_1 S_2\right]^{1/2} \quad \text{...(1)}$$

Comsel v.6 software offers Von Mises stress analysis on composite sheet using finite element method to show the distribution stresses and strains on epoxy composite sheet. There are main steps for simulation of composite sheet: First step: three dimension of epoxy composite sheet was draw to find out the Silicon carbide reinforcing particles and epoxy matrix. In addition, Distribution particles were arrangement in epoxy matrix due to discover the effective design. Second step: materials types were selected: epoxy for matrix materials and SiC particles for reinforcing material. Third step: boundary condition was used to show the effect of tension load in one side and fixing in another side. Fourth step: making the meshing pattern for all composite sheet: reinforcing particles and epoxy matrix as shown in figure (1). Finally, well be run software to solve and analysis for composite sheet model.

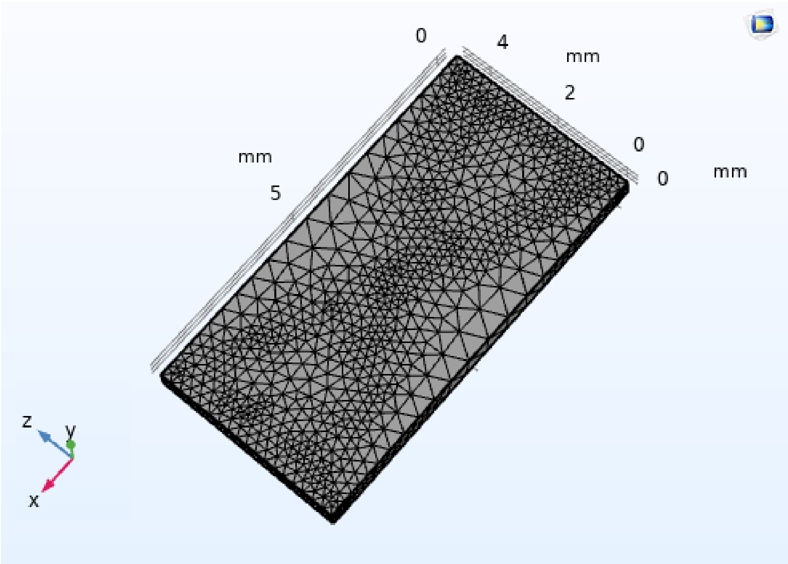

Fig.1 Meshing net for composite sheet.

4. Results and Discussions

The impact of reinforcing materials plays an important role in composite sheet that the mechanical properties of composite sheet will be change and improve when add reinforcing materials. The effect of particles reinforcing quantities had investigated using FEM to show the effect of quantities of particles on mechanical properties of composite sheet. A composite sheet (10 cm length, 5 cm wide, and 0.5 cm thick) were numerically simulated using Comsol software. A tension load 100N was applied in the right-hand side of composite sheet.

Figure (2) illustrates the distribution of von-mises stresses on composite sheet using FEM software. The 200 Silicone carbide particles (d=0.4mm) are used on composite sheet to make support for sheet. The highest value of effective stress is 299.2 Mpa.

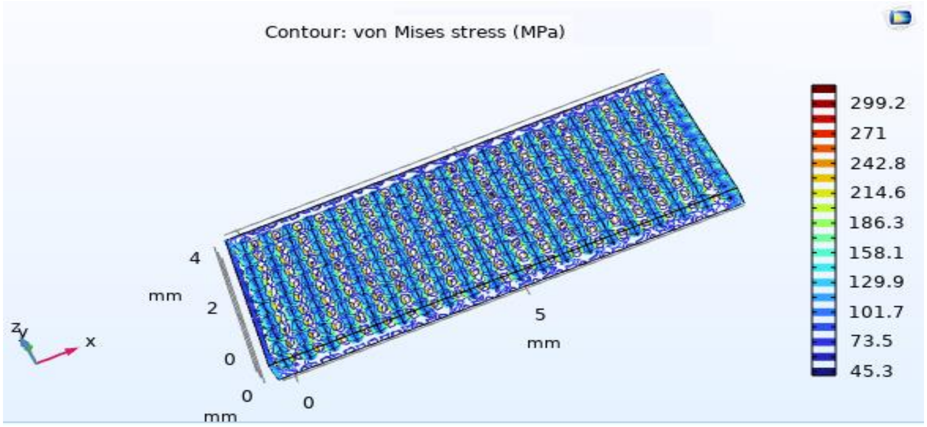

Figure (2) Distribution of Von-Mises stress on composite sheet.

