Assessment the Wear Properties of Biodiesel-diesel Blends with the Addition of Copper Oxide Nanoparticles

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Abstract
Normal lubricants such as petroleum, coals or natural gases are limited and will keep depleting due to high fuel consumption all over the world; so nano-lubricants can be considered as the alternatives. In the present study, copper oxide nanoparticles were mixed with biodiesel-diesel blends to evaluate the wear properties of the mixture by 4-ball wear tribo-tester. CuO nanoparticles (25, 50 and 75 ppm) were dispersed in B10, B20, and B50 blends. The results showed that with increasing the CuO nanoparticle fraction up to 50 ppm in the fuel blend, the wear scar diameter (WSD) decreased. Also, the results indicated that using copper oxide nanoparticles with a dosage of 75 ppm in the fuel blend causes a higher WSD compared with 50 ppm dosage. Based on the results, the scratches and roughness on the surface also decreased with an increase of biodiesel concentration and addition of nanoparticles up to 50 ppm in the fuel mixture.

Keywords
Wear Scar Diameter, Copper oxide, Nanoparticles, Wear

1. Introduction

Lubricants with solid nanoparticles can reduce the friction coefficient and increase the load-carrying capacity of the lubricant fluid at the same time [1]. Nowadays, normal lubricants such as petroleum, coals or natural gases have been used, however, these sources are limited and will keep depleting due to high fuel consumption all over the world [2–4].

For a few components of an automobile such as fuel injectors and pumps, the lubricity issue is very important as they are lubricated by the fuel itself [5, 6]. In the automobile engine, the temperature of the fuel inlets is appeared to be above 60°C [7, 8] which also can influence lubricity. Especially, the lubricity of the fuel at fuel injectors and high-pressure fuel pumps could be greatly changed because of existing higher temperatures. The lubricity of conventional diesel fuel is poor so it is needed to use some material to improve the lubricity of diesel fuel.

The nanoparticles itself is good as it has a self-repair function for the worn surface [9], in another word, it creates a protective layer, which is deposited at the contact area to improve tribological properties [10]. Some studies investigated the effect of using nanoparticles in lubricating oil on the tribological properties of the oil. According to Zhang et al. [11], the interposed layer between two surfaces will improve the smoothness of the relative movement and prevent damage in a variety of materials in many forms such as gas, liquid and solid. The new variant of lubricant developed when the combination of any type of the nanoparticles was mixed with the lubricating oil [12, 13]. The study from Padgurskas et al. [13] showed that the combination of different nanoparticles will result in different additive effect as the lubricant. Most researchers stated that the size, concentration, shape, hardness influence tribological behavior and play important roles in a lubricating oil as an additive [14-17]. Nano-lubricant also can fill in and repair the worn surface with good environmentally friendly characteristics, but not all combinations improve friction and wear characteristics. The tribological effect of different combinations of nanoparticles is better than base oil for reducing friction coefficient. However, according to Padgurskas et al. [13], copper nanoparticles are more effective in mixed lubrication than full film lubrication and are the most active in combination or alone. The literature survey described above demonstrates thatnanoparticle additives are a useful means of improving the lubri-cating properties of oils. In the present study, the effects of CuO nanoparticles on the wear properties of biodiesel-diesel blends were evaluated experimentally.

2. Materials and methods

In the present research wear characteristics of nano-fuels were studied using a four-ball wear testing machine according to the ASTM D4172 standard. Also, CuO nanoparticles (25, 50 and 75 ppm) on a weight basis were selected as the tribological behavior modifier. CuO nanoparticles were weighed using a precision electronic weighing balance. The nanoparticles were dispersed in biodiesel-diesel blends (B10, B20, and B50) by an ultrasonic homogenizer. Figure 1 shows the mixture of the biodiesel-diesel blend with the nanoparticles. Figure 2 shows a schematic diagram of the 4-ball wear tribo-tester. According to the standard, a load of 392N was applied and the tests were performed with a duration of 1500 seconds. Finally, the optical micrographs of worn surfaces of the steel balls were prepared by using an optical microscope.

Figure1. The mixture of the biodiesel-diesel blend with the nanoparticles

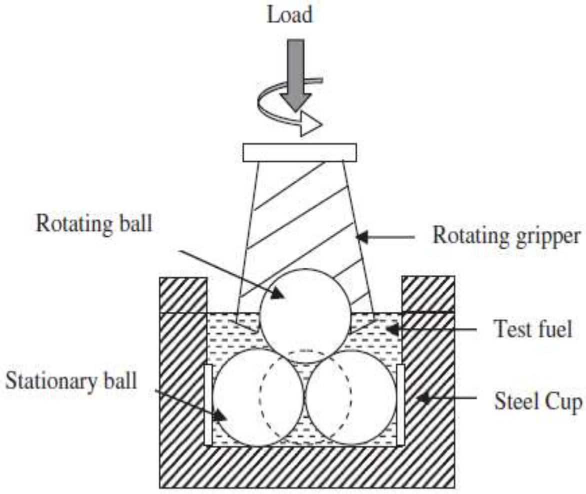

Figure2. A schematic diagram of the 4-ball wear tribo-tester [22]

3. Results and discussion

3.1 Effect of nanoparticles concentration in B10 blend on wear scar diameter

Figure 3 shows the wear scar diameter versus different nanoparticles concentration in B10 blend.

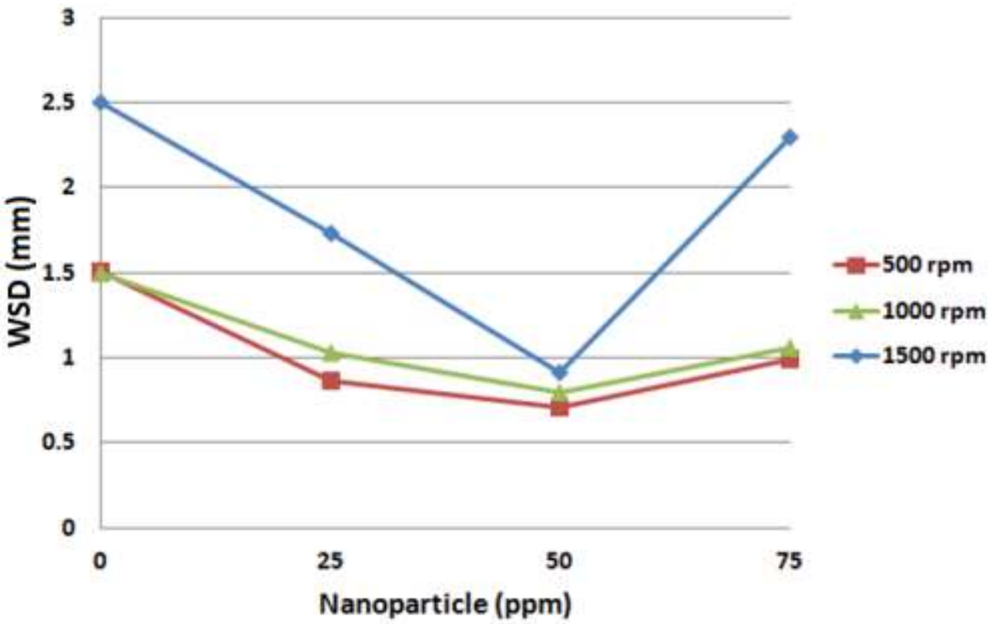

Figure3. The wear scar diameter versus different nanoparticles concentration in B10 blend

According to the figure, with increasing the CuO nanoparticles fraction in the biodiesel-biodiesel blend (up to 50 ppm), the wear scar diameter decreases for all RPMs. It indicates the better lubrication property of the mixture at this condition. The reason is filling the friction surface with the nanoparticles as the micro asperities and replacement of sliding friction with the rolling effect in the contact zone [18, 19]. Also, wear resistance is closely related to the properties of the tribo-film in the boundary lubrication regime. Moreover, the nano-lubricant viscosity was found to increase along with the nanoparticles volume fraction, although this effect was diminished at higher temperatures

[20, 21]. On the other hand, using copper oxide nanoparticles with a dosage of 75 ppm in the fuel blend causes a higher WSD compared with 50 ppm dosage. Based on the results, this increase is higher for speed of 1500 RPM compared to 500 and 1000 RPMs.

