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Fabrication and Evaluation of Mechanical Properties of CF/GNP Composites

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Abstract

CNT/CFRP (Carbon Nanotube/ Carbon Fiber Reinforced Plastic) composites and GNP/CFRP (Graphene Nano platelet/ Carbon Fiber Reinforced Plastic) have several excellent mechanical properties including, high strength, young's modulus, thermal conductivity, corrosion resistance, electronic shielding and so on. In this study, CNT/CFRP composites were manufactured by varying the CNT weight ratio as 2wt% and 3wt%, While GNP/CFRP composites were manufactured by varying the GNP weight ratio as 0.5wt% and 1wt%. The composites ware manufactured by mechanical method (3-roll-mill). Tensile, impact and wear tests were performed according to ASTM standards D638, D256 and D3181 respectively. It was observed that, increasing the CNT weight ratio improves the mechanical properties, e.g., tensile strength, impact and wear resistance.

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Keywords: *CNT, GNT, CFRP, Composites, 3-roll-mill, Wear*

1. Introduction

Carbon nanotube are increasingly attracting scientific and industrial attention by virtue of their outstan -ding characteristics. The CNT and GNT walls resemble rolled up graphite like sheets with strong covalent sp2 bonds. According to their graphitic structure, CNTs and GNTs possess high thermal conductivity and an electrical

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conductivity that can be either semi-conducting or metal like. The Young's modulus of carbon nanotubes can be as high as 1000GPa and 1100Gpa. Which is approximately five times higher than steel. The tensile strength of carbon nanotubes can be up to 150GPa and 200GPa, around 40 times higher than steel [1-5].

The combination of the previously mentioned material properties together with an aspect ratio in the range of several thousand makes CNTs promising candidates as reinforcement for polymer composites. In addition, the development of CNT/polymer Nano composites opens new perspectives for multi-functional materials. Research results on the effect of CNTs on the wear properties of several polymers have been reported. It was found that CNT-based Nano composites exhibit a better wear resistance compared with the pure matrix [6-8].

All studies reported a beneficial effect of CNT reinforcement on the wear resistance of the polymers. Due to excellent properties of CNT, this composites is used in aerospace application and energy material. And this composites is spotlighted as the aircraft or racing car brake disk material because indicate to large absorb energy and stable braking. If these mechanical parts used for long time, noise occurs and performance will be degraded.

In general, wear resistance should be excellent in order to use as friction material. Thus, research about wear property is important. To date, wear and frictional heat of the actual aircraft brake disc the main reason was found to be due to oxidation of carbon. But the wear by the friction of pure occurred also. Therefore we should complement the causes of wear.

In this study, Wear tests were performed after manufacturing composites. The aim of this study would be to apply in actual mechanical parts.

2. Experimental

2.1. Materials

The CNT were obtained from Hanwha Nanotech., Korea. The properties of the CNT were: purity > 95%, average diameter 10 – 15 nm, average length 10 – 20 μm and surface area 225m2/g. The GNT were obtained from Angstrom Materials, USA. The properties of the GNT were: purity > 95%, average diameter 0.1 – 0.3 nm, average length 0.1 – 0.2 μm and surface area 470m2/g. Plain weave carbon fabrics and epoxy resin were obtained from Mitsubishi TR30, 3k and Borden Chemical, Inc., USA. CNT, GNT and plain weave carbon fabrics were used as the Nano and micron sized reinforcements, respectively, for the composites. To study the mechanical and wear properties, epoxy resin was used to be the matrix material of composites.

2.2. 3-Roll mill method

A 3 roll mill is a machine that uses shear force created by three horizontally positioned rolls rotating in opposite directions and different speeds relative to each other, in order to mix, refine, disperse or homogenize viscous materials fed into it. 3 roll mill machine is shown in Fig. 1, the three adjacent rolls are called the feed roll, center roll and apron roll, respectively.

