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ScienceDirect

Procedia Manufacturing 21 (2018) 623–629

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

15th Global Conference on Sustainable Manufacturing

Carbon nanotube grease and sustainable manufacturing

Haiping Hong*, Greg Christensen, and Christian Widener

Arbegast Material Processing and Joining Laboratory, South Dakota School of Mines and Technology, 501 E Saint Joseph Street, RapidCity, SD 57702, USA

Abstract

A stable and homogeneous grease based on carbon nanotubes (CNTs, single wall and multi wall) in polyalphaolefin oil has been produced without using a chemical surfactant. For example, for a 11 wt% (7 vol%) single wall CNT (diameter 1~2 nm, length 0.5-40 μm) loading, the thermal conductivity (TC) of the grease shows a 60-70% increase compared to that for no nanotube loading. In addition, the grease is electrically conductive, has a high dropping point, good temperature resistance and doesn't react with copper at temperatures up to 177ºC. The performance of carbon nanotube grease could be much better with the improvement of base oil, nanotube functionality, quality and purity. A possible explanation for these results is that for a high loading of CNTs (>10wt%), they become associated with each other by van der Waals forces in the grease to form three dimensional percolation networks. These greases could be sustainably manufactured.

Peer-review under responsibility of the scientific committee of the 15th Global Conference on Sustainable Manufacturing (GCSM).

Keywords: Grease, Carbon nanotube, Manufacture, Sustainable

Nomenclature

C	Volume of
ρ	Density of
K	Thermal conductivity of
Ψ	Ratio of the surface area of a sphere

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: haiping.hong@sdsmt.edu

2351-9789
Peer-review under responsibility of the scientific committee of the 15th Global Conference on Sustainable Manufacturing (GCSM).
10.1016/j.promfg.2018.02.164

1. Introduction

The discovery of carbon nanotubes has instigated considerable research efforts in recent years, due to their promising thermal, electrical, mechanical, and functional properties. For example, single-wall carbon nanotubes (SWNTs) exhibit thermal conductivity as high as 2000–6000 W/mK under ideal circumstances [1]. In theory, metallic nanotubes can have an electrical current density more than 1,000 times greater than metals such as silver and copper [3]. Carbon nanotubes remain stable for temperatures estimated to be up to 2800 ºC in vacuum and 750 ºC in air.

By contrast, typical oils, such as polyalphaolefin and polyol ester, have thermal conductivity values of around 0.16-0.18 W/mK and are electrically nonconductive. The currently used commercial greases (for example, lithium, calcium, aluminum, silica and polyurea) are all insulating and have low thermal conductivities (equivalent to their base oils). There is a great need to increase the thermal and electrical conductivities of greases for wide range applications.

Although nanotubes have superior thermal and electrical properties, the relatively high price of nanotubes inhibits efforts to pursue projects in which large quantities of nanotubes are needed. Recently, Xie et al [3] discovered a method to synthesize a high yield of single wall carbon nanotubes using CH_4 where the presence of a small amount of water vapor prohibited the generation of amorphous carbon and multi wall carbon nanotubes on the surface of the catalysts and promoted the generation of single wall carbon nanotubes. This discovery makes it possible to produce nanotubes at a much lower cost because CH_4 is a main component of natural gas and its price is very low. Therefore, developing carbon nanotube greases that contains at least 10 wt% nanotubes becomes viable. Very recently, a US based high tech corporation SouthWest NanoTechnologies (SWeNT®) has announced that in the near future, they could produce new SWNTs in Ton quantities and, the new SWNTs will be the most conductive material they've ever made.

In this paper, we added carbon nanotubes (single wall and multi wall) into polyalphaolefin oils (DURASYN® 166) to form stable and homogeneous carbon nanotube greases with potential heat transfer, conductive and lubricative applications. Interesting properties such as thermal conductivity, electrical conductivity, dropping point, oil separation, copper corrosion, etc will be characterized. Finally, sustainable manufacture will be evaluated.

2. Materials and Methods

Single-wall carbon nanotubes (SWNTs) and multiwall carbon nanotubes (MWNTs) were purchased from Carbon Nanotechnologies Incorporation (CNI, Houston, Texas, now Unidym Inc). We used the carbon nanotubes as received and with no further purification or functionalization.

Single wall carbon nanotubes are of average diameter 1.4 nm and are found in "ropes" which are typically ~20 nm in diameter or approximately 50 tubes per rope with lengths of 0.5 ~ 40 microns. Thermal conductivity is around 35 W/mK at room-temperature. No electrical conductivity data is available. The sample purity is 70~90 vol%. There are 10~25 vol% carbon black and <5 vol% residual catalyst metal impurities in the samples.

For multi wall carbon nanotubes, diameter is around 20~40 nm, standard length is around 0.5-40 micron. No thermal and electrical conductivity data are available. The sample purity is around 90 vol%. There are <10 vol% carbon black (amorphous carbon) and small amount (<0.5 vol %) catalyst metal impurities in the samples.

DURASYN® 166 is a commercial polyalphaolefin oil product purchased from Chemcentral (Chicago, IL). Sonication was performed using a Branson Digital Sonifier, model 450. A three roll mill (Ross Engineering Inc, New York) was used to incorporate the CNTs to make the stable and well dispersed greases.