3.2 Effect of nanoparticles concentration in B20 blend on wear scar diameter

Figure 4 shows the wear scar diameter versus different nanoparticles concentration in B20 blend.

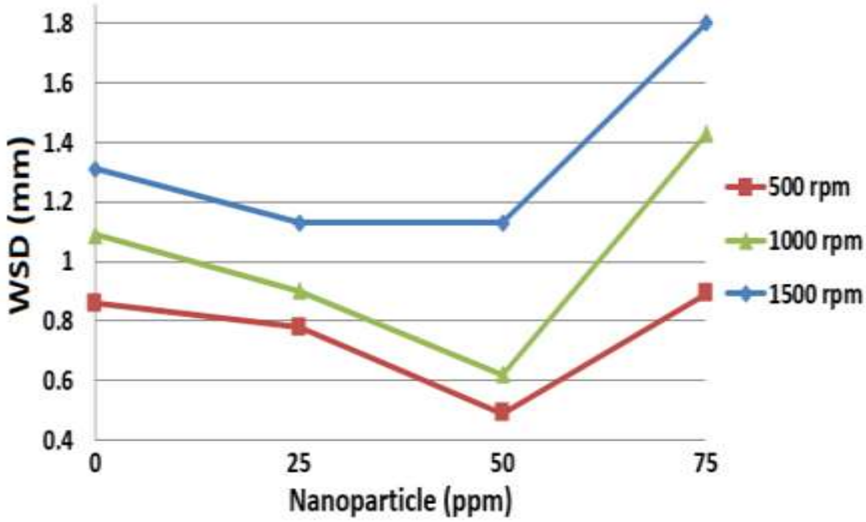

Figure4. The wear scar diameter versus different nanoparticles concentration in B20 blend

Similar to B10, with increasing the concentration of copper oxide nanoparticles (up to 50 ppm) in the fuel mixture the wear scar diameter decreases at all speeds. On the other hand, the use of CuO with a dosage of 75 ppm causes a higher WSD compared with 50 ppm. Same as before, this increase is higher for speed of 1500 RPM compared with 500 and 1000 RPMs.

3.3 Effect of nanoparticles concentration in B50 blend on wear scar diameter

Figure 5 shows the wear scar diameter versus different nanoparticles concentration in B50 blend.

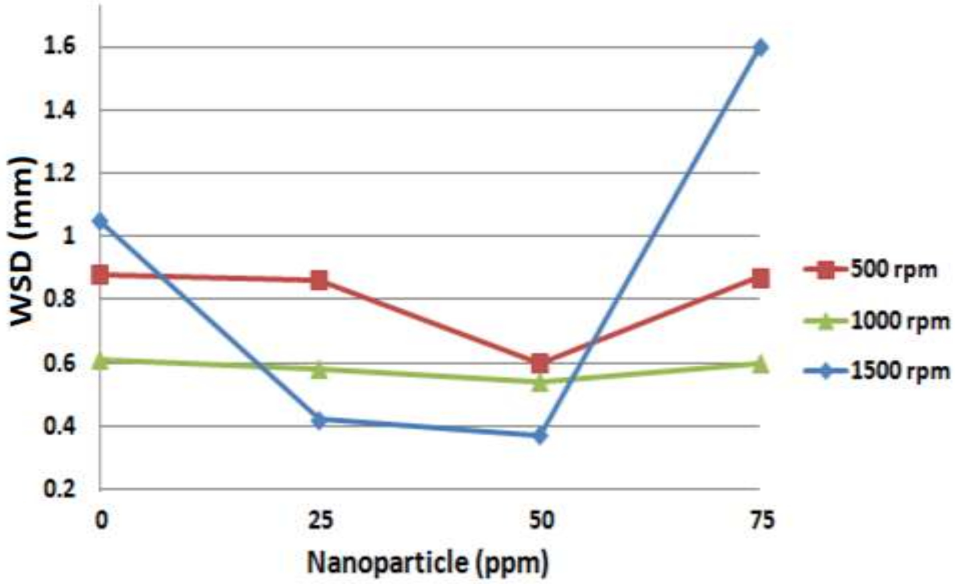

Figure5: The wear scar diameter versus different nanoparticles concentration in B50 blend

The figure shows that as the percentage of copper oxide nanoparticles in the fuel mixture changes, the wear scar diameter also changes. At the rotational speeds of 500 and 1000 RPM the WSD is approximately constant with the addition of nanoparticles up to 50 ppm; then it enhances with a fraction of 75 ppm. At the rotational speed of 1500rpm, the wear scar diameter initially decreases up to 50 ppm nanoparticle concentration. After that, the diameter intensively increases when the dosage of nanoparticles changes to 75ppm. Generally, the WSD increases for all fuel blends when the speed increased as the result of higher temperature conditions and lower viscosity of fuel mixture at high RPMs.

3.4 Effect of biodiesel percentage in fuel blends without nanoparticles on wear scar diameter

The effect of biodiesel percentage in fuel blends without nanoparticles on wear scar diameter under various RPMs is presented in Figure 6.

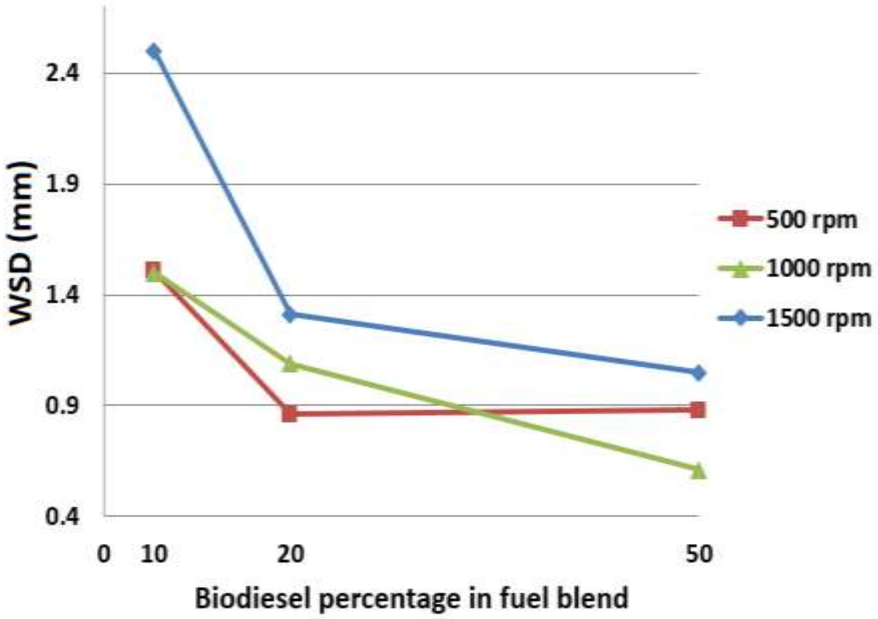

Figure6. Effect of biodiesel percentage in fuel blends without nanoparticles on wear scar diameter

The results show that the wear scar diameter reduces as the biodiesel content of the mixture increases for all rotational speeds. This is due to the thin layer of the neat biodiesel helps to reduce the friction [22-24]. Another reason is related to free fatty acids, monoglycerides, and diglycerides which are in trace components of biodiesel. These organic carbon compounds improve the lubrication properties of biodiesel [25, 26]. Although this impact is more considerable for changing biodiesel fraction from 10 to 20%.