The material to be milled is placed between the feed and center rolls. Each adjacent roll rotates as progressively higher speeds. Material is transferred from the center roll to the apron roll by adhesion. Due to the dispersing effect, resulting from the high shear stresses generated in the gap between the rolls, stress intensity can be increased by reducing the width of the gap between the rollers and by increasing the rotational speed of the rollers and the mass concentration of the suspension. In this study, the rotational speed is fixed, however, one gap width between the feed and center rolls is set as 45, 30, 15, 5 and 0μm, while the other gap is set as 15, 10, 5, 0 and 0 μm.

2.3. Film casting and B-stage process

The hopper should be set in a proper position, so that the mixture of CNT/epoxy resin and GNT/epoxy resin should not flow out from either side. Then, the gap between the rollers was set up. After putting the mixture into the hopper, the machine was run with a speed of 0.5m/min. Finally, the casted film was obtained. Small pieces resin films having a size of 200mm × 200mm were prepared for B-stage. Fourteen pieces of resin films were put into the oven. The B-stage condition for temperature and time are 80℃ and 9.5 min, respectively.

2.4. Hot pressing

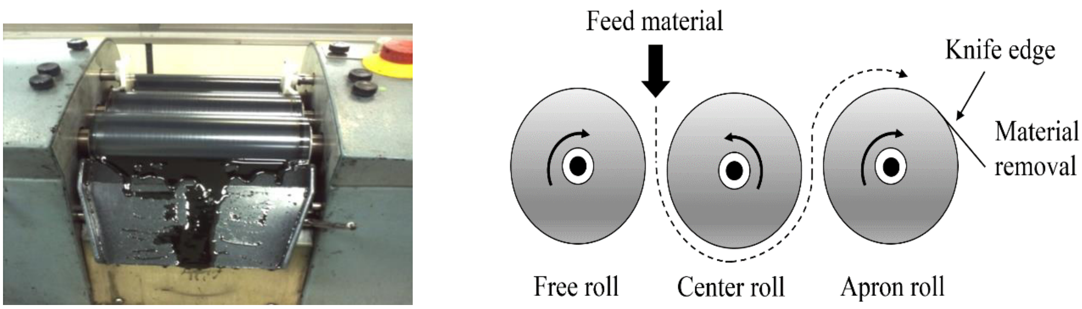
Films and carbon fabrics were piled up alternately, and two layers of the films were placed at both sides of the whole thickness. One convex die was used as the top mold, and the other concave die was used as the bottom mold. After cleaned by ethanol, the surfaces of molds were sprayed with the releasing agent. Then, the molds were packaged by using Teflon cloth.

The piled carbon fabrics and films were placed in the packaged bottom mold. Both open sides of the mold were blocked by the soft compound board. The top mold covered the bottom mold and fixed with two pins. Before the hot pressing, the molding was vacuum packaged with double vacuum bag as shown in Fig. 2 (a). The molding was placed in the hot press as shown in Fig 2 (b). The hot pressing conditions are as follows; Temperature of hot pressing is 80~120℃, pressure is 0.5~10ton and time is 4hr.

2.5. Test methods

Mechanical tests: Tensile and impact tests were performed according to ASTM standards D638 and D256 respectively. The study of the tensile behaviour was performed by UTM and impact behaviour was performed by izod impact tester. Cross head speed of tensile test was 3mm/min. And conditions of izod impact test were load capacity: 22J, impact speed: 3.5m/sec.

Wear test: The study of the wear behaviour was performed by UFW200 according to ASTM standards D3181. Conditions of wear test were; load: 10, 20 and 30N, RPM: 300, track radius: 10mm and test time: 1,800s.



(a) (b)

Fig. 1. (a) Equipment and (b) Working mechanism of 3 rolls mill

(a) (b)

Fig. 2. The process of sample prepared by hot press: (a) vacuum packaged and (b) curing in hot press

3. Results and Discussion

3.1. Composites manufacturing

Manufacturing of CNT/CFRP and GNT/CFRP composites was completed by this sequence, ① 3 roll mill, ② film casting, ③ oven and ④ hot press. CNT volume ratios of composites were 2wt% and 3wt%. GNT volume ratios of composites were 0.5wt% and 1wt%. All manufacturing conditions of composites were same except CNT volume ratios. Tensile, impact and wear test specimens were fabricated. Then, mechanical properties of composites were evaluated according to tensile, impact test.

