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Short communication

Tribological properties of nickel-based self-lubricating composite at elevated temperature and counterface material selection

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Abstract

Solid lubricating materials are necessary for development of new generation gas turbine engines. Nickel-based self-lubricating composites with graphite and molybdenum disulfide as lubricant were prepared by powder metallurgy (P/M) method. Their tribological properties were tested by a MG-2000 high-temperature tribometer from room temperature to 600 °C. The structure of the composite was analyzed by XRD and worn surface morphologies were observed by optical microscope. The effects of counterface materials on tribological behavior of composites were investigated. It was found that chromium sulfide and tungsten carbide were formed in the composite by adding molybdenum disulfide and graphite, which were responsible for low-friction and high wear-resistance at elevated temperatures, respectively. The average friction coefficients (0.14–0.27) and wear rates ($1.0–3.5 \times 10^{-6}$ $mm^3/(N\,m)$) were obtained for Ni–Cr–W–Fe–C–MoS_2 composite when rubbed against silicon nitride from room temperature to 600 °C due to a synergetic lubricating action of graphite and molybdenum disulfide. The optimum combination of Ni–Cr–W–Fe–C–MoS_2/Ni–Cr–W–Al–Ti–C showed lower friction than other counter pairs. The graphite played the main role of lubrication at room temperature, while sulfides were responsible for low friction at high temperature.

Keywords: Powder metallurgy (P/M); High temperature; Solid lubrication; Nickel-based composite; Synergetic effect

1. Introduction

Advanced jet engines require lubricants that can function over a wide range of temperature, from room temperature to 800 °C [1]. The maximum useful temperature for most common solid lubricants such as MoS_2, is limited to about 400 °C in air. Another common lubricant is graphite which generally works at room temperature and above 425 °C [2]. Since no single material can provide adequate lubricating properties over a wide range of temperatures [3], an approach of a synergetic lubricating action was proposed in the present study.

It is well known that when two or more solid lubricants are incorporated, an unexpected synergetic lubricating effect can be observed, which is superior to any one of the single lubricants. Examples include mixture of graphite and calcium fluoride, and MoS_2 and PbO. The application of a mixture of inorganic solid lubricants is one of promising approaches to fabricate high-temperature self-lubricating composites.

Zabinski et al. [4] prepared the composite films of PbO–MoS_2 with excellent lubricating properties at elevated temperatures by pulsed laser deposition. Tian [5] reported the lower friction coefficients and wear rates of $MoS_2 + CrO_3$ compared with MoS_2 alone. Lu [6] realized a synergetic effect of silver and CeF_3 on reducing friction at 700 °C, and the corresponding friction coefficient was as low as 0.11. Furthermore, these authors also proved synergetic lubricating effect of CeF_3 and graphite [7]. Xiong [8,9] revealed the self-lubricating properties of the combination of LaF_3 and MoS_2 was superior to LaF_3 or MoS_2 alone.

The tribological performance of self-lubricating composite varied with counterface materials. Dellacorte [10] investigated

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the friction behavior of Alumina/PS300 and Inconel alloy/PS300 from 25 to 600 °C and found that the metal counterface generally exhibited lower friction and wear at 25 °C but higher friction and wear at 650 °C. Each counterface combination is affected by the ability of the solid lubricant additives to form an adequate transfer film [11,12].

The objective of this study was to explore the concept of synergetic lubricating action of MoS_2 with graphite. A nickel-based self-lubricating composite was prepared by powder metallurgy, in which molybdenum disulfide and graphite were used as lubricants to improve the tribological properties of the composite. The friction and wear properties were evaluated on a MG-2000 high-temperature tribometer from room temperature to 600 °C. Furthermore, transfer films at elevated temperature and tribological compatibility were discussed.

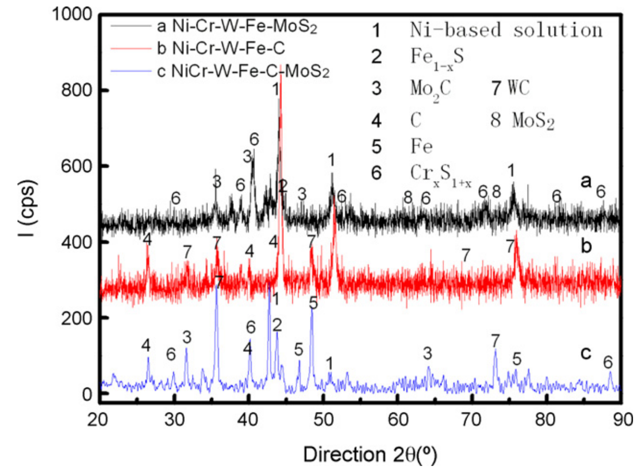

Fig. 1. XRD spectrum: (a) Ni–Cr–W–Fe–MoS_2, (b) Ni–Cr–W–Fe–C, and (c) Ni–Cr–W–Fe–C–MoS_2.

