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Tribological performance of rice husk ceramic particles as a solid additive in liquid paraffin

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ABSTRACT

Rice husk ceramic (RHC) particles were prepared and its effect on the lubrication performance of liquid paraffin (LP) was investigated using a four-ball tribometer to expand the comprehensive utilization of rice husk. The wear and friction mechanisms of RHC particles were also investigated. Results showed that RHC particles can strengthen the antiwear and friction reduction properties of LP in the presence of 2 wt% polyisobutylene succinimide (T154A) at 75 or 100 °C. The friction and wear mechanisms of RHC particles were ascribed to high temperature, which ensures the involvement of RHC particles in the formation of boundary lubrication film.

1. Introduction

As a renewable biomass resource, rice husk (RH), which is often burned in farms, releases pollutants that adversely affect the environment. Therefore, the comprehensive utilization of RH is particularly important. RH can be utilized to prepare biomass fuel [1], solid molding fuel [2], as a biosorbent [3], and as functional materials [4,5]. The preparation of rice husk ceramic (RHC) particle is an appropriate technology for the comprehensive utilization of RH. RHC can be used as sliding elements in linear guiders and slides because of their special physical characters, such as high hardness, low Young's modulus, low friction coefficient, and high abrasion resistance.

At present, investigations on the tribological behaviors of RHC and rice bran ceramic (RBC) particles have been extensively reported. Dugarjav et al. [6] investigated the dry tribological behaviors of disk-shaped RHC with different friction pairs, such as high carbon–chromium steel, austenitic stainless steel, and Al_2O_3, under dry conditions using a ball-on-disk tribometer. The antiwear and friction reduction properties of RHC particles were ascribed to film formation on the steel balls. The same authors also investigated the effect of the variation of carbonization temperature (900, 1400, and 1500 °C) on the tribological performance of RHC particles. They found that 900 °C was the optimum carbonization temperature [7]. Shibata et al. [8] also investigated the tribological performance of disk-shaped RHC materials sliding against stainless steel, alumina, silicon carbide, and silicon nitride under dry conditions. They determined that RHC particles exhibited the best tribological performance when sliding against silicon nitride balls, which was again be ascribed to the formation of a transfer film on the Si_3N_4 balls. Moreover, they also assessed the tribological behavior of the disk-shaped copper/carbon/RBC (Cu/C/RBC) composite materials, which evidently promoted antiwear and friction reduction properties in composite materials under water-lubricated conditions [9]. The microscopic wear mechanism of the Cu/C/RBC composite included the appearance of different wear modes under low or high wear conditions, and was verified, with a corresponding wear map [9–11]. Akiyama et al. [12,13] developed five thermoplastic resin/RBC composite materials, and their tribological performances were assessed using a linear reciprocating tribometer under dry and oil lubricated conditions. They determined that the friction coefficient and antiwear properties of composite materials were evidently lower than those of neat thermoplastic resins. From these results, it can be concluded that RHC or RBC particles have and continue to be extensively applied as a composite fillers in variety of materials.

In view of the superior tribological performance of RHC and RBC particles, it seems reasonable therefore to test RHC particles as an additive in lubricating oils. At present, research on the use of RHC particles as an lubricant additive, particularly on the effect of

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RHC on the tribological behavior of liquid paraffin (LP) remains limited. In the present study, a series of system tribological tests have been conducted to investigate the effect of RHC particles as an additive on the lubrication properties of LP containing 2 wt% polyisobutylene succinimide (T154A) to extend the application of RHC particles.

2. Experimental

2.1. Materials and samples preparation

The RHC particles were prepared using the carbonization process with a mass rate of 3:1 for RH powder (mesh size 10, purchased from Yuanyang Yanbing Rice Industry Co. Ltd. China) and phenolic resin (PR, Model 3122, purchased from Wuxi Mingyang Adhesive Material Co. Ltd. China). Exactly 2.5 g of PR was added to 7.5 g RH power, and the mixture was stirred using a glass rod for 15 min. 3 g the mixture was transferred to a porcelain crubile and placed in a tube furnace (Model OTF-1200X) at 900 °C and under N_2 atmosphere conditions for 2 h and then removed and allowed to cooled to room temperature. The remaining power was RHC particles [14]. The productivity of RHC particles was approximate 31%.

A commercially available LP was purchased from Tianjin Fuyu Chemical Co. Ltd. in China. A dispersant, Poly-isobutylene succinimide (T154A supplied by the Shang hai Demao Chemical Co., Ltd.) was utilized to ensure the uniform dispersion of the RHC particles in the LP, in a method described by [15]. The oil samples were LP+2 wt% T154A, LP+2 wt% T154A+0.01 wt% RHC, LP+2 wt% T154A+0.03 wt% RHC, and LP+2 wt% T154A+0.05 wt% RHC. The tests samples were prepared by magnetic stirring for 2 h to reduce experimental deviation. The other reagents, such as ethanol and acetone, were all analytical grade.

