SYNTHESIS AND PROPERTIES OF PHENOLIC BASED HYBRID CARBON NANOTUBE/INORGANIC FILLED COMPOSITES

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by

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LIST OF ABREVIATIONS

Al_2O_3	Alumina
ANOVA	Analysis of variance
ASTM	American Society for Testing Materials
BBD	Box-Behnken Design
C	Carbon
$CaCO_3$	Calcium carbonate
$CaMg(Ca3)_2$	Calcium magnesium carbonate
CF	Carbon Fiber
CH_4	Methane
CNTs	Carbon nanotubes
COF	Coefficient of friction
CVD	Chemical vapour deposition
DOE	Design of experiment
DWCNTs	Double walled carbon nanotubes
EDX	Energy dispersive X-ray
FESEM	Field emission scanning electron microscopy
GNP	Graphene nanoplatelets
H	Hydrogen
HRTEM	High resolution transmission electron microscopy
MgO	Magnesium oxide
MWCNTs	Multi walled carbon nanotubes
Ni	Nickel
$NiAl_2O$	Nickel aluminate

O_2	Oxygen
PMC	Polymer matrix composites
POD	Pin-On-Disk
PP	Polypropylene
RBMs	Radial breathing modes
RSM	Response surface methodology
SEM	Scanning electron microscopy
SiC	Silicon carbide
TEM	Transmission electron microscopy
TPS	Transient plane source
XRD	X-ray Diffraction

LIST OF SYMBOLS

%	Percentage
<	Less than
>	More than
°	Degree
°C	Degree Celsius
°C/min	Degree Celsius per minute
F	Force
g	Gram
H	Hour
L	Litre
m	Meter
min	Minute
mm	Millimetre
nm	Nanometer
m/s	Meter per second
μm	Micrometer
rpm	Revoltution per minute
V	Wear volume loss
wt %	Weight percent
w	Normal load
W/mK	Watts per meter kelvin
μ	Coefficient of friction

SINTESIS DAN SIFAT-SIFAT KOMPOSIT BERASASKAN FENOLIK TERISI HIBRID TIUB NANO KARBON/BUKAN ORGANIK

ABSTRAK

Penggunaan pengisi tunggal dalam komposit polimer tidak selalu memenuhi syarat-syarat permintaan untuk aplikasi polimer komposit termaju. Oleh itu, adalah perlu untuk menghasilkan pengisi hibrid yang mengandungi lebih daripada satu pengisi. Kebelakangan ini, tiub nano karbon (CNTs) dihibridkan dengan pengisi yang lain untuk mencapai kesan gabungan pengisi. Gabungan pengisi-pengisi tersebut (hibrid pengisi) harus mempunyai interaksi fizikal dan kimia yang kuat antara satu sama lain untuk mencapai kesan penguatan yang optimum. Kajian ini mencadangkan kaedah pemendapan wap kimia (CVD) untuk menghasilkan hibrid CNTs dengan pengisi bukan organik dan CNTs hybrid yang disintesiskan, akan digunakan sebagai pengisi dalam komposit fenolik. Bahagian pertama kajian adalah penyiasatan mengenai hibrid CNTs/alumina dan parameter pemprosesannya seperti suhu dan tempoh pengkalsinan. Kajian perbandingan di antara CNTs hibrid menggunakan kaedah CVD dan kaedah fizikal (konvensional) ke atas sifat-sifat komposit fenolik turut dikaji. Komposit fenolik telah difabrikasikan dengan menggunakan kaedah cagak panas. Sifat tribological telah dikaji dengan menggunakan penguji pin-atas-cakra di bawah keadaan gelongsor yang berbeza. Hasil kajian menunjukkan bahawa tempoh pengkalsinan selama 10 jam pada suhu 900^{o}C adalah parameter yang terbaik untuk menumbuhkan hibrid CNTs. Hasil kajian juga mendedahkan bahawa hibrid CNTs menggunakan cara CVD telah meningkatkan kekerasan, kekonduksian terma dan sifat–sifat tribologikal komposit fenolik hibrid. Dalam bahagian kedua kajian, model empirikal dengan pembolehubah bebas yang berbeza bagi kelakuan tribologikal

untuk CNTs/alumina terisi komposit fenolik telah dibangunkan menggunakan pendekatan metodologi permukaan respon (RSM). Pengoptimuman fungsi pemboleh ubah bebas juga telah dijana. Ia menunjukkan bahawa 5HYB/FENOLIK menunjukkan prestasi kehausan yang lebih baik berbanding komposit 5PHY/FENOLIK. Dalam bahagian ketiga, kesesuaian kalsium karbonat, talkum dan dolomit untuk pertumbuhan CNTs dalam penghasilan sebatian hibrid CNTs/bukan organic menggunakan kaedah CVD telah dikaji. Hasil kajian menunjukkan bahawa CNTs tumbuh di atas partikel kalsium karbonat, talkum dan dolomit, yang mana menunjukkan bahawa mereka juga sesuai untuk menjadi bahan sokongan dalam penghasilan hibrid CNTs (pertumbuhan menggunakan pemangkin logam nikel dan metana sebagai stok suapan karbon pada suhu 800^{o}C). Hasilnya juga mendedahkan bahawa hibrid CNTs/bukan organik meningkatkan kekerasan dan sifat terma komposit fenolik.

SYNTHESIS AND PROPERTIES OF PHENOLIC BASED HYBRID CARBON NANOTUBE/INORGANIC FILLED COMPOSITES

ABSTRACT

The use of a single filler in polymer composites does not always meet the on-demand requirements of an advanced polymer composite application. Therefore, producing a hybrid filler that contains more than one filler is necessary. Recently carbon nanotubes (CNTs) were hybridized with others fillers to achieve the combined effects of the filler. The combinations of the filler (hybrid filler) should have a strong physical and chemical interaction with each other in order to achieve the optimum reinforcing effect. This study proposed the chemical vapour deposition (CVD) method to produce a CNTs hybrid with inorganic fillers and this synthesised CNTs hybrid, was used as filler in phenolic composites. The first part of the research was the investigation of the CNTs/alumina hybrid and its processing parameter such as calcinations temperatures and duration. The comparative study of hybrid CNTs using the CVD method and the physical method (conventional) on the properties of the phenolic composite were also studied. The phenolic composites were fabricated via hot mounting process. The tribological properties were investigated using a pin-on-disk tester under different sliding conditions. The results showed that 10 hours duration of calcination and 900^{o}C were the best parameters to growth the CNTs hybrid. The result also revealed that hybridising the CNTs via CVD improves the hardness, thermal conductivity and tribological properties of the phenolic hybrid composite. In the second part of the research, empirical models with different independent variables for the tribological behaviour of CNTs/alumina filled phenolic composites were developed using the response surface methodology (RSM)

approach. The optimisation of the response as a function of the independent variable was generated. It shows that 5HYB/PHENOLIC exhibited better wear performance than 5PHY/PHENOLIC composites.In the third part, the suitability of calcium carbonate, talc and dolomite to growth the CNTs in the production of CNTs/inorganic hybrid compounds using the CVD method was investigated. The results showed that the CNTs growth on the calcium carbonate, talc and dolomite particles, which means they are also suitable as a support material in CNTs hybrids (growth using a nickel metal catalyst and methane as the carbon feedstock at 800^{o}C). The result also revealed that the CNTs/inorganic hybrid improved the hardness and thermal properties of the phenolic composites.