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# ENHANCING TRIBOLOGICAL PROPERTIES OF EPOXY COMPOSITES WITH NANO PARTICLES OF ZnS

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## ABSTRACT
**Because of their special properties, ZnS nanoparticles have a number of benefits and can be used in a variety of applications. These include of coating, biomedical, photovoltaic, sensors, and UV and optical light. Zinc sulfide's many uses and benefits are what motivated us to employ it as an epoxy reinforcing ingredient to create epoxy composites with superior mechanical and tribological properties. Furthermore, very few researches have examined the tribological characteristics of zinc sulfide as an epoxy reinforcing material. This study examined the friction, hardness, and wear of epoxy composite reinforced with varying concentrations of zinc sulfide nanoparticles (0.1, 0.3, 0.5, 0.7, and 0.9 wt. %) under dry sliding condition and at room temperature under normal loads of 5 and 7 N. The test samples' hardness was measured using hardness tester (DVK-1A-6 Time Group Inc., Taiwan). Scaninng electron microscope (SEM) was used to examine the samples' worn surfaces. The findings demonstrated that zinc sulfide in its nanoform improved the epoxy composites' friction, hardness, and wear, making them viable materials for a variety of tribological applications.**

## KEYWORDS
**ZnS, nano composites, friction, hardness, epoxy, wear.**

## INTRODUCTION
**The variety of uses for epoxy resin can be expanded by adding reinforcing elements, such as organic and inorganic fibers, to strengthen the epoxy resin. Adding these organic and inorganic fibers enhances the epoxy composite's mechanical properties. Creating a friction layer on the friction surface, which keeps the two surfaces from coming into direct contact, lowers the coefficient of friction and improves tribological properties. Additionally, adding these fibers to the composite increases its strength, improving wear resistance, [1-7]. As prior studies have shown, epoxy composites are interesting materials, particularly for tribological applications.**

**Recent research has examined nano-additions' application as reinforcing agents in epoxy composites. A combination of alumina and graphite or alumina and silica in nanoparticle form has been utilized as reinforcing materials for epoxy composites.**

**Further studies have employed titanium or $Ti_3C_2$ nano-additions as reinforcing agents in epoxy composites, [8–12]. These studies produced encouraging findings that enhanced the mechanical and tribological properties. Nevertheless, alumina and silica-containing epoxy composites exhibited a higher wear rate.**

**Other researchers have used molybdenum dioxide in the presence of carbon nanotubes as a reinforcing material for epoxy composites. Results showed that using a ratio of 6% molybdenum dioxide and 4% carbon nanotubes in the epoxy composite improved the tribological properties of the composite, [13, 14]. Some researchers have been interested in improving the tribological properties of epoxy as a coating material by adding nano- and micron-sized materials to obtain epoxy coating composites with distinctive tribological properties, [15]. Epoxy composites are compounds with many tribological uses that show promise. Nevertheless, little study has been done on employing nano ZnS as reinforcing elements for epoxy composites. This study aims to create epoxy composites with promising tribological properties by examining the tribological characteristics of novel epoxy composites reinforced with ZnS nanoparticles.**

## EXPERIMENTAL

**Zinc sulfide in nanoparticle form was employed as an epoxy reinforcement to increase epoxy composites' mechanical and wear resistance and to investigate how adding it affected the coefficient of friction. With particle sizes varying from 30 to 200 nm, Fig. 1 displays the TEM of the zinc sulfide that was used and bought from a store.**

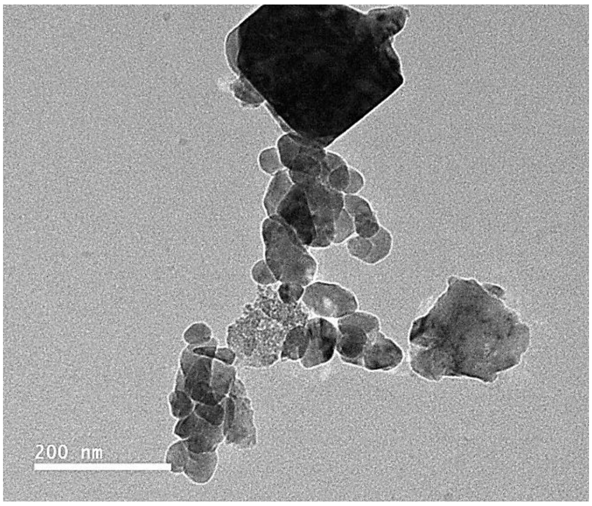


**Fig. 1 TEM analysis of ZnS nano particles.**

**In a plastic container, zinc sulfide was mixed with epoxy at weight ratios of 0.1, 0.3, 0.5, 0.7, and 0.9 wt. %, to prepare the samples. After 10 minutes of slow, constant stirring, the sample was drawn via a syringe that was 30 mm long and 9 mm in diameter, which served as a sample mold. The curing process was then allowed to finish for a full day while the syringe was kept vertical.**

