Energy Absorption of Glass Fiber Reinforced Plastic (GFRP)-Woven Composites in Different Nano Clay Loading Using Numerical Method.

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Abstract: In this work, the numerical investigation for impact behavior of GFRP (Glass Fiber Reinforced Plastics) composite along modified with nano-clay (Cloisite® 20B) at 0.5%wt., 1%wt., and 2%wt concentrations was done. The finite element analysis was carried out in ABAQUS/Explicit to investigate the low-velocity impact response. The numerical results showed that adding 0.5% wt. and 1%wt. nano-clay significantly increased the stiffness of GFRP compared to a pristine one. In contrast, adding 2%wt nano-clay decreased the stiffness of GFRP. With regard of energy absorption, a 0.5%wt. nano-clay modified GFRP showed a maximum energy absorption, whereas, a 2%wt. nano-clay modified GFRP exhibited the lowest performance for all impact energy levels.

Keywords: Glass fiber reinforced plastics (GFRP), Cloisite® 20B, nano clay, woven, impact

1. INTRODUCTION

For the last decades, the use of laminated composites especially glass fiber reinforced composites is highly used for improvement of advanced structure and cruel areas like oil walls is increased. And the need is also come to table to study low velocity impact behavior and damage. [1] [2]. To study the delamination of thick composite laminates under the low-energy impact, damage forecast and investigation were displayed in [3]. The simulation comes about appeared a great relationship to the experimental perceptions. The delamination area was restricted by the affected zone and the fiber dispersion.
A low-velocity impact test was done in carbon fiber/epoxy composite laminates reinforced by short fiber and other material to investigate damages in [4] and the results showed that the composite experience a various fracture, delamination, Intra ply cracking, matrix cracking, fiber breakage, and damage depending on the interlayer material. From experiment done in [5] different binder volume which is 3%wt. and 6%wt. have little effect in in-plane stiffness (twist and weft heading), delamination resistance for different matrix for preparing GFRP also was investigated by [6]. And conclude that for low velocity, the same impact condition polyurethane-based GFRP created a little damage measure and impact toughness, but two GFRPs appeared small contrast within the add up to energy absorbed during the impact.

Several researchers have proposed different failure theories to model the failure envelope of various types on composite materials among those failure criterion Hashin and puck failure criteria taken as good predictors of damage for laminated composites [7] [8]. Hence, in this work the constitutive intralaminar modes for studying the damage initiation and propagation of Cloisite® 20B nano clay modified GFRP were joined into the ABAQUS/Explicit FE code by user-defined VUMAT material subroutines to adopt the 3D Hashin criteria.

2. MATERIALS

As a material GFRP woven composite is used as a materials for structure crashworthiness analysis. The GFRP–plain weave composites are four types the first is a pristine material that is free of nano clay. The second is 0.5 %wt. per volume 20B nano clay modified, the third is 1%wt. per volume 20B Nano clay modified, and the fourth 2%wt. per volume 20B Nano clay modified. In this work, S-glass plain weave fabric and Cloisite® 20B (Southern Clay Products, Inc., TX) were used as a material and reported in [9] and mechanical properties [10], as shown in table 1 and table 2

| Direction | Warp | weft |
|-----------|------|------|
| Loading   |      |      |
| Tensile strength (MPa) | 513.9 | 552.9 | 529.99 | 480.99 | 510.6 | 515.5 | 545.1 | 465.9 |
| Tensile modulus of elasticity (GPa) | 25.0 | 23.1 | 23.5 | 20.6 | 23.2 | 26.5 | 24.4 | 20.7 |
| Tensile poisson’s ratio | 0.121 | 0.124 | 0.089 | 0.082 | 0.120 | 0.153 | 0.089 | 0.072 |

Table 1. Tensile results of mechanical properties [10]

| Loading   | Warp | weft |
|-----------|------|------|
| Compressive strength (MPa) | 86.3 | 77.2 | 83.5 | 97.7 | 92.7 | 77.1 | 76.9 | 91.7 |

Table 2. Compressive results of mechanical material properties [10]
Compressive modulus of elasticity (GPa)

|                | 25.2 | 25.9 | 26.3 | 28.3 | 24.8 | 25.1 | 26.1 | 22.2 |
|----------------|------|------|------|------|------|------|------|------|
| Compressive poisson's ratio | 0.058 | 0.086 | 0.060 | 0.078 | 0.101 | 0.091 | 0.065 | 0.079 |

3. MATERIAL MODELLING

The damage initiation and advancement show applied in this work were based on the Hashin 3D failure criteria. In this demonstration, four distinctive modes of failure were considered, to be specific, fiber crack in tension, fiber buckling and kinking in compression, matrix splitting beneath transverse tension and shearing, and matrix pulverizing beneath transverse compression and shear.

The equations used in this paper is based on Hashin 3D formulation and are taken from [3,8] and the short form are listed below

Where:

\( X^T \) – tensile strength in longitudinal direction

\( \chi^c \) – compression strength

\( S^b \) – shear strength in longitudinal direction

\( S^T \) – transvers shear strength

\( \alpha \) is a coefficient of shear stress contribution to the fiber tensile failure initiation criterion; and

\( \sigma_{11}, \sigma_{22}, \sigma_{33}, \sigma_{12}, \sigma_{13}, \) and \( \sigma_{23} \) are components of the effective stress tensor, \( \sigma \), that is used to evaluate the initiation criteria.