The displacement of composite sheet happens due to tension load. Figure (3) shows the distribution of displacement for Sic particles of epoxy composite sheet. A sphere reinforcing (r=0.2mm) inside of epoxy matrix with volumetric ratio is 27%. It can be seen that the highest value of effective displacement is 166.02 µm.

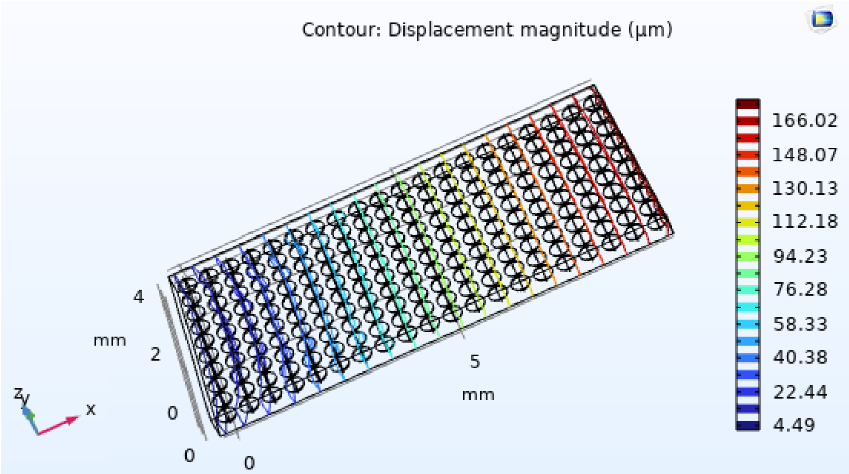

Figure (3) contour diagram of displacement 27% SiC epoxy composite sheet.

The strength of composite sheet will be improved via increasing number of reinforcing particles inside epoxy matrix. The effect of number of particles on the strength of composite sheet are shown in figure (4). It illustrates the strength improving for composite sheet due to increase quantity of particles. The vertical axis represents the Von-Mises stress, whereas the horizontal axis represents the number of particles (100, 200, 300). Overall, it can be seen that as the number of SiC reinforcing particles has increased, which causes the von Mises stress to grow.

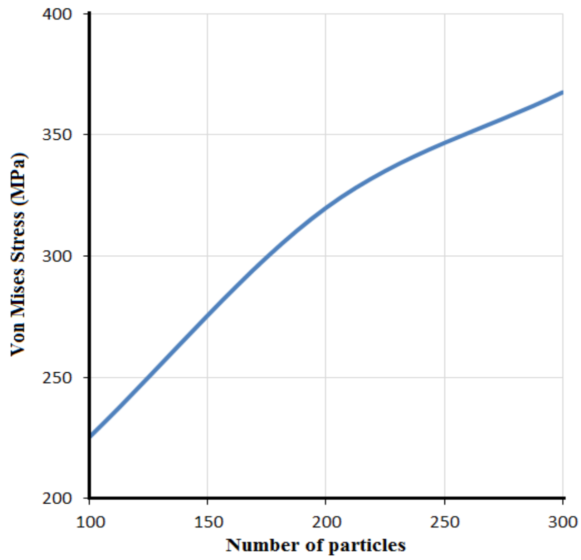

Figure (4) Impact of SiC reinforcing particles quantity on Von Mises stress.

A displacement of composite sheet is one of the required mechanical properties in industry, and it happens due to tension load that applied to composite sheet. Figure (5) shows the impact of SiC particles quantity on the displacement due to tension load. The horizontal axis indicates the quantity of particles (100, 200, 300), while the vertical axis signifies the displacement of composite sheet. Overall, it is clear that the increased quantity of SiC reinforcing particles causes the displacement to decrease.

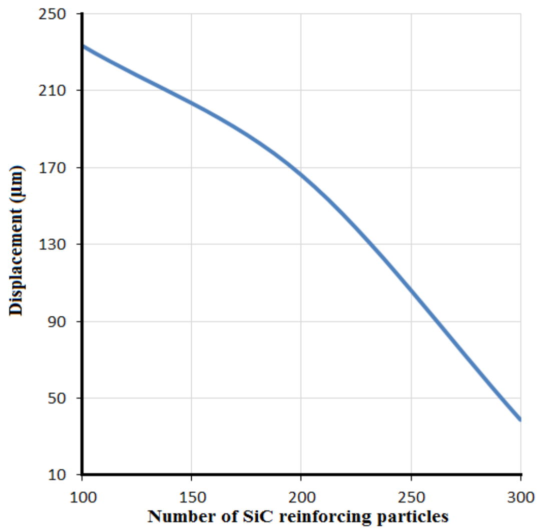

Figure (5) Impact of SiC reinforcing particles quantity on displacement of composite sheet.

