2017 STLE Annual Meeting & Exhibition
May 21-25, 2017
Hyatt Regency Hotel
Atlanta, Georgia, USA

Comparative Tribological Properties of Modified Magnesium Silicate Hydroxide and Serpentine Powder as Lubricant Additives

TRACK OF CATEGORY

Tribochemistry

AUTHORS AND INSTITUTIONS

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INTRODUCTION

The species of lubricant additives expanded along with the development of technology, extending from natural minerals to synthetic compounds. Advancements in technologies and production capabilities have allowed for size controlled differentiation from a large micron scale to nanoparticles. Meanwhile, the performance improves with finer particles, especially for anti-wear properties. With the encouragement of clean and environmentally friendly additives, ZDDP and other anti-wear agents are constantly being replaced because of its environmental hazards, the researchers turn to the environment-friendly and more efficient anti-wear additives[1]. Serpentine, as a natural mineral, has been widely studied since it was found to be used as lubricant additives[2]. However, the complex composition of natural minerals brings difficulties to explain its specific anti-wear mechanism. As the main component of serpentine, magnesium silicate hydrate was synthesized and added into the base oil for better tribological properties[3]. In this work we prepare modified magnesium silicate hydroxide (MSH) and compare the tribological performances as lubricant additives between synthetic MSH and serpentine mineral under different experiment conditions, such as load, speed.

MAIN BODY

1. Experimental and materials

Modified magnesium silicate hydroxide (MSH) nanoparticles were synthesized hydrothermally by using MgO and SiO_2 as precursors and oleic acid (OA) as modification agent under alkaline condition. As for the preparation of natural serpentine, it is crushed into pieces and ball-milled for 1h. We add the powders into ploy-alpha-olefin (PAO) at a specific ratio (1wt%), meanwhile, 4wt% organic dispersant is added for the sake of improving the powders' stability in oil. We stir the mixture for 10 min and ultrasonically vibrated for 10 min to obtain uniformly dispersed oil samples.

The comparative of tribological properties of MSH and serpentine as lubricant additive were tested by MRS-10A four-ball machine. The test ball was GCr15 with a diameter of 12.7 mm and a hardness of 62 ~ 64 HRC. The tribological properties of the two samples were compared under different loads (500N, 600N) and speeds (400RPM, 600RPM). Tribological tests were carried out at room temperature for 2h. In order to ensure the reliability of the test, each test was repeated three times, and the average value was taken as the final result. After tests, the morphologies and elements of the worn surfaces were characterized by SEM and Energy Dispersive X-Ray Spectroscopy (EDX).

2. Results and discussion

Fig. 1 shows the morphologies and XRD patterns of serpentine and MSH, respectively. It could be found that the size of serpentine powders is at micron level and ranges from 1 μm to 2 μm. The morphology of serpentine exhibits a schistose structure. The synthetic MSH nanoparticles with the size about 50nm show an aggregation state as the result of high surface energy between nanoparticles.

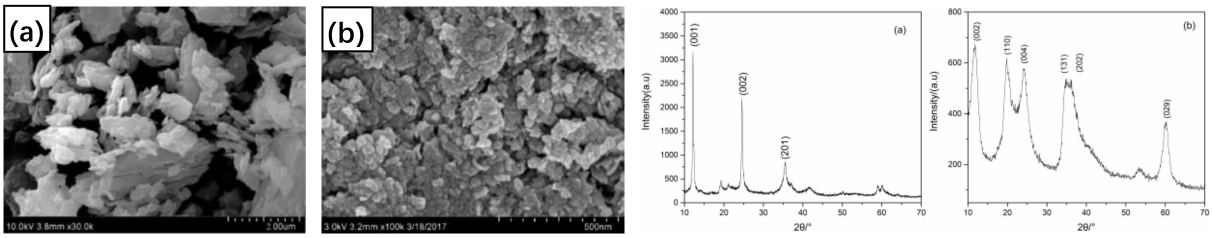

Fig. 2 SEM images and XRD patterns of (a) serpentine (b) MSH

The XRD results in Fig. 1 show that the diffraction pattern of natural serpentine is matched with the PDF card 07-0417, which belongs to antigorite (a type of serpentine). Meanwhile, the synthetic MSH matches the PDF card 25-0645, which belongs to a variety of serpentine. The diffraction peaks of serpentine are very sharp, which indicates that the crystallization degree is very high, but the synthetic MSH is not as high as the natural serpentine due to the limitation of synthesis time.

