LOW VELOCITY IMPACT TEST RESEARCH OF CARBON FIBRE COMPOSITES INCORPORATING NANOCLAY AND NANOTUBE

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Abstract- The study purpose is to determine the interactions of widely-used Nanoclay (NC) at various rates and of Multi-Walled Carbon Nanotube (MWCNT) between each other on carbon fiber composite materials. During their production via the vacuum infusion method, the carbon fiber composite laminates were produced by reinforcing the montmorillonite-based NC organized at various rates via homogenizer and the MWCNT at a constant rate into its resin. By taking the antecedent studies as basis, the constant rate of MWCNT was determined as 0.3%. The produced samples were applied low-velocity impact tests. D7136/D7136M – standard no. 12 Standard Test Method for Measuring the Damage Resistance of a Fiber-Reinforced Polymer Matrix Composite to a Drop-Weight Impact Event was utilized in the tests, and samples were prepared at the aspect ratio 100*150 mm in accordance with the measures provided by Figure 8 in the standards. 0.3% MWCNT, which gave the optimum result in the previous studies, was added to the tests that were conducted at 25J energy along with 1%, 3%, 5% NC, and the results were examined.

Keywords- Nanoclay, Multi-Walled Carbon Nanotube, Impact Test, Carbon Fiber Composite

I. INTRODUCTION

Nano-technology is an interdisciplinary branch that includes physics, chemistry, engineering and biology. Additionally, it is a research branch whose study field has expanded widely due to the inclusion of other branches, which mostly depends on the properties of the study at hand; for example, if it is a medical study, then the branch included is medicine etc. Researches made on the materials that are manufactured via nano-technology are continuously rising. The interest in nano-technology, which we will define as the studies conducted at an atomic level, is increasing and helping technology improve, as the apparatus of nano-technology are becoming increasingly sophisticated as parallel with the studies and improvements made by scientists on the building stones of said apparatus at an atomic level. Carbon fiber is light, expensive and has high durability, therefore it is generally used in the fields of aviation, space and defense. Recently there have been studies conducted for the purpose of increasing lightness, durability, rigidity or flexibility.

B. Ashrafi, J. Guan, V. Mirjalili et al. (2011) used the single-walled carbon nanotube (SWCNT) on the epoxy/carbon fiber laminated composites and examined its mechanical properties. They utilized SWCNT containing 0.1 wt% epoxy, which resulted in a 5% reduction of the area of impact damage, a 3.5% increase in the Compression After Impact (CAI) strength, a 13% increase in the fracture toughness, and 28% increase in the interlaminar fracture toughness [1].

E. M. Soliman, M. P. Sheyka, M. R. Taha (2012) used the MWCNT on carbon fiber composite laminates and applied low-velocity impact tests. They utilized MWCNT containing 0.5 wt%, 1.0 wt% and 1.5 wt% epoxies, and conducted tests with 15, 24, 30, 60, 120 J energies. Loading, strain, speed and energy measurements were made depending on the time. They concluded that MWCNT increased the impact strength and limited the impact damage. Additionally, there was a 50% increase in the energy absorption of the nanotube-added laminates [2].

V. Kostopoulos, A. Baltopoulos, P. Karapappas et al. (2010) used the MWCNT containing 0.5 wt% epoxy; Carbon Fiber Reinforced Polymer (CFRP) matrix composite. They examined during-the-impact and after-the-impact properties of the plate. After a comparison between the MWCNT-added plates and no MWCNT-added plates, they concluded that the impact strength properties improved, high energy was absorbed, the isostatic pressure strength and the compressive strength increased. In addition, the fatigue strength of the material increased [3].

M. M. Rahman, S. Zainuddin, M. V. Hosur et al. (2012) utilized a functionalized MWCNT added epoxy matrix containing glass fiber at rates of 0.1 – 0.2 – 0.3 – 0.4 wt%, and conducted tests to research the material of optimum mechanical and thermo-mechanical characteristics on the composite plates that they produced using hand layup, then hot-press. In the fracture and Dynamic Mechanical Analysis (DMA) tests that they conducted, it was determined that the most appropriate added rate was 0.3 wt%; in addition, 37% - 21% - 21% increases were observed for the yield strength, the elasticity module and the strain, respectively [4]. K. L. Kepple, G. P. Sanborn, P. A. Lacasse et al. (2008) studied the fracture toughness of carbon fibers after the addition of CNT. In the tests that they conducted on the CFRP matrix composites in accordance with the ASTM D 5528 standards, it was observed that the fracture toughness increased by 50%; and in the three point bending tests, the bending strength increased approx. by 5%.
P. N. B. Reis, J. A. M. Ferreira, Z. Y. Zhang et al. (2012) examined the relation between the low-velocity impact and the impact damage by adding nanoclay at 1.5 wt%, 3 wt% and 6 wt% ratios of the epoxy weight to the epoxy matrix kevlar fiber composite plates. Even though the best result was obtained at 6%, the best improvement was obtained, as the weight percentage increased from 1.5 to 3. It was noted that a 1.15% improvement was seen from 3% to 6%, whereas a 32.22% improvement was noted from 1.5% to 3% [6]. K. Iqbal, S. U. Khan, A. Munir and J. Kim (2009) added nanoclay into the resins of the matrix composites to determine the impact-damage relation, and to conduct the low-velocity impact and the CAI tests. They added nanoclay at 1.5%, 3% and 5% of the resin weight into the samples that they prepared for the tests, then carried on with the tests. The best result was obtained from the samples, to which 3% nanoclay was added [7].

