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Original Research Paper

Microstructural and tribological properties of nanostructured Al6061-CNT produced by mechanical milling and extrusion

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ABSTRACT

Wear properties of Al6061-CNT nanocomposites have been studied using dry sliding method. Nanostructured Al6061 powder has been prepared using 30 h mechanical milling of atomized powder, and mixed with different percent of CNT. The yielded mixture was subjected to mechanical milling for 0.5 and 4 h. Mixtures were cold compacted, homogenized and extruded to achieve 13 mm diameter round cross section bars. Relative density and hardness of specimens were determined for extruded samples. Maximum relative density was achieved for specimen without CNT which was about 99.848%, while maximum hardness of 236.1 HV was for specimen with 1.25 wt% CNT. Pin on disk method wear test results indicated that weight loss and wear mechanism strongly depends on normal load. At lower normal load, minimum weight loss achieved for Al6061-1.25 wt% CNT nanocomposite at abrasive and delamination mechanisms, while by increasing of normal load, minimum weight loss achieved for specimen without CNT that its wear mechanism was adhesive and delamination.

1. Introduction

Nanocomposites are composed of two or more separate elements, one or more of which have dimensions smaller than 100 nm. These elements consist of a matrix and a reinforcing material. Presence of particles or short and long reinforcing fibers usually contributes to strengthen the matrix and provides uniform distribution of the forces applied to the composite. Because of their high strength-to-weight ratio, various applications are considered for Al matrix composites such as automotive, aerospace, and military industries. Carbon nanotubes (CNT), due to their high length-to-diameter ratio, low weight, desirable mechanical, physical, and thermal properties, thermal stability up to 2700 °C in argon atmosphere as well as the self-lubricating property, are the promising candidates for reinforcing composites [1–3]. Since mechanical and physical properties of CNT are conveyed to the matrix, they are employed to produce ceramic [4], metal [5,6] and polymer [7,8] matrix composites. In addition to the potential of CNT in improving the properties of composites, production of nanostructured matrix enhances the composite efficiency more than coarse-grained matrix composites in terms of thermal stability, hardness, and wear resistance.

In recent years, CNT have attracted great attentions due to their excellent mechanical properties such as tensile strength of ~150 GPa and Young's modulus of ~1.2 TPa [1]. However, because of their severe agglomeration, distribution of CNT in the metal matrix composite by conventional methods is difficult. Also, due to the possibility of chemical reaction between CNT and Al matrix and formation of Al_4C_3, preparation of these nanocomposites through melting methods is problematic. In contrast, Al-CNT nanocomposite powder has been produced by mechanical milling resulting in the quick formation of nanostructured and nanocomposite materials [9].

Al-Qutub et al. investigated the applied load of 1wt.%CNT reinforced Al6061 composite produced by ball milling and spark plasma sintering (SPS) and compared to Al6061 monolithic alloy. Their finding revealed that, the wear rate increased linearly with the applied load. At lower loads of 5–15 N, the composite displayed better wear resistance. At higher loads of 20–30 N, the wear resistance of monolithic alloy was better than the composite. These results show that addition of 1 wt% CNT improves wear resistance of the Al6061 alloy at lower loads only [10]. Abdullahi et al. [11] investigated the wear behavior of Al-CNT nanocomposite prepared by mechanical milling and hot isostatic pressing. Their findings revealed that the wear rate is decreased as the CNT content is

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Table 1
Chemical composition (wt%) of Al6061 powder.

Element	Al	Cu	Mg	Si	Fe	Mn	Na	S	Cr	Zn
Content	Balance	0.39	0.82	0.33	0.50	0.12	0.10	0.023	0.17	0.063