3.5 Effect of biodiesel percentage in fuel blends containing 25 ppm nanoparticles on wear scar diameter

Figure 7 shows the effect of biodiesel percentage in fuel blends containing 25 ppm on wear scar diameter under various RPMs.

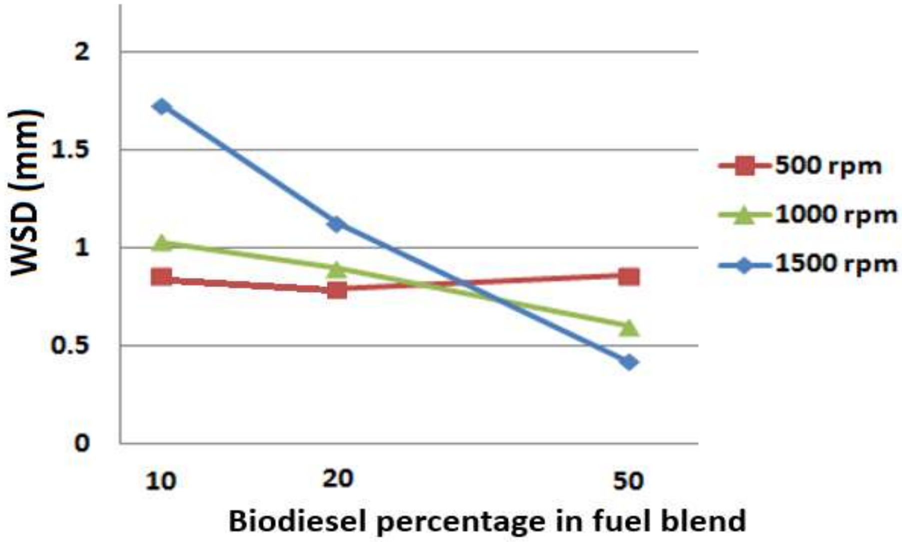

Figure7. Effect of biodiesel percentage in fuel blends containing 25 ppm nanoparticles on wear scar diameter

Similar to previous results, the wear scar diameter reduces at all rotational speeds as the biodiesel content of the mixture increases. Although, this reduction is more obvious at 1000 and 1500 RPMs.

3.6 Effect of biodiesel percentage in fuel blends containing 50 ppm nanoparticles on wear scar diameter

Figure 8 indicates the effect of biodiesel percentage in fuel blends containing 50 ppm on wear scar diameter under various RPMs.

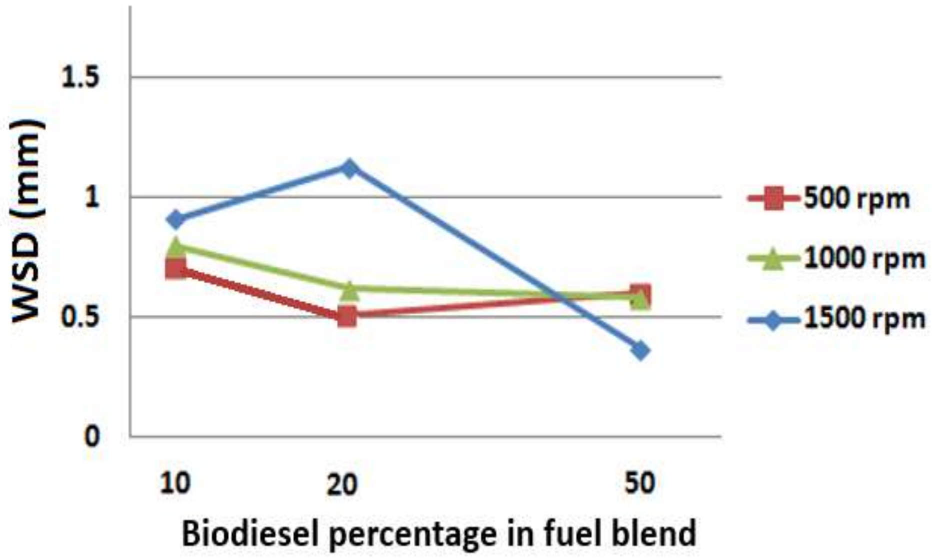

Figure8. Effect of biodiesel percentage in fuel blends containing 50 ppm nanoparticles on wear scar diameter

Based on the figure, there is no significant variation in wear scar diameter while the biodiesel fraction in fuel mixture increases at 500 and 1000 RPMs, but at 1500 RPM the WSD significantly decreases as the biodiesel percentage increases from 20 to 50%.

3.7 Effect of biodiesel percentage in fuel blends containing 75 ppm nanoparticles on wear scar diameter

Figure 9 shows the effect of biodiesel percentage in fuel blends containing 75 ppm on wear scar diameter under various rotational speeds.

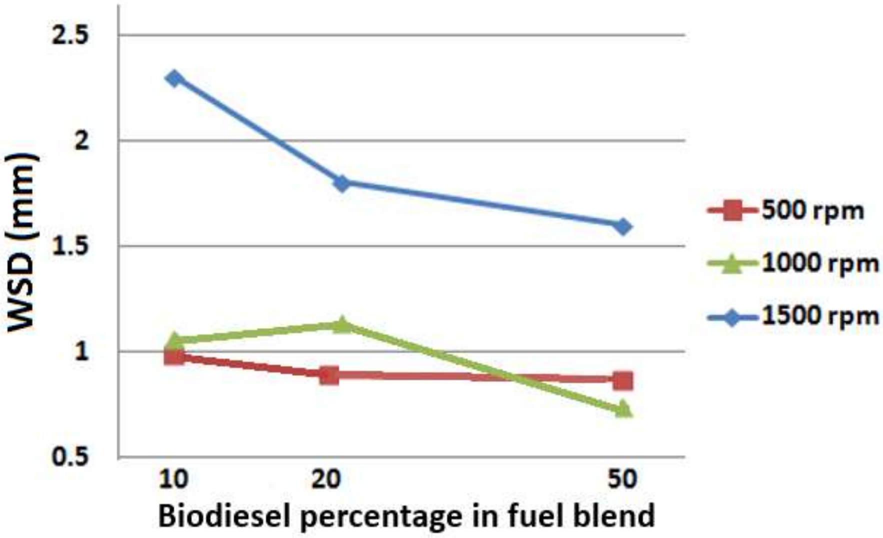

Figure9. Effect of biodiesel percentage in fuel blends containing 75 ppm nanoparticles on wear scar diameter

Similar to fuel blends containing 50 ppm nanoparticles, there is no significant variation in wear scar diameter while the biodiesel fraction in fuel mixture increases at 500 and 1000 RPMs, but at 1500 RPM the WSD decreases significantly while the biodiesel percentage increases from 20 to 50%. Moreover, the Simultaneous effects of high rotational speed and addition of nanoparticles with 75 ppm dosage tend to sudden increase in the wear scar diameter.