**Using the syringe plunger to remove the sample and cutting the nozzle, the sample was extracted from the syringe (mold). A description and explanatory photos of the**

**samples are presented in Fig. 2. The sample's dimensions are 9 mm in diameter and 12 mm in length.**


**Fig. 2 Epoxy and Epoxy composite samples.**

**Using the Pin-on-Disc device depicted in Figure 3, friction tests were performed. The device comprises of a disc mounted on an electric motor with a vertical reduction gear and a 140 rpm rotating speed. The disc is 10 mm thick, 170 mm in diameter, and has a hardness of (269 HB). The disc and the pin meet at a wear track diameter of (100 mm). A load cell is incorporated inside the device to measure the tangential friction force. Dividing the friction force by the vertical load yields the coefficient of friction. The weight loss (the difference between the sample weight before and after the experiment) is used to calculate wear. Every experiment was carried out at room temperature with a normal load set to 5 and 7 N and moving at a speed of 0.73 m/s. The disc surface was sanded prior to the experiment in order to guarantee constant experimental conditions. To assure accuracy, three repetitions of the tests were conducted, and the average findings were obtained. The hardness of the tested samples was evaluated using Vicker's hardness tester (DVK-1A-6 Time Group Inc., Taiwan). The cylindrical specimen's top circular base was used to assess the hardness against a 1 kg weight. Three measurements were averaged to determine the hardness values. To examine the worn surface of the tested specimens, a Scanning Electron Microscope was employed (SEM).**

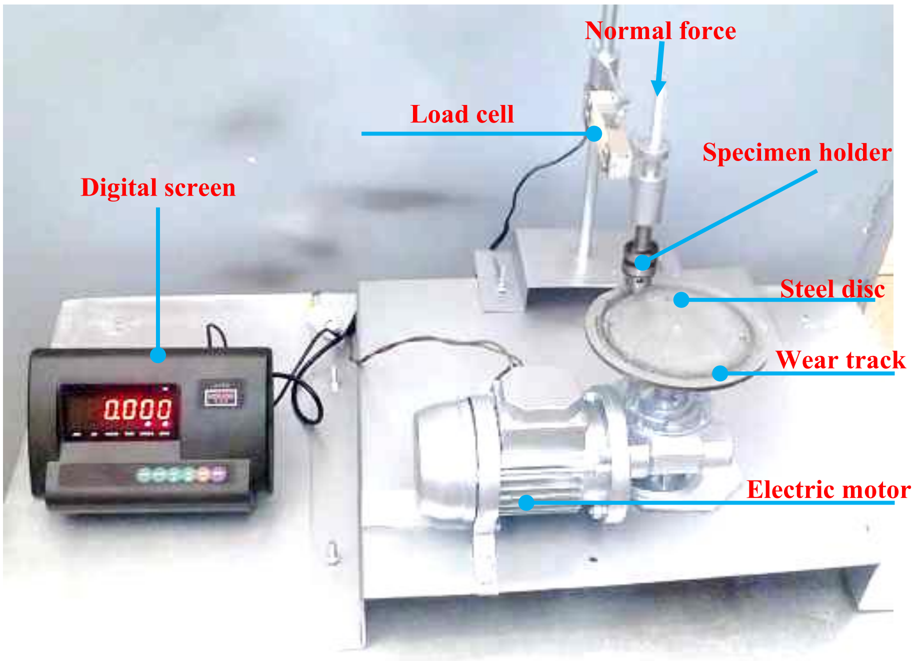


Fig. 3 Configuration of pin-on-disc tester.

## RESULTS AND DISCUSSION

This section presents a study of the outcomes of wear, friction, and hardness tests for epoxy composite samples with varying weight percentages of nano zinc sulfide concentrations (0.1, 0.3, 0.5, 0.7, and 0.9). Figure 4 shows how the content of nano-zinc sulfide in the epoxy composite and its coefficient of friction relate to vertical loads of 5 and 7 N at room temperature in a dry experimental condition. As the concentration of nano-zinc sulfide rises, the figure indicates that the coefficient of friction values fall marginally in comparison to the pure epoxy until they approach 0.5%, at which point they start to increase. The vast range of sizes of the nano-zinc sulfide particles, from 30 to 200 nm, may account for the variations in the coefficient of friction values. There is a greater chance of existence big zinc sulfide particles on the wear surface when high quantities of nano-zinc sulfide are introduced to the epoxy composite, which raises the coefficient of friction values. With a concentration of 0.9 wt. % zinc sulfide, the coefficient of friction rises to 0.82, 20% higher than that of pure epoxy. The graphic also illustrates how friction coefficients are affected by normal load. Friction coefficients were shown to rise in proportion to the normal load.