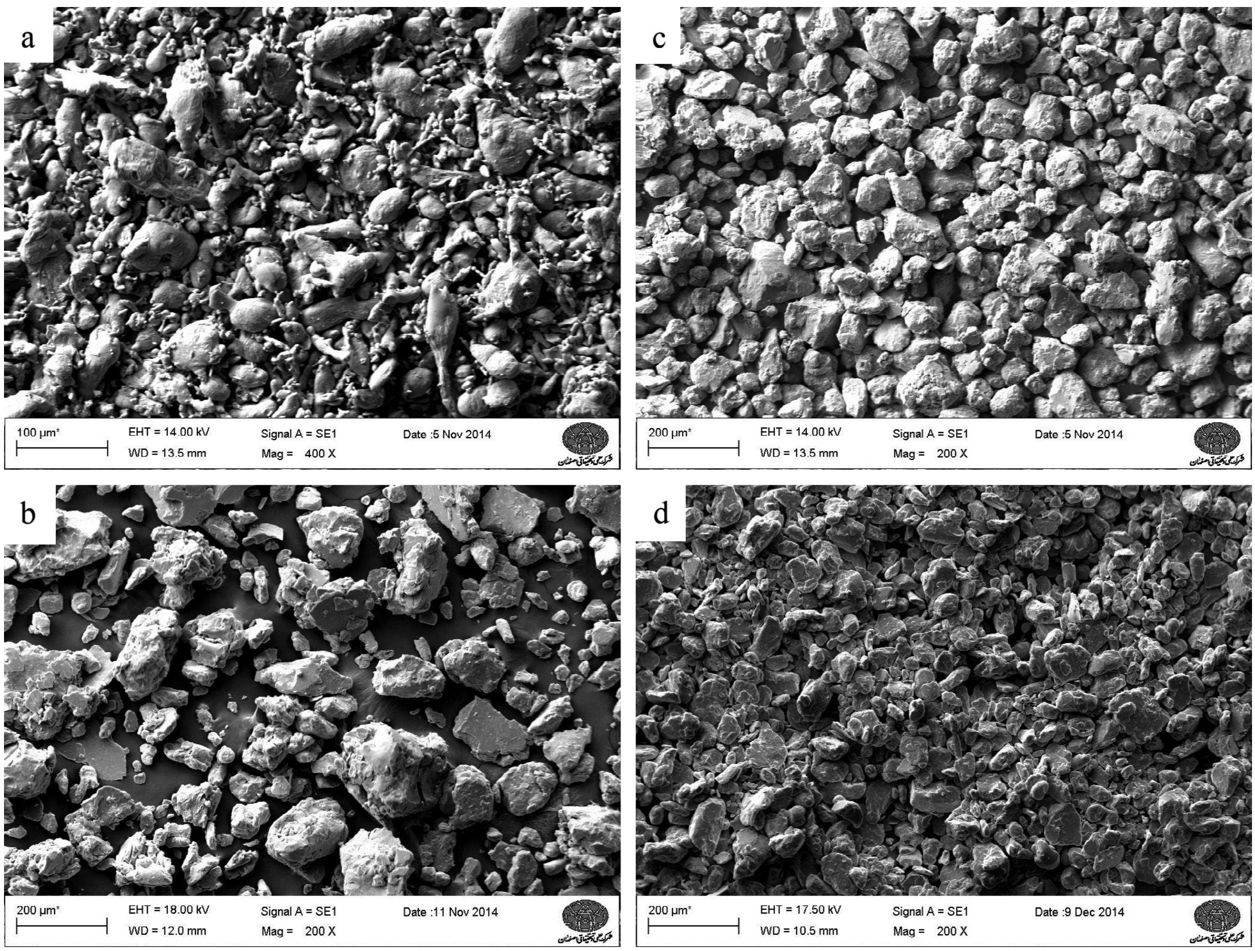

Fig. 1. SEM micrographs of Al6061 powder particles (a) without milling or after milling for (b) 4, (c) 12, and (d) 30 h.

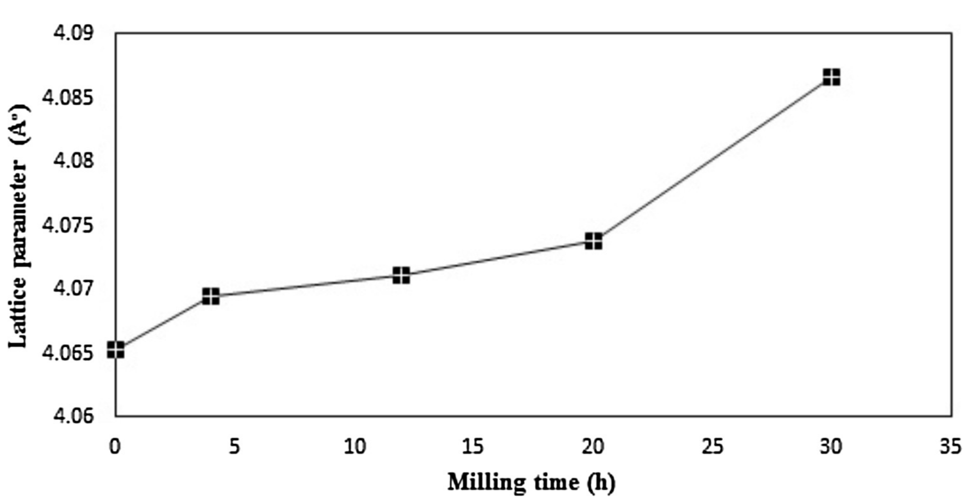

Fig. 2. Variation of Al lattice parameter versus milling time for Al6061 powder.

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