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Improvement in tribological properties of lubricating grease with quartz-enriched rice husk ash

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ABSTRACT

This study deals with the isolation of quartz-enriched ash from the rice husk by heating at 450 °C and subsequent treatment with an acid solution. It was characterized by scanning electron microscopy, X-ray diffracometry and energy-dispersive X-ray analysis. Various amounts of this ash were mixed with commercial lithium based grease at room temperature and tested for their antiwear performance. Four ball tribometer was used as a wear tester. Results revealed that the mentioned additive improved the performance of grease to a significant extent. The optimum amount of the dispersed ash was established in which the composite grease showed highest antiwear performance. In all cases, the performance of the composite grease was found better than the plain grease under the given test conditions.

1. Introduction

Lubricating grease gives protection to the machine components against wear and reduces friction. It is generally desirable that the grease should maintain its antiwear and antifriction performance for a longer period of time in order to keep the moving parts of the machine functional. In fact, wear can be mild and may not cause catastrophic failure; however, in most of the cases the surfaces of the mating components of the machine undergo structural changes which affect their physical properties and ultimately causes severe damage to them. As such, protection of the components is of great importance for smooth running and life of the machine. In this regard, researchers are actively involved in the search for lubricants which could prove to be very effective in the reduction of tribological wear in a wide range of industrial applications. For instance, different types of inorganic powders, such as molybdenum disulfide [1,2], titanium dioxide [3], ferric oxide [4], silicon dioxide [5–8], calcium carbonate [9,10], zinc oxide [11], lanthanum hydroxide [12], graphene [13], etc. were used as solid additives for improvement in tribological properties of different types of lubricants. The observed improvement in tribological properties was generally attributed to the accumulation of the additive particles in the grooves of the worn surfaces at the sliding contacts, which supported part of the applied load and thus resulted in the reduction of wear at the sliding contacts. However, it was concluded from the above mentioned studies that the extent of improvement in tribological properties of the lubricants was dependent upon the chemical composition, concentration, particle size etc. of the dispersed materials. As such, the search in this field is going on for the production of greases of enhanced tribological properties.

In the present work, an attempt has been made to produce rice husk ash (RHA) from the locally available rice husk (RH), characterize it, and use it as an antiwear additive in a typical lithium-based commercial lubricating grease. The idea of this work stemmed from the findings of the researchers [5–8], who used SiO_2 particles as the solid additive in lubricants for improving their antiwear performance. Since RH is a silica rich material [14–18]; therefore, it is anticipated that it might prove to be effective and cheap additive for the formulation of grease of improved tribological properties. The latter properties are evaluated under different experimental conditions by using a Four Ball Tribometer.

2. Experimental

2.1 Materials

Rice husk (RH) was obtained from the local rice processing mills in Mardan, Pakistan. The RH was converted into rice husk ash (RHA) by burning it in air atmosphere at the 450 °C in a tube furnace for 4 h. In some cases, the RHA was boiled under reflux in 1 Mol/L hydrochloric acid solution for 1 h. On filtration, washing and subsequent drying in open air, the acid treated RHA (RHA_a) was kept in the air tight bottles before further use.

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Commercial lithium-based grease of NLGI 3 grade was obtained from the Momin Oil Industries, Dubai. Composite grease samples were produced by mixing this grease with known amounts (0–1.5 wt%) of the RHA_a powder by a mechanical blender, comprised of a mixing-blade rotating at the speed of 700 rpm. The mixing was performed for the period of 40 min which was sufficient for uniform distribution of the RHA_a particles in the grease matrix. In addition, the mixing process of each composite grease sample was followed by homogenization with a triple-roller mill and then its de-aeration for 1 h in a homemade system, composed of a thick-walled Pyrex glass vessel, attached to a vacuum pump.

Steel balls (12.7 mm in diameter) were purchased from FAG Bearing Centre, Babu Bazar, Rawalpindi, Pakistan, which had a microhardness 128 HV and composed of various elements in wt% of 70.03 (Fe), 7.27 (Ni), 19.63 (Cr), 1.02 (Mn), and 0.08 (C).

Doubly distilled water was used for making stock and working solutions and all Pyrex glass vessels were employed for the solutions storage and carrying out reactions.

2.2 Characterization

2.2.1 Scanning electron microscopy (SEM)

Morphology of the particles of the desired RHA powder samples was inspected with scanning electron microscopy (SEM: JSM-6490, JEOL). For this purpose, small amount of the powder sample was sprinkled over a piece of the conducting carbon tap, pasted on the standard aluminum stub. The stub was then transferred to the vacuum chamber of the sputter/coater (JFC-1600, JEOL) and coated with gold under standard condition. The coated samples were then inserted inside the sample observation compartment of the scanning electron microscope and the images were recorded at the accelerating voltage of 15 kV and working distance of 10 mm. For qualitative analysis of the metal contents of the selected samples, an energy-dispersive X-ray analyzer (Oxford, Inca-200) was used.