4. NUMERICAL CONFIGURATION

The drop-weight analysis was done based on ASTM D7136[11]. 12.7 mm distance across with side of the equator head impactor was utilized all through the quasi-static space and affect tests [12]. The mass of the impactor for this numerical analysis is 23.55 kg. based on Research Council for Automobile Repair (RCAR) low velocity consideration is also (5-20 km/h). The material properties were taken from [9] [10].

Finite element simulation of GFRP is based on ASTM – Designation D7136M-15 and the fixtures are shown in figure 1.
The finite element simulation of all nano clay modification GFRP-WOVEN composites is based on ASTM – Designation D7136 M-15 with dimension 62.5 x 37.5 x 5.4 mm with 8 laminas. Each lamina is 0.675 mm thickness. The impactor diameter was 16 mm, the impact velocities used in this work were 1.2 m/sec, 1.7 m/sec, and 1.9 m/sec. To reduce the simulation time, a quarter of a GFRP specimen and impactor were used.

5. RESULT AND DISCUSSION

Figure 2 shows the comparison of reaction forces for pristine 0.5%wt. nano clay and shows 0.5%wt. nano clay loading shows a higher reaction force than pristine material. From the figure, the peak load for each material configuration reaches at approximately equal interval, which indicates that no significant damages were observed with 28.8 J impact energy. Figure 3 shows the comparison of pristine, 0.5%wt., 1%wt., and 2%wt. nano clays at 72.2 J impact energy. Results show that highest reaction force is gained from 0.5%wt. Nano clay modified and the second highest reaction force is pristine one, thirdly 1%wt Nano modified and the least reaction force is 2%wt. Nano clay modified GFRP. The 2%wt. nano clay loading reaches its maximum reaction force first and is followed by the pristine. This implies that the inclusion of excessive nanofillers for the present material, S-glass GFRP, has a notable effect on the damage resistance. On the other hand 0.5 %wt. Nano clay inclusion increased the reaction force and improved the damage resistance.

Figure 1. numerical specimen

Figure 2. Comparison of 0%wt., 0.5%wt., 1%wt. and 2%wt. nano
The affect damage resistance plots appeared in Figure 2, can be characterized by two limits, early stack, and crest stack. The beginning stack is recognized by the primary sudden drop within the reaction-time bend which shows the primary fabric harm such as interface disappointment or matrix splitting which is show ordinarily at/or close the back confront of laminates [14]. From figure 2 and figure 3 incipient load of 2%wt. nano clay is first followed by 1%wt. and 0.5%wt. nano clay loading and pristine is the last.

As per [13] adding nano clay with 1%wt. loading increase, the energy absorption capacity, while [14] concludes samples with 1.5 wt.%wt. nano clay loading absorbs less energy as compared to 3 wt.%wt. and GFRE (0%wt.) samples. But in this research, the capacity of energy absorption in comparison with pristine is dependent on the amount of percent of nano clay. Based on Figures 4, 5, and 6, the energy absorption of 0.5%wt. nano clay exhibited a more energy absorption capability, with a variation of 5 to 10 %wt. for different impact energies, compared with the pristine, 1%wt., and 2%wt. nano clay modified GFRP.

Figure 3. Comparison of pristine, 0.5%wt., 1%wt. and 2%wt. nano clay at 28.8J

Figure 4. Energy vs time graph in 39.2J

Figure 5. Energy vs time graph in 39.2J
In [15], stiffness of the material is indicated by displacement or deflection at peak load which is the higher deflection the smallest in stiffness. As shown in Figure 7, the addition of nano clay with 0.5%wt. and 1%wt. nano clay increases the stiffness while adding nano clay with 2%wt. nano clay decreases the stiffness. As proven in [10], the results have a direct relationship to the modulus of elasticity. The modulus of elasticity in transverse direction for 0.5 and 1%wt. showed increased values, respectively, compared with the pristine one. On the other hand, 2%wt. nano clay showed the lowest transverse modulus of elasticity. As a result, the stiffness of 2%wt. nano clay reduced significantly.

Figure 7. Variation of peak deflection with impact energy

6. CONCLUSION

The following conclusion is drawn from this research.

1. Loading Cloisite® 20B nano clay with 0.5% wt. shows good energy absorption than loading it 1%wt., 2%wt. and 0%wt. of GFRP.

2. The addition of nano clay with 0.5%wt. and 1%wt. nano clay increases the stiffness while adding nano clay with 2%wt. nano clay decreases the stiffness. Increased Young’s modulus observed in stiff material and, in this work as validation 0.5%wt. nano clay has the highest
modulus of elasticity of all material in the transverse direction followed by 1%wt. nano clay loading. 2%wt. nano clay loading has a list in modulus of elasticity and stiffness.

3. Optimal concertation of nano clays introduces the desired phenomenon, increased energy absorption. A better and novel design is drawn from understanding of such situation in improvement of damage and impact behavior.

7.REFERENCE

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