3.2. Mechanical tests

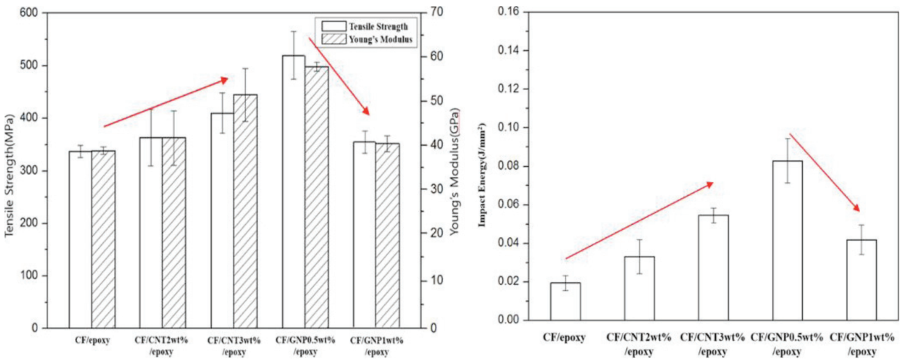
Results of tensile and impact test are shown in Fig. 3. The results revealed that, at higher CNT volume ratios, the tensile strength and young's modulus were increased. Tensile strength of CNT 2wt% and CNT 3wt% composites is 360MPa and 415MPa respectively, and Young's modulus of CNT 2wt% and CNT 3wt% composites is 40GPa and 52GPa respectively. Thus tensile strength and young's modulus were increased by 15% after CNT reinforcement. Impact energy of CNT 2wt% and CNT 3wt% composites is 0.0348J/mm2 and 0.0538 J/mm2 respectively. Impact energy also increased of 5% according to the CNT volume ratio increase. Tensile strength, impact energy and young's modulus were found to increase.

Looking at the tensile test, at lower GNT volume ratios, the tensile strength and young's modulus are increased. Tensile strength of GNT 0.5wt% and GNT 1wt% composites is 538MPa and 365MPa respectively, and Young's modulus of GNT 0.5wt% and GNT 1wt% composites is 58GPa and 40GPa respectively. Thus tensile strength and young's modulus were decreased by 30% after GNT reinforcement. Impact energy of GNT 0.5wt% and GNT 1wt% composites is 0.0828J/mm2 and 0.0413 J/mm2 respectively. Impact energy also decreased of 50% according to the CNT volume ratio increase. Tensile strength, impact energy and young's modulus were found to decrease.

3.3. Wear test

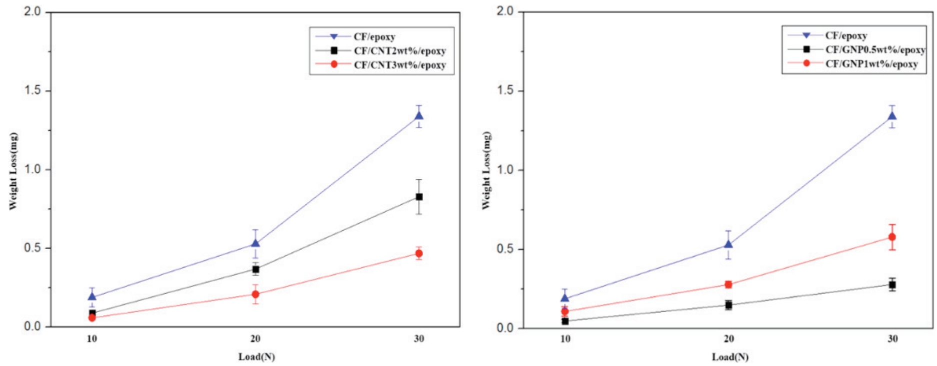
Results of wear test are shown in Fig. 4. After increasing CNT volume ratio, the weight loss is decreased. Through this result, effect of CNT on wear property found are positive. At higher loads, the weight loss of CNT 2wt% and CNT 3wt% composites increased. After decreasing GNT volume ratio, the weight loss is decreased. Through this result, effect of CNT on wear property found are positive. At higher loads, the weight loss of GNT 0.5wt% and GNT 1wt% composites increased. Through this result, effect of GNT on wear property is better.