2.2.2 X-ray Diffractometry (XRD)

The crystallinity of the desired samples was assessed with the X-ray diffractometer (XRD, JEOL JDX-3532) using Cu-Kα radiations. The diffractometer was operated with 40 kV voltage and 20 mA current. In each case, the scanning of the sample was performed in the 2θ range 2–80°, keeping the step angle of 0.05° and the scan speed at $0.1^\circ\ s^{-1}$. Composition of the crystalline phases was then identified by using the standard software (JDX-3500).

2.3 Wear measurement

Four Ball Tribometer (FBT), conforming to the ASTM D 2266, was used as the wear tester. All the four steel balls were ultrasonically cleaned with toluene before use and then mounted them in the tribometer in the proper locations, i.e. the upper ball in the machine spindle and the lower three balls in the grease cup. The grease cup was a double-walled brass vessel assembled with the antifriction support under the spindle, holding the upper ball. Then 50 g of the test grease was transferred to the grease cup, which was sufficient to submerge the three stationary balls. Temperature of the grease cup was adjusted to the desired value (25 °C) by circulating water from the thermostatic water bath through the double-walled jacket around the grease cup. The upper ball, rotating at the speed of 1650 rpm, was allowed to come in three point contact with the lower stationary balls under the applied load of 350 N. In each case, the test duration was 60 min. The frictional force at the sliding contacts was recorded automatically by a load sensor, attached to the computer through the data acquisition system during the whole test period. At the end, the upper ball was lifted up from the lower stationary balls. The three balls in the grease cup were removed from there and washed extensively with toluene in an ultrasonic bath. These balls were then inspected by an optical microscope (equipped with a calibrated scale) for measuring diameter of the wear scars, formed on them in the wear experiments. It is mentioned that each grease sample was tested four times and the average value of the wear scar was noted.

3. Results and discussion

3.1 Materials

The rice husk (RH) obtained from the source was yellowish in color and was composed of small pieces, with rather rough surfaces. The bulk of RH had a spongy texture with a tap density of 0.38 g/cm^3. SEM analysis (Fig. 1A) indicated that the outer surface of the RH flake was composed of non-porous pattern of nearly linear and continuous ridges. The observed pattern was different

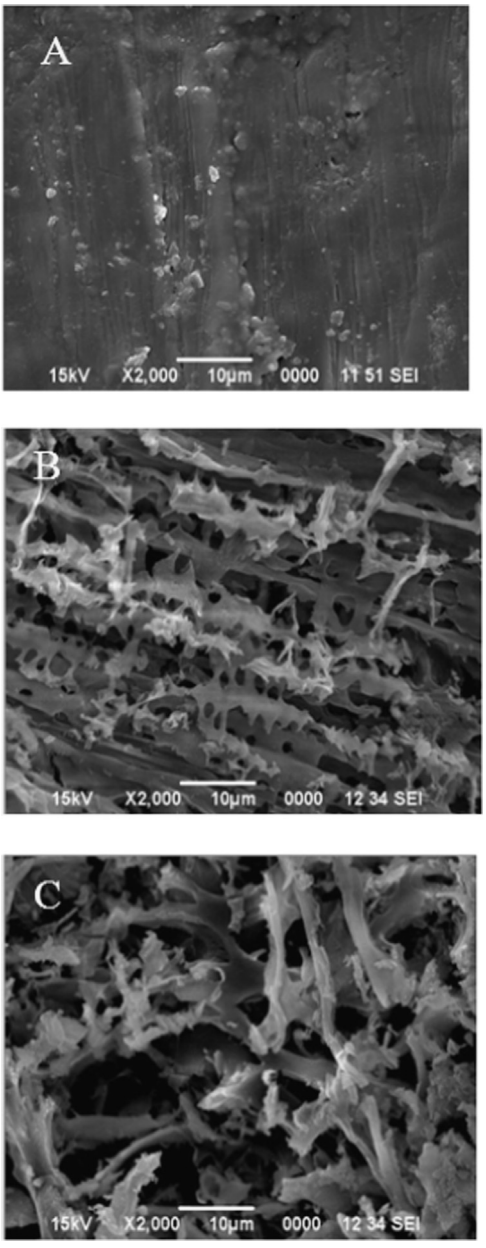

Fig. 1. Scanning electron micrograph (SEM) of the (A) rice husk (RH); (B) rice husk ash (RHA); and (C) acid treated rice husk ash (RHA_a).