3.8 Optical micrographs of worn surfaces

Figures 10 to 18 show the optical micrographs of worn surfaces for various nanoparticles fractions in the biodiesel-diesel blends under different rotational speeds.

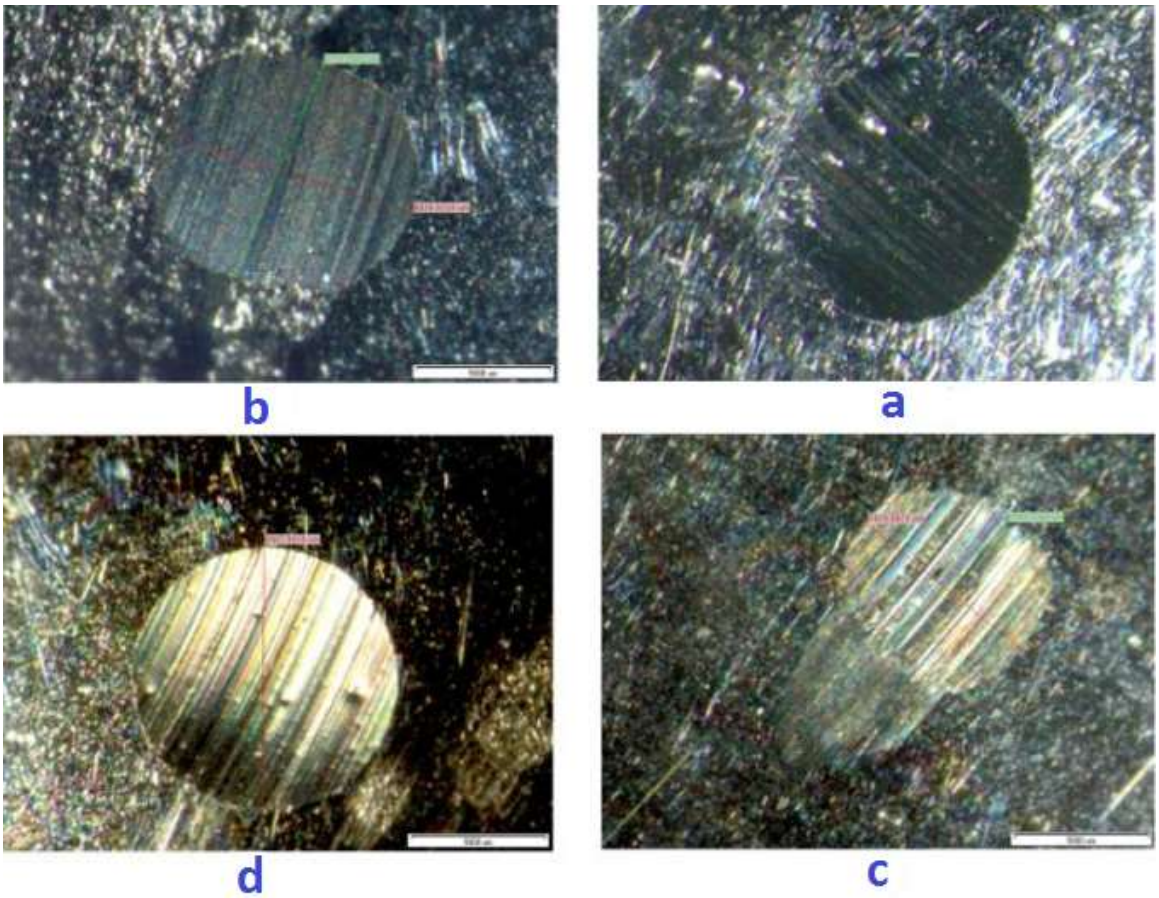

Figure10. The optical micrographs of worn surfaces for the B10 blend containing a) 0 ppm b) 25 ppm c) 50 ppm d) 75 ppm nanoparticles under 500 RPM