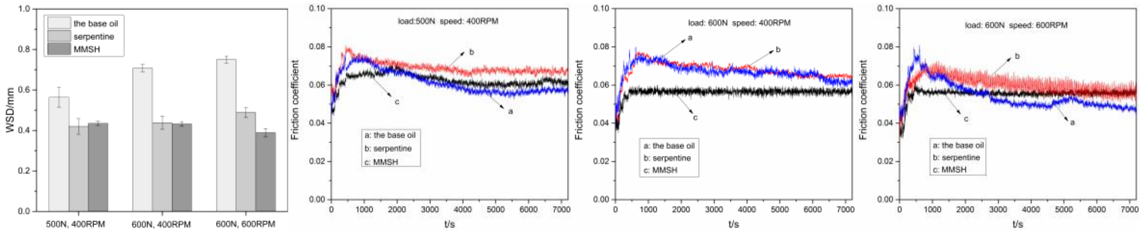

Fig. 3 wear scar diameter and friction coefficient evolutions under different conditions

Fig. 3 shows the compare of wear scar diameter (WSD) and friction coefficient of different oil samples. Under the conditions of 400RPM, the MSH-containing oil showed a close anti-wear ability with the serpentine-containing oil. However, under the condition of 600N-600RPM, the MSH containing oil presented a better anti-wear performance than that of serpentine. In addition, the WSD of MSH containing oil decreases with the increase of speed or load. In contrast, the WSD of the base oil and the serpentine-containing oil increases with the increase of load or speed. It could be concluded that MSH as lubricant additive plays a better role in the case of heavy load or high speed. From the friction coefficient of different oil samples under different conditions, it can be found that the MSH containing oil presents the most stable trend, especially with the condition of 600N-600RPM. At the beginning of the test, with the increasing of load, the friction coefficient increases. As for the MSH containing oil, the increase of friction coefficient stops at a lower value and maintains it until the end of the test. In order to clarify the mechanism of friction reduction and anti-wear, the morphologies and chemical elements on the worn surfaces with the condition of 600N-400RPM are analyzed.

It can be seen from Fig. 4 and Fig.5 that the worn surface lubricated with the MSH containing oil is smoother than that of serpentine.

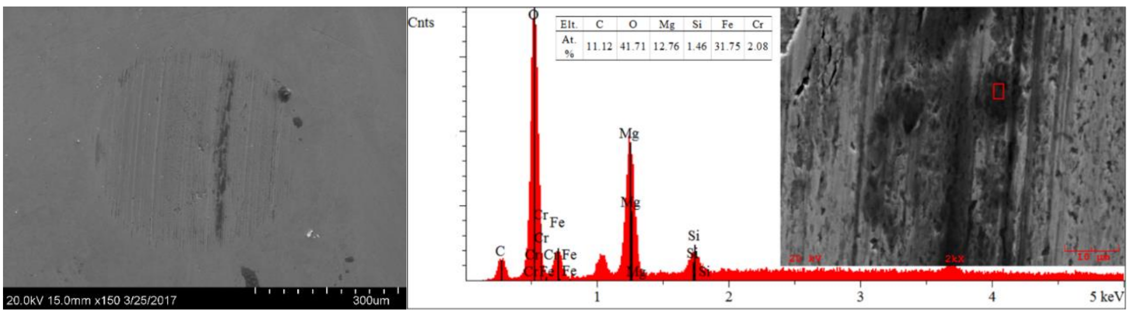

Fig. 4 SEM images and EDS patterns of the worn surface lubricated with MSH containing oil

