

# UV/OZONE TREATED MULTI-WALLED CARBON NANOTUBES REINFORCED POLYETHYLENE COMPOSITE FIBRE BY MELT SPINNING

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## Introduction

The superior characteristics associated with their inherently good mechanical and electrical properties makes CNTs exceptionally interesting for the production of such chemical fibres [1,2]. There were variances of the main melt spinning process parameters (process temperature, distance from nozzle to a winder, winder revolution and nozzle's diameter) from literatures [3,4]. However, there have been few attempts to study the influence of melt spinning process parameters on the mechanical strength of CNTs polymer fibres by design of experiment such as robust design. Therefore, a self constructed melt spinning system was fabricated based on the commercialized melt spinning system to find optimize condition for mechanical strength enhancement of fabricated fibres composite [5]. The robust design had been used by researchers in various fields to eliminate the try and error experiment, and hence optimized experiment parameters for achieved the objectives with detail analysis of experiment control factors and noise [6]. The production of fibres makes the control of the orientation and/or alignment of nanoscaled fillers at a macroscopic level more practical than ever. Most of the researchers used as produced of SWCNTs [7,8], and MWCNTs [9] for fabrication of CNTs polymer fibres via melt spinning. Only, Hanggenmueller et al. [10] and Chen et al. [11] used CNTs reacted with sodium stannate ( $H_2O_2$ ), and concentrated acids, respectively. UV treatment is photosensitized dry oxidation process, where it also capable for introducing carboxylic functional groups on CNTs [12], similar to the common wet oxidation process (reaction with concentrated acids) [13].

## Experimental

### Materials

The polymer matrix is polyethylene (PE), purchased from Sigma Aldrich. It has 0.906 g/mL density, and 35,000 molecular weight (Mw). The reinforcement filler is Multi-walled carbon nanotubes (MWCNTs), purchased from ILJIN Nanotech (South Korea), and has 5~10 nm diameter, 10~20  $\mu$ m length and 95 %

purity. In this study, as produced MWCNTs were mechanically cut by a high speed stirrer and followed by sonication with a horn type ultra sonicator [13]. Mechanically cut MWCNTs were exposed to the ultraviolet radiation for 60 minutes at 38 mW/cm<sup>2</sup> of radiation intensity. 0.5 wt% of UV treated CNTs powder were added to the PE powder, and mixed manually by a spatula for 5 minutes. Then, the CNTs were mixed with PE powder by mechanical shear mixing using ball milling machine at 600 rpm for 2 hours. It was melted at 150°C for an hour, soon after.

## Results and Discussion

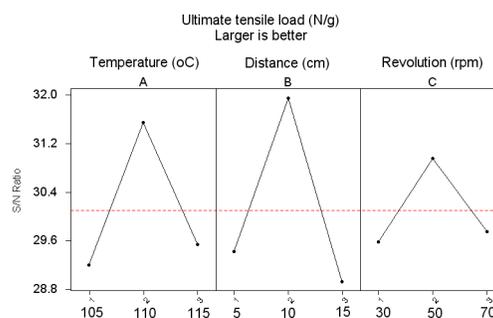


Fig. 1 Robust design analysis of ultimate tensile load of 0.5 wt% UV treated MWCNTs PE fibres.

The robust design analysis of these result based on large-the-better calculation is plotted as Signal to Noise ratio (S/N ratio) in Fig. 1. It can be calculated from S/N ratio of fig.3 that the optimized parameter of melt spinning in this study are 110 °C of process temperature, 10 cm of distance from nozzle to winder, and 50 rpm of winder revolution in order to obtain the highest ultimate tensile load, by given the highest S/N ratio and hence peaks. The robust design analysis also reveals that the distance gives the highest influence to enhance mechanical strength in this study, followed b the temperature and revolution. Fig. 2 shows that the ultimate tensile load of pure PE bulk composite is increased up to 41 % after applied mechanical drawing through melt spinning. This indicates that mechanical drawing by melt spinning is

improved/influenced by the crystallization of PE polymer, resulting in enhancement of the mechanical strength of bulk pure PE polymer. The ultimate tensile load of pure PE fibers are increased up to 69 % after reinforced with UV treated MWCNTs and form as fibers through melt spinning. The aligned CNTs in fibers polymer matrix, which are assumed to be induced by mechanical drawing through melt spinning, yield a significantly higher mechanical strength than randomly oriented CNTs bulk polymer composites fabricated from hot pressed of the molten CNTs PE suspension. The ultimate tensile load of UV treated CNTs PE Fibers composites is increased up to 93% compare to UV treated CNTs PE bulk composite.

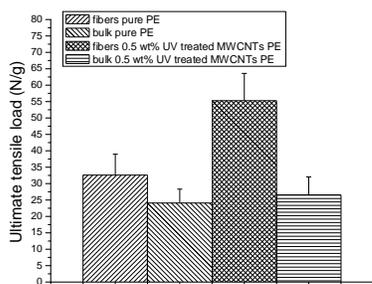


Fig. 2 Ultimate tensile load of pure PE and 0.5 wt% UV treated CNTs PE composite fabricated at optimized melt spinning's parameters in bulk and fibre polymer composites.

## Conclusion

CNTs polymer fibres composite were fabricated by the self constructed melt spinning system, and its process parameter was optimized (temperature, distance from nozzle to winder, and winder revolution – control factors) by the robust design for enhancement of the mechanical strength of pure polymer fibres. The mechanical strength of fibres (objective function) was measured by tensile test. The results were analyzed in form of signal to noise (S/N) ratios and interaction between control factors also had been performed. In this study, distance from nozzle to winder gave the highest sensitivity to the objective function, followed by process temperature and winder revolution. Moreover, verification results through experiment gave close value to the predicted value from the robust design model. Therefore, it can be deduced that the robust design model developed from this study is efficient and relevant to use for design of experiment. Comparison of mechanical strength was conducted with randomly oriented bulk polymer composites. It has been found that the addition of CNTs significantly increase the mechanical strength of pure polymer. Addition of CNTs in polymer matrix contributes to the acceleration of the nucleation and crystal growth mechanism of polymer. Then, higher

thermal conductivity of the CNTs as compared to that of the polymer is responsible for increasing of polymer crystallization, as heat will be more evenly distributed in the specimen containing the CNTs.

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