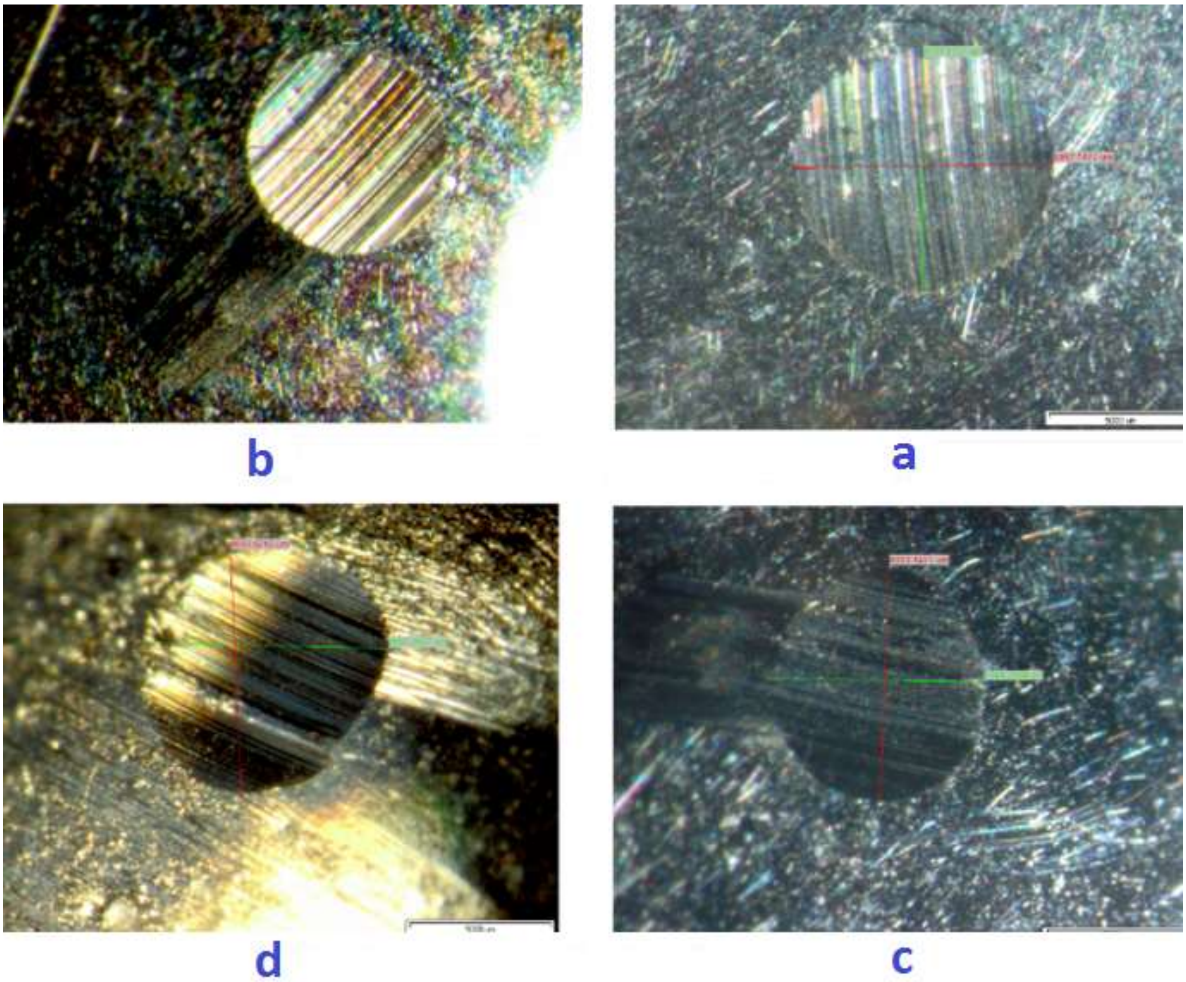

Figure11. The optical micrographs of worn surfaces for the B20 blend containing a) 0 ppm b) 25 ppm c) 50 ppm d) 75 ppm nanoparticles under 500 RPM

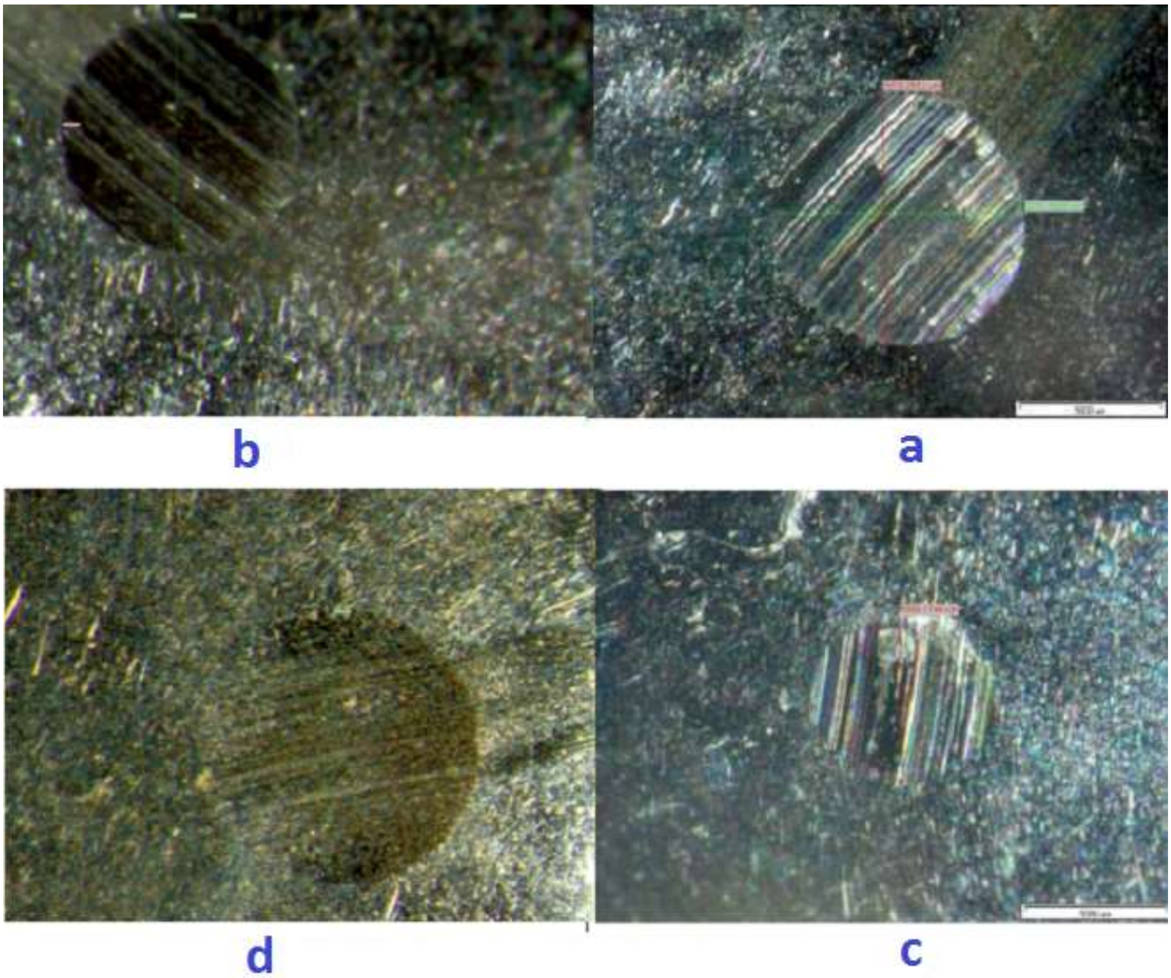

Figure12. The optical micrographs of worn surfaces for the B50 blend containing a) 0 ppm b) 25 ppm c) 50 ppm d) 75 ppm nanoparticles under 500 RPM