4.1. Model of New Design For Composite Sheet

New design means using a new distribution of reinforcing of particles in matrix to decrease the particles quantity with high quality for mechanical properties.

Figure (6) shows the new design for composite sheet with a new position of reinforcing SiC particles inside epoxy matrix which was named: edge reinforcing composite sheet. 36 SiC reinforced particles were used with a new position of these particles to illustrate a new design of epoxy composite sheet. The maximum Von Mises stress is 380.6 MPa.

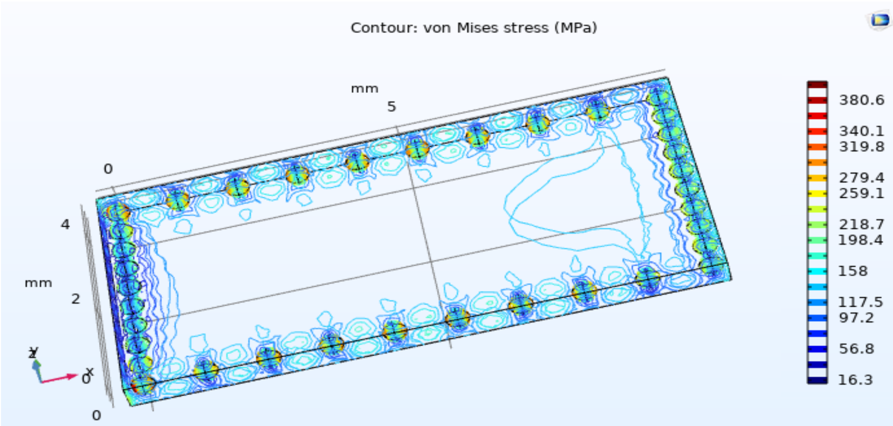

Figure (6) Von Mises stress contour diagram for a new design of composite sheet (edge reinforcing composite sheet).

Figure (7) illustrates contour of displacement for a new design of epoxy composite sheet (edge reinforcing composite sheet), and it happens due to tension load. 36 SiC filled particles were selected with a new distribution of reinforcing particles to show a new design: of epoxy composite sheet. The maximum displacement is 289.3µm.

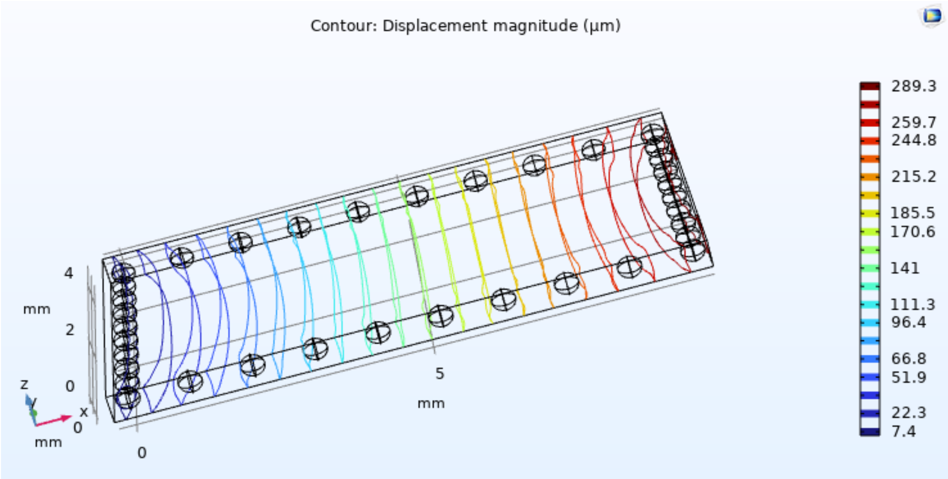

Figure (7) contour diagram of a new design of composite sheet: edge reinforcing composite sheet.

Figure (8) displays the effective design of epoxy composite sheet with a new position of reinforcing SiC particles inside epoxy matrix which was named: diagonal reinforcing composite sheet. 36 SiC reinforced particles were used with a new position of these particles to illustrate a new design of epoxy composite sheet. The maximum Von Mises stress is 397.7 MPa.