II. EXPERIMENTAL

The low-velocity impact tests were conducted in a test device specifically manufactured for the task. Experiments at various energy levels or at various impacts speeds can be realized in the test device seen in Figure 1 and the impact value can be recorded and evaluated during said experiments.

As NC, the montmorillonite-based Eczacıbaşı’s EsanNano 1-140 coded clay was used. Montmorillonite is a clay type that is formed with the combination of laminates in very soft crystal forms. This clay has a white and pure structure, and enables improvements in regards to the incombustibility, strength, moisture and gas permeability of the material that it is introduced into. As can be seen from Figure 3., the initial interlaminar distance values of the montmorillonite clay, which is the property of nanoclay, are approx. 15 Å, but when the same nanoclay is organically modified, the obtained value can attain ranges between 38-40 Å. Montmorillonite is purified and organically modified in the manufacture of EsanNANO 1-140. This modification enables the clay to be homogeneously distributed in the matrix material [12].

The properties of the MWCNT, which the corporate Timesnano manufactured and is used in the study, are given in Table 2 [11].

![Figure 2.a) TEM image, b) SEM image of the MWCNT](image1)

![Figure 3. a) Montmorillonite Structure b) After Organic Modification of Montmorillonite Structure](image2)
Nanoclay chemical properties and grain size are given in Table 3. and Table 4.

### Table 3. The Chemical Properties of Nanoclay [12]

<table>
<thead>
<tr>
<th></th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Al}_2\text{O}_3 )</td>
<td>6 ± 1</td>
<td>CaO</td>
</tr>
<tr>
<td>( \text{SiO}_3 )</td>
<td>44 ± 1</td>
<td>MgO</td>
</tr>
<tr>
<td>( \text{Na}_2\text{O} )</td>
<td>0.6 ± 0.2</td>
<td>( \text{TiO}_2 )</td>
</tr>
<tr>
<td>( \text{Fe}_2\text{O}_3 )</td>
<td>0.4 ± 0.2</td>
<td>( \text{LOI} )</td>
</tr>
<tr>
<td>( \text{K}_2\text{O} )</td>
<td>0.3 ± 0.1</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4. EsanNANO Clay Grain Size Analysis[12]

<table>
<thead>
<tr>
<th>( \mu \text{m} )</th>
<th>%</th>
<th>( \mu \text{m} )</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 0.5</td>
<td>2.27</td>
<td>2.7 – 5</td>
<td>32.25</td>
</tr>
<tr>
<td>0.5 – 1</td>
<td>8.66</td>
<td>5 – 7.5</td>
<td>12.6</td>
</tr>
<tr>
<td>1 – 2</td>
<td>23.8</td>
<td>7.5 – 10</td>
<td>3.94</td>
</tr>
<tr>
<td>2 – 2.7</td>
<td>15.84</td>
<td>10 – 15</td>
<td>0.64</td>
</tr>
</tbody>
</table>

### III. RESULT AND DISCUSSION

The impact was initiated as the pin touched the sample; thereby the dent, or the strain was initiated as well, and this continued until the force reached its maximum value.

Nanoclay increases the toughness of the resin and makes it more rigid, conclusively the damage was not as impactful on the back side as it was on the front side. According to the 1% NC reinforced samples, a 4% increase was observed in the samples reinforced by 3%, and in the samples reinforced by 5%, a 41% increase was observed. Nanoclay made the resin in the composite plate more rigid, thus caused it to be more responsive to the incoming loads.

![Figure 4. Low-velocity impact test force and time graph](image)

Measured energy time graphics are shown in Figure 5. As the impact energy increases, the impulse value and the absorbed energy are expected to increase as well.

![Figure 5. Low-velocity Impact Test Energy-time graph](image)

The impact energies, and the energy levels absorbed from these impact energies by the samples are shown in Figure 6.

![Figure 6. Low-velocity Impact Test Bounce and Absorbed Energy Graph](image)

As can be clearly seen from Figure 7., the damage that the sample takes decreases, as the nanoclay ratio increases. Nanoclay increases the toughness of the resin and makes it more rigid, which is why the damage is less impactful on the back side.

![Back side of the a) CNT0,3NC1 b) CNT0,3NC3 c) CNT0,3NC5 25J samples](image)
REFERENCES