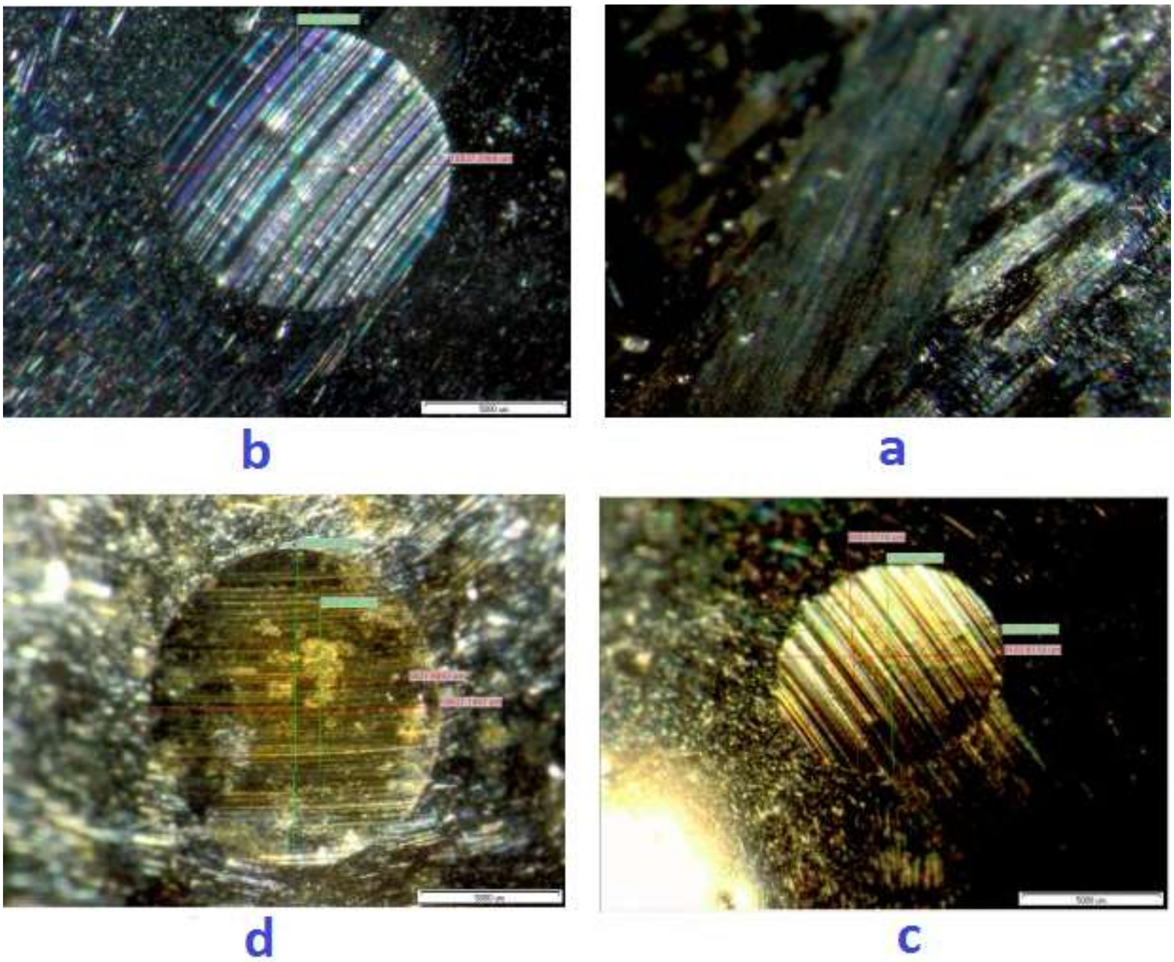

Figure13. The optical micrographs of worn surfaces for the B10 blend containing a) 0 ppm b) 25 ppm c) 50 ppm d) 75 ppm nanoparticles under 1000 RPM

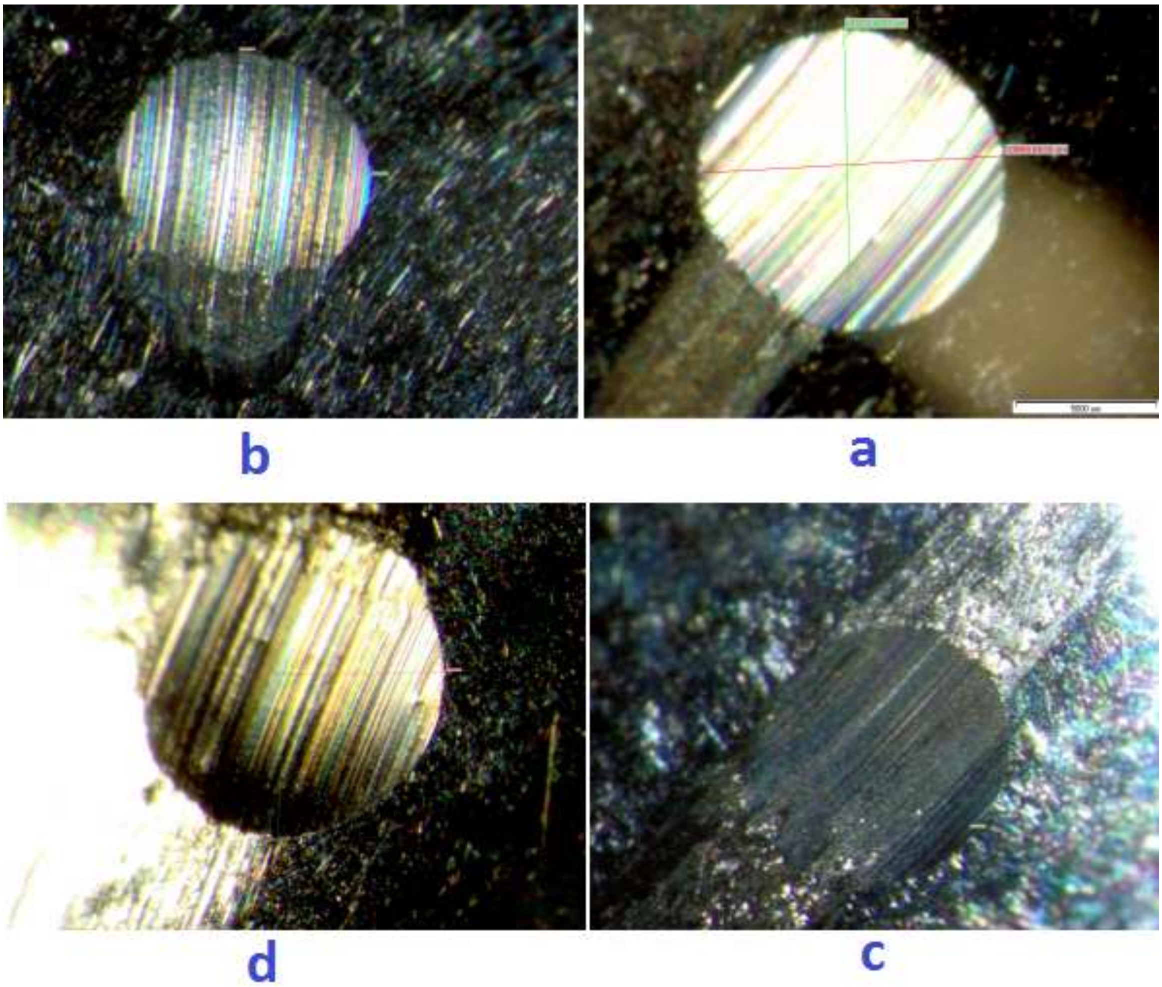

Figure14. The optical micrographs of worn surfaces for the B20 blend containing a) 0 ppm b) 25 ppm c) 50 ppm d) 75 ppm nanoparticles under 1000 RPM