Fig. 5 shows friction coefficient test result and Fig. 6 shows SEM images of wear test specimens. In SEM images, composites with smaller content of GNT have more wear depth. And higher wt% caused, more wear depth. Because, wear resistance increased after increase in the content of GNT. Initial wear caused abrasive wear. And adhesive wear occurred mainly because of the occurrence of frictional heat over time.



(a) (b)

Fig. 3. Results of (a) tensile test and (b) izod impact test



(a) (b)

Fig. 4. Result of wear test, (a) CF/CNT/epoxy composites, (b) CF/GNT/epoxy composites

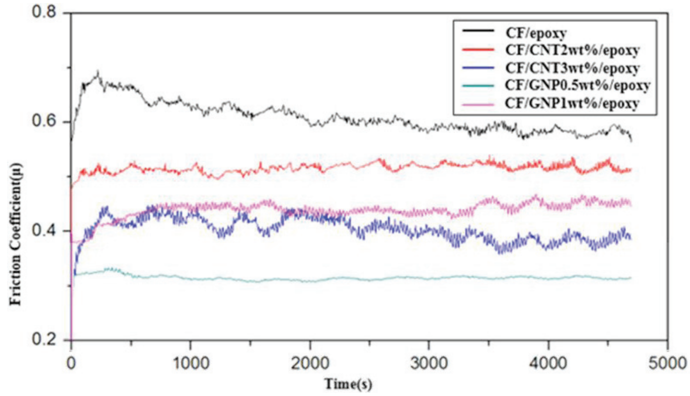
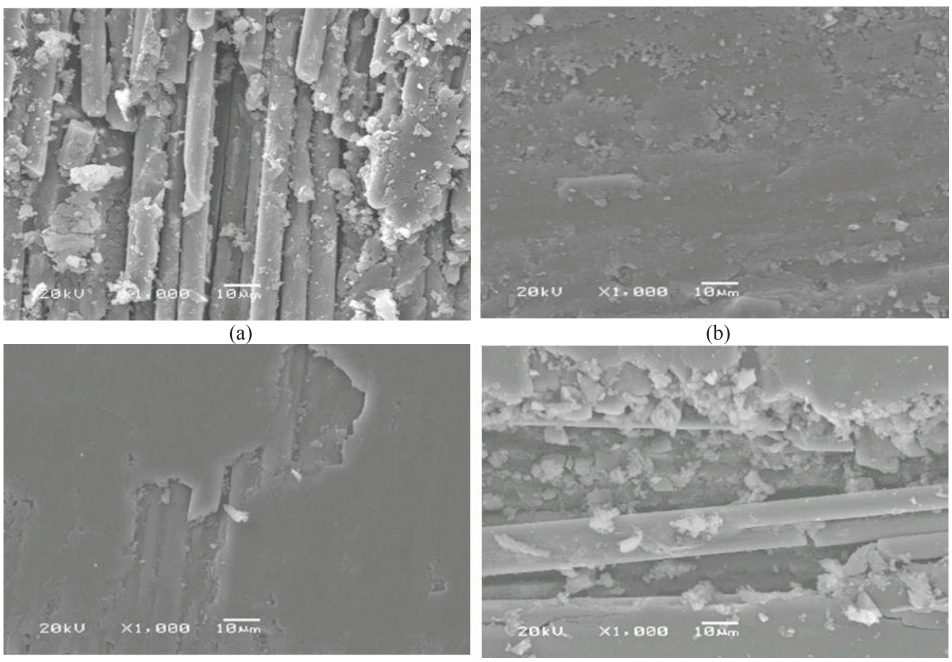