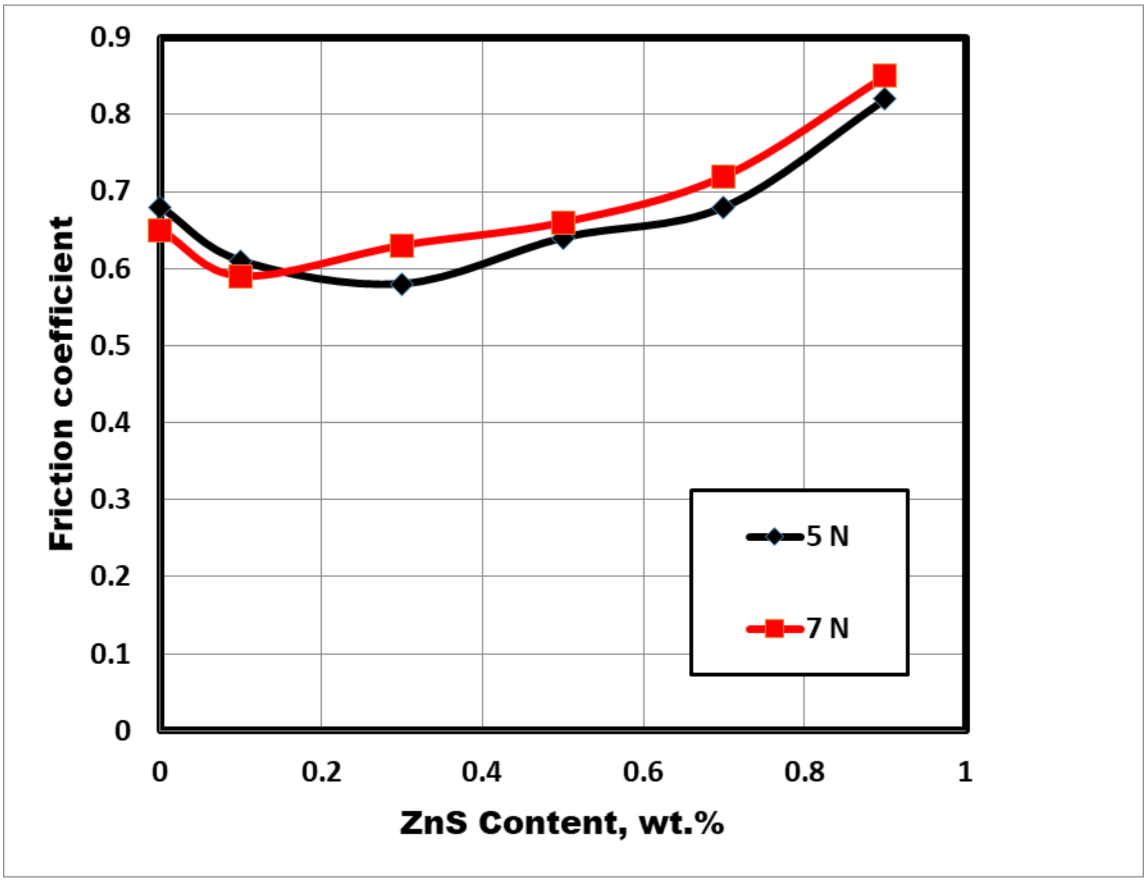


**Fig. 4 Friction coefficients of Epoxy composites reinforced by varying ZnS nanoparticles concentrations.**

**The investigation of adding varying percentages of nano zinc sulfide to epoxy composite and its impact on wear at vertical loads of 5 and 7 N is depicted in Fig.5. The figure illustrates how wear values vary as the weight percentage of nano zinc sulfide increases. At a rate of 0.3% zinc sulfide, the wear value drops to its lowest of 3 mg. Following that, the curve's form starts to change as wear and the concentration of nanozinc sulfide rise. The epoxy composite's hardness and mechanical properties have increased with the inclusion of nano zinc sulfide. An explanation for the variation in wear values can be found by examining curves 6 and 7. Wear and hardness are inversely correlated; the harder the composite, the less wear there is, and vice versa. The epoxy composite with 0.3% nano zinc sulfide had the lowest wear value (3 mg), and the highest hardness value (33.3%). Epoxy composite with 0.9% nano zinc sulfide had the lowest hardness value (14.5) and the highest wear value (19.5 mg). As the vertical load increases, the wear value rises as well; this is especially noticeable when the load goes from 5 to 7 N.**

**The hardness of epoxy composites is greatly influenced by the dispersion of ZnS nanoparticles, more especially the size and location of the particles within the epoxy. When fine, hard particles are scattered across a softer matrix, dislocations are impeded, reinforcing and hardening the material. This process is known as dispersion strengthening. A number of variables, including particle size, spacing, and volume fraction, affect how successful this strengthening mechanism is. In the current research, the size of zinc sulfide nanoparticles ranges from 30 to 200 nanometers, which is a wide range. Therefore, we find this large variation in the**

**hardness values shown in Fig. 5, which results in different wear values. This range of zinc sulfide particles contains very fine and coarse grains. Fine grains are well dispersed and distributed within the epoxy, resulting in a harder epoxy composite and vice versa. Therefore, we recommend researchers use only very fine zinc sulfide nanoparticles to achieve better dispersion and high hardness in the composite.**

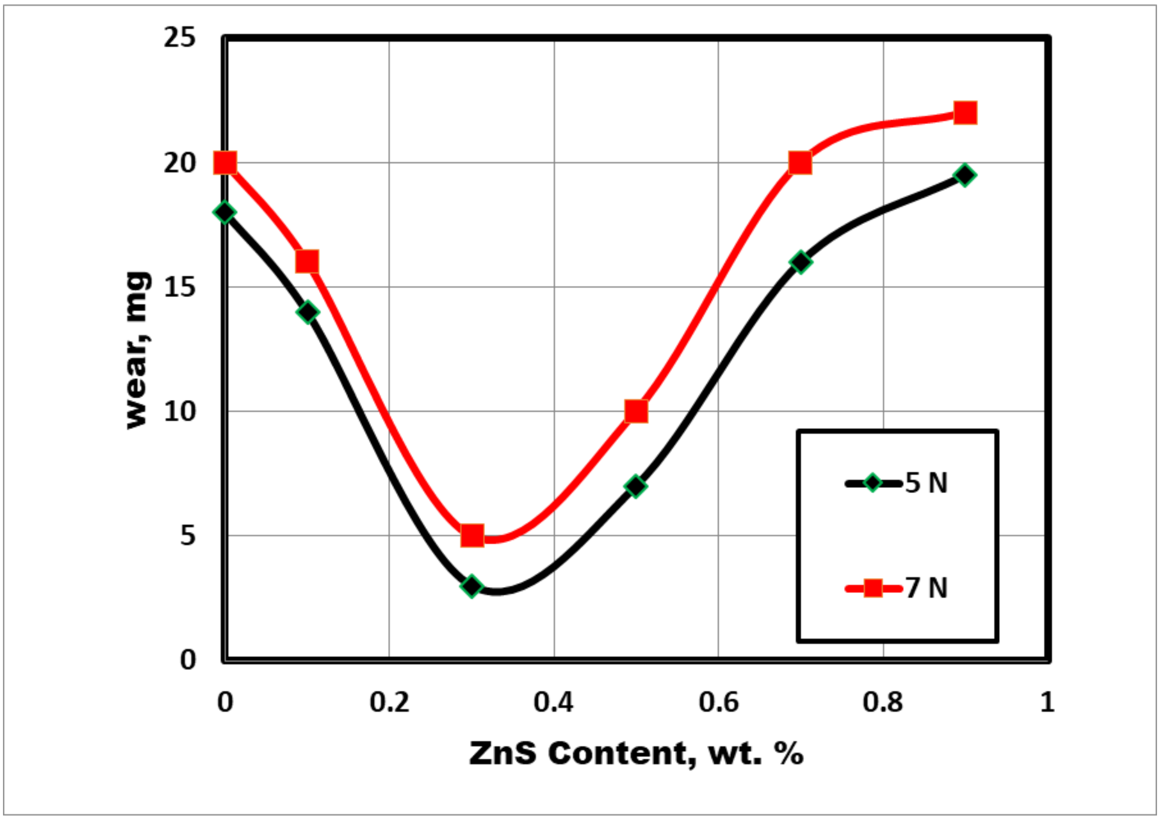


**Fig. 5 The wear of Epoxy composites reinforced by varying ZnS nanoparticles concentrations.**