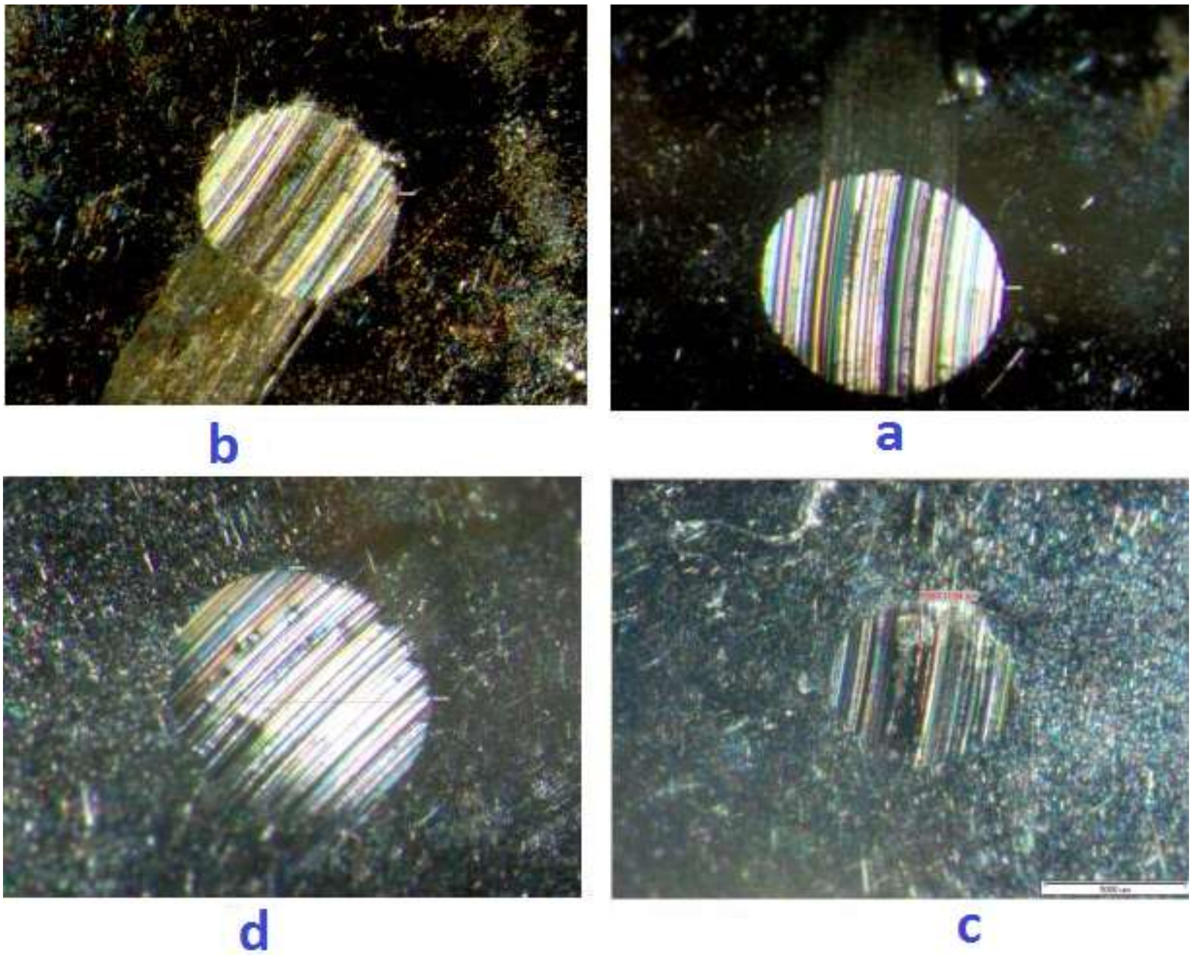

Figure15. The optical micrographs of worn surfaces for the B50 blend containing a) 0 ppm b) 25 ppm c) 50 ppm d) 75 ppm nanoparticles under 1000 RPM

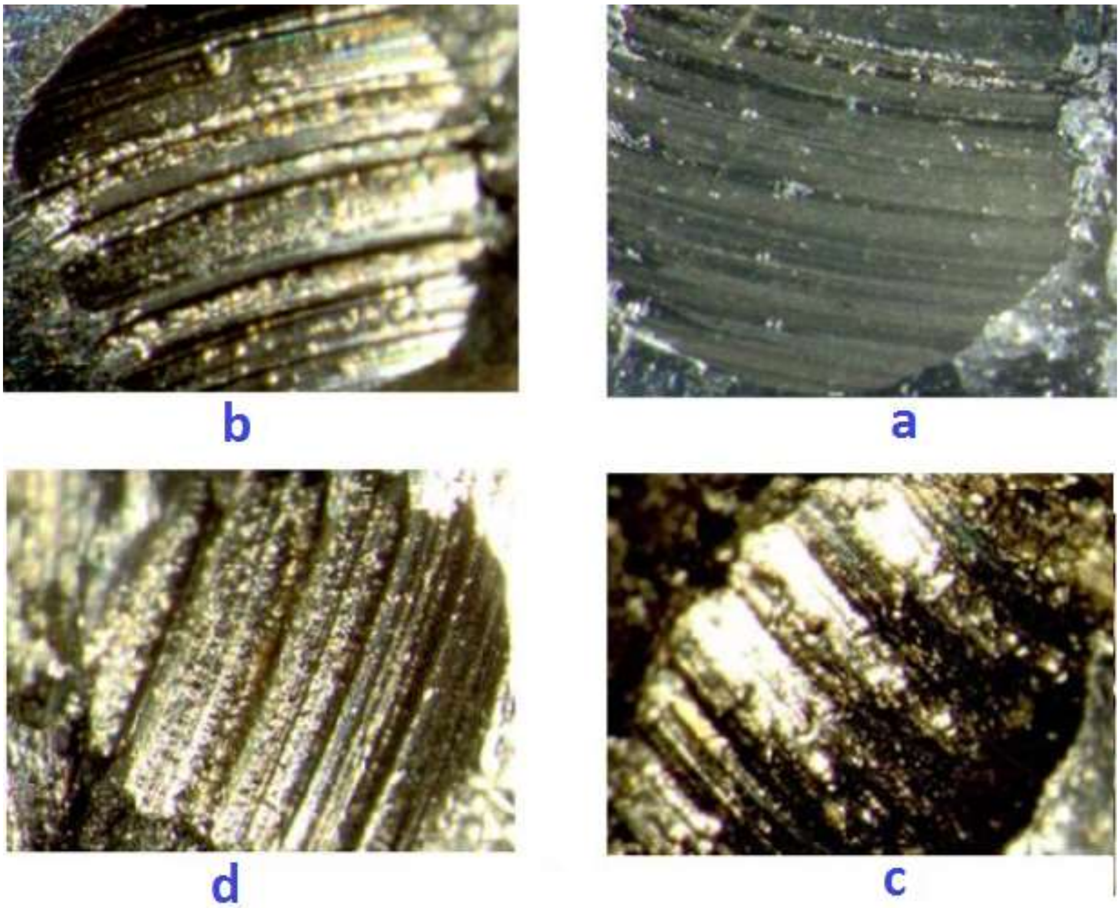

Figure16. The optical micrographs of worn surfaces for the B10 blend containing a) 0 ppm b) 25 ppm c) 50 ppm d) 75 ppm nanoparticles under 1500 RPM