2. Experiment setup

2.1. Material preparation

The powders of nickel–chromium alloy (60 μm), iron (60 μm), tungsten (20 μm), silicon (60 μm), graphite (30 μm) and molybdenum disulfide (30 μm) were mechanically mixed. Their compositions are shown in Table 1. The mixed powders were put into a steel mould and pressed into circular disks (Ø45 mm × 8 mm). Then the disks were set in a graphite mould

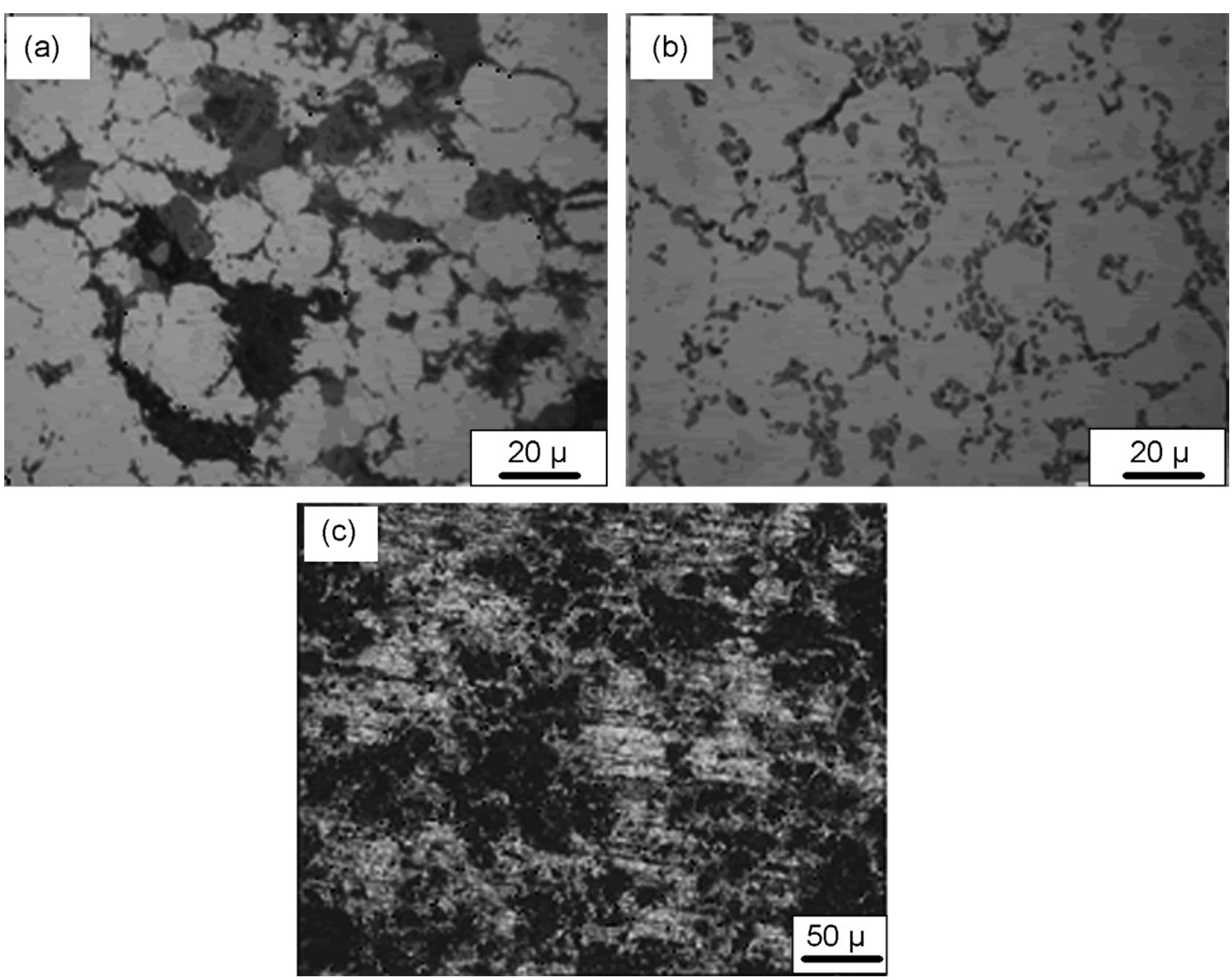

Fig. 2. Morphology of Ni-based composite: (a) Ni–Cr–W–Fe–C, (b) Ni–Cr–W–Fe–MoS_2, and (c) Ni–Cr–W–Fe–C–MoS_2.