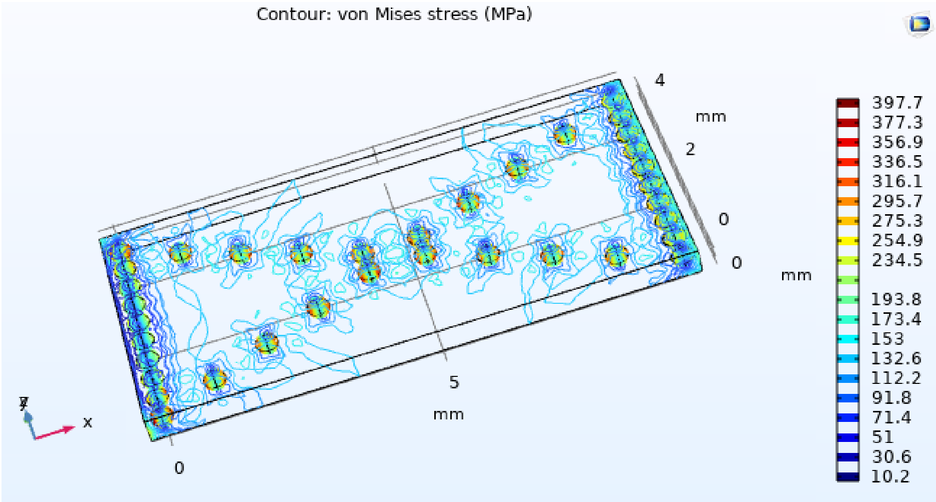

Figure (8) Von Mises stress contour diagram for a new design of composite sheet (diagonal reinforcing composite sheet).

Figure (9) illustrates contour of displacement for a new design of epoxy composite sheet (edge reinforcing composite sheet), and it happens due to tension load. 36 SiC filled particles were selected with a new distribution of reinforcing particles to show a new design: of epoxy composite sheet. The maximum displacement is 272.6µm.

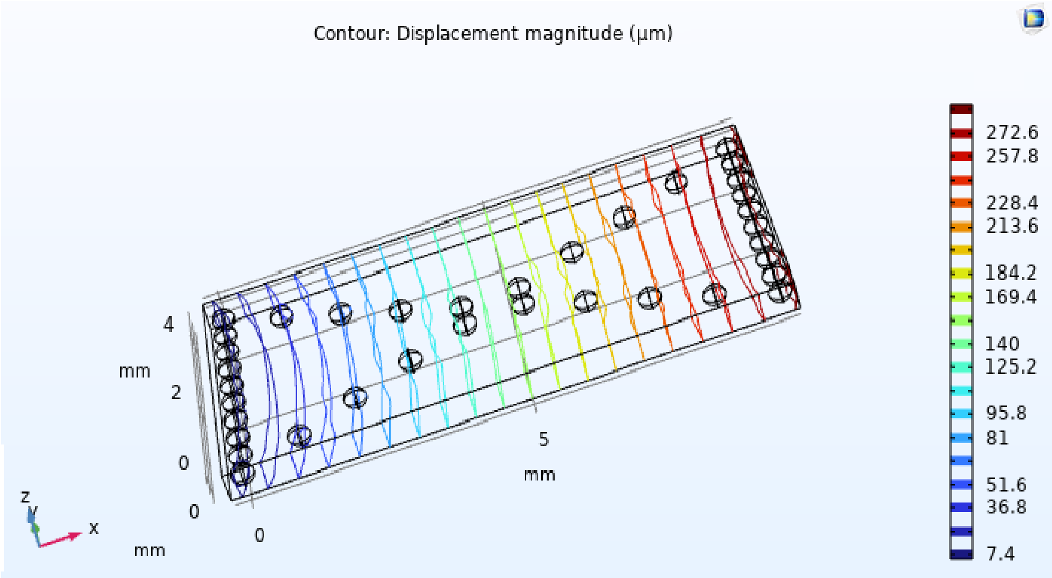

Figure (9) contour diagram of a new design of composite sheet: diagonal reinforcing composite sheet.

5. Conclusions

The SiC particles reinforcing epoxy composite sheet was numerically modeled to show the impact of reinforcing particles position inside epoxy matrix. The major conclusion will be noted below:

1-The effective stress increases as the number of SiC reinforcing particles increase inside composite sheet.

2- The displacement in composite sheet deceases as the number of SiC reinforcing particles increase inside composite sheet.

3- The suggested designs had better mechanical properties than the traditional method of reinforcing the composite sheets.

4- The effective stress of diagonal composite sheet is higher than other types of arrangement.

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