Fig. 5. Result of wear test: friction coefficient



(a) (b) (c) (d)

Fig. 6. SEM images of results of wear test, (a) CF/CNT2wt%/epoxy, (b) CF/CNT3wt%/epoxy, (c) CF/GNT0.5wt%/epoxy and (d) CF/GNT1wt%/epoxy

4. Conclusion

In this study, CNT and GNT reinforced CFRP composites were manufactured and mechanical properties (tensile strength, impact energy) and wear resistance were evaluated.

(1) Manufacturing CNT and GNT reinforced CFRP composites: CNT and GNT film of fourteen sheets were prepared using the method of 3 roll mill. Then, CNT and GNT film of fourteen sheets were laminated to twelve sheets of carbon fabric. Finally composites were manufactured using the hot press.

(2) Mechanical properties of CNT reinforced CFRP composites: tensile strength, young's modulus and impact energy of CNT volume ratio of 3wt% increase of 15% more than CNT volume ratio of 2wt%. Reason to increase of Tensile strength, young's modulus and impact energy is that the more volume ratio of CNT then specific properties of CNT to be improved further.

(3) Mechanical properties of GNT reinforced CFRP composites: tensile strength, young's modulus and impact energy of GNT volume ratio of 0.5wt% increase of 30% more than GNT volume ratio of 1wt%. Reason to increase of Tensile strength, young's modulus and impact energy is that the more volume ratio of GNT then specific properties of GNT to be improved further.

(4) Wear properties of GNT reinforced CFRP composites: wear resistance with GNT volume ratio of 0.5wt% increase of 25% more than GNT volume ratio of 1wt%. And the increase in application load increased the weight loss of GNT volume ratio of 0.5wt% and 1wt% composites. Through this result, effect of GNT about wear property is better at higher loads. Through the SEM images, Initial wear test can be seen as abrasive wear. And adhesive wear occurred mainly because the occurrence of frictional heat over time.

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References

[1] M. Meyyappan, CRC Press, Boca Raton, FL, 2005.
[2] Ph. Werner, V. Altsta dt, O. Jacobs, R. Jaskulka, K.W. Sandler, S.P. Saffer, A.H. Windle, Tribological behaviour of carbon-nanofiber-reinforced poly(ether ether ketone), Wear 257 (2004) 1006–1014.
[3] B. Dong, Z. Yang, Y. Huang, H.L. Li, Study on tribological properties of multi-walled carbon nanotubes/epoxy resin nano composite, Tribol. Lett. 20 (2005) 251–254.
[4] Y. Xue, W. Wei, O. Jacobs, B. Scha¨ del, Tribological behaviour of UHMWPE/HDPE blends reinforced with multi-wall carbon nanotubes, Polym. Test. 25 (2006) 221–229.
[5] L. Chang, Z. Zhang, C. Breidt, K. Friedric, Tribological properties of epoxy nano composites I. Enhancement of the wear resistance by nano-TiO2 particles, Wear 258 (2005) 141.
[6] Haiyan Chen, olaf Jacobs, Wei Wu, Gerrit Rudiger, Birgit Schadel, "Effect of dispersion method on tribological properties of carbon nanotube reinforced epoxy resin composites", Polymer Testing, Vol. 26, (2007) pp. 351-360
[7] Brian B. Johnson, Michael H. Santare, John E. Novotny, Suresh G. Advani, "Wear behavior of Carbon Nanotube/High Density Polyethylene composites" Mechanics of Materials, Vol. 41,(2009) pp. 1108-1115
[8] H. Meng, G. X. Sui, G. Y. Xie, R. Yang "Friction and wear behavior of carbon nanotubes reinforced polyamide 6 composites under dry sliding and water lubricated condition" Composites Science and Technology, Vol. 69, (2009) pp. 606-611