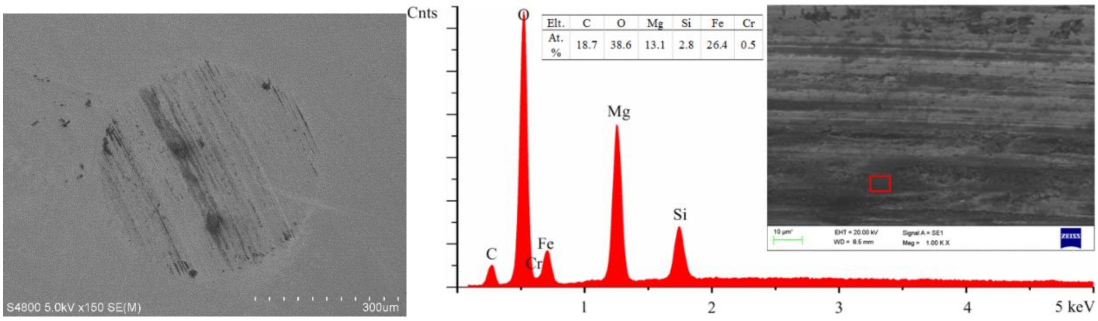

Fig. 5 SEM images and EDS patterns of the worn surface lubricated with serpentine–containing oil

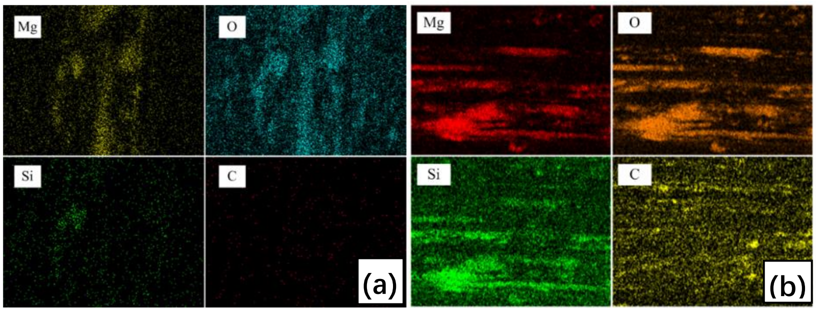

Fig. 6 Elemental distribution of the worn surface lubricated with: (a) MSH (b) serpentine

Fig. 6 shows the elemental distribution of the worn surface lubricated with MSH containing oil and serpentine-containing oil. It can be seen that in the black region of the worn surface, a tribofilm with elements of carbon, magnesium, silicon, oxygen, iron, chromium formed on the worn surface. The ratio of Mg and Si on the worn surface is much larger than that of the serpentine or MSH. As for the carbon, it uniformly distributes on the worn surface. It could be concluded that the serpentine or MSH decomposes in the process of lubrication, not simply spreading on the surface by mechanical action, at the same time, serpentine and MSH have the same tribological mechanism as lubricating oil additives.

From the above analyses, it can be concluded that both serpentine and MSH can improve the anti-wear properties of the base oil. MSH as lubricant additives demonstrate better tribological properties than serpentine. In the process of friction, serpentine and MSH decomposed and a Si and Mg rich tribofilm forms on the worn surface.

ACKNOWLEDGMENTS

The authors would like to thank the National Natural Science Foundation of China (Grant No.51075026) and the National Defense Pre-Research Foundation of China (Grant No.H092013B001). Collaborative work in the United States is supported by the NSF SBIR program: NSF SBIR Phase I (Grant #1315855) and NSF SBIR Phase II (Grant #1456394) to TriboTEX. Postdoctoral Fellowship work is supported by the NSF under Grant # IIP-1059286 to the American Society for Engineering Education.

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KEYWORDS: Additives: Antiwear Additives, Additives: Friction Modifiers