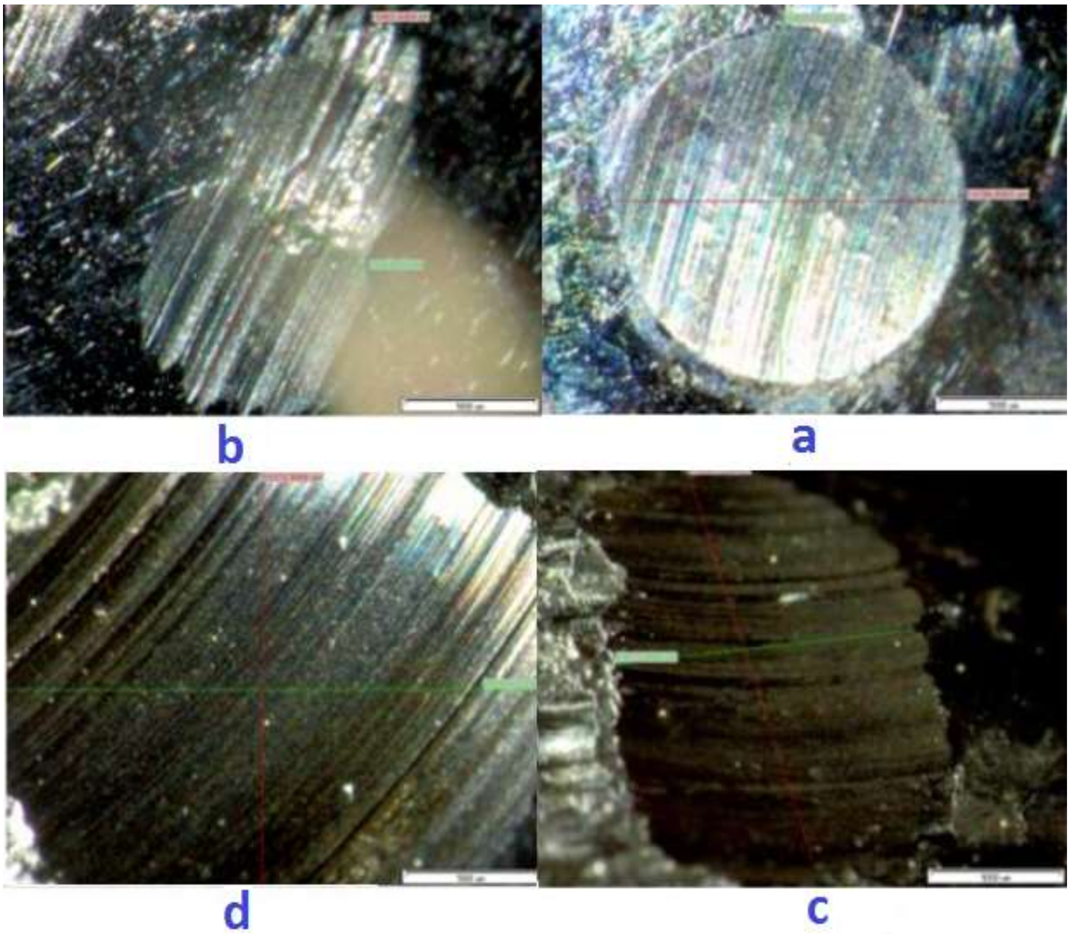

Figure17. The optical micrographs of worn surfaces for the B20 blend containing a) 0 ppm b) 25 ppm c) 50 ppm d) 75 ppm nanoparticles under 1500 RPM

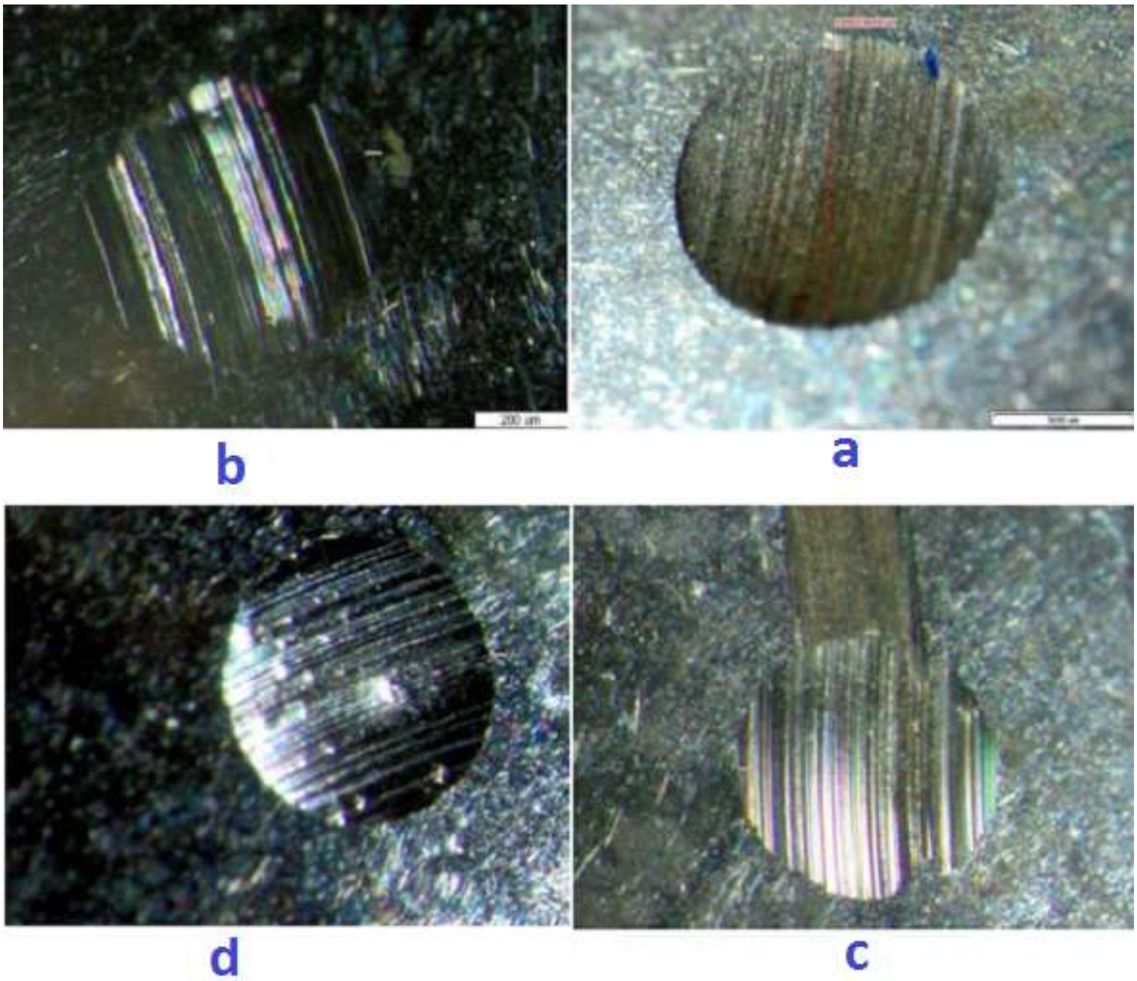

Figure18. The optical micrographs of worn surfaces for the B50 blend containing a) 0 ppm b) 25 ppm c) 50 ppm d) 75 ppm nanoparticles under 1500 RPM

The figures demonstrate that the wear scar diameter decreases with the increase of biodiesel concentration and also with the addition of nanoparticles up to 50 ppm. On the other hand, the scratches and roughness on the surface also decreased. However, an increase in rotational speed resulted in an enhanced roughness on the surface of balls. Moreover, CuO nanoparticles form a self-laminating protective film on the friction-bearing surfaces that converts sliding friction to rolling friction [20].

5. Conclusion

In the present study, copper oxide nanoparticles were used in biodiesel-diesel blends to evaluate the wear scar diameter on the balls. It can be concluded that:

-With increasing the CuO nanoparticles fraction in the biodiesel-biodiesel up to 50 ppm, the wear scar diameter decreases that it indicates the better lubrication property of the mixture.

-Using copper oxide nanoparticles with a dosage of 75 ppm in the fuel blend causes a higher WSD compared with 50 ppm. This increase is higher for speed of 1500 RPM compared with 500 and 1000 RPMs

-Generally, the WSD increases for all fuel blends when the speed increases as the result of higher temperature conditions and lower viscosity of fuel mixture at high RPMs

-The wear scar diameter reduces as the biodiesel content of the mixture increases for all rotational speeds.

-The scratches and roughness on the surface also decreased with an increase of biodiesel concentration and addition of nanoparticles up to 50 ppm in the fuel mixture.

-CuO nanoparticles form a self-laminating protective film on the friction-bearing surfaces that converts sliding friction to rolling friction.

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