2.2. Analysis methods

The internal structure and primary particle of RHC were analyzed using a high-resolution transmission electron microscope (HRTEM, JEOL-2010) at an acceleration voltage of 200 kV. For the investigation, a drop of ethanol solution, including RHC particles, was placed onto the HRTEM Cu grids that were supported by thin carbon films. Then, scanning electron microscopy coupled with energy dispersive spectroscopy (SEM/EDS, model JSM-6700F) was used to investigate the agglomeration morphology of the RHC particles.

Fig. 1 shows the agglomerated morphology, internal structure, and primary particle of the RHC particles. The SEM image shown in Fig. 1(a) reveals that the morphology of RHC particles was sheet-shaped, which was consistent with that shown in Fig. 1(b). A large amount of amorphous carbon exists in a single RHC particle, as shown in Fig. 1(c) and proven by Raman analysis shown in Fig. 1

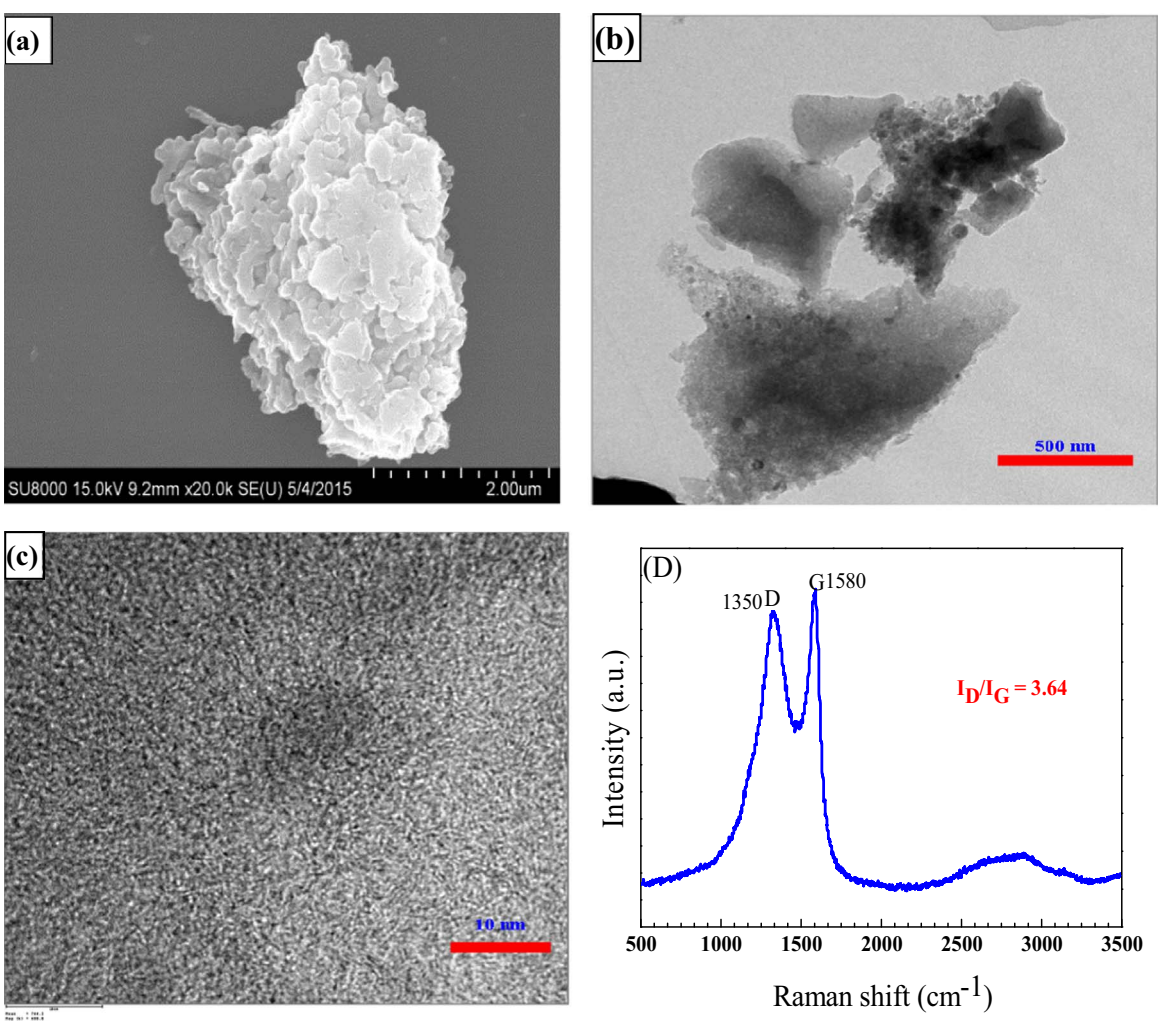

Fig. 1. SEM and HRTEM images and Raman analysis of RHC particles (a) SEM image (b)and (c) HRTEM images (d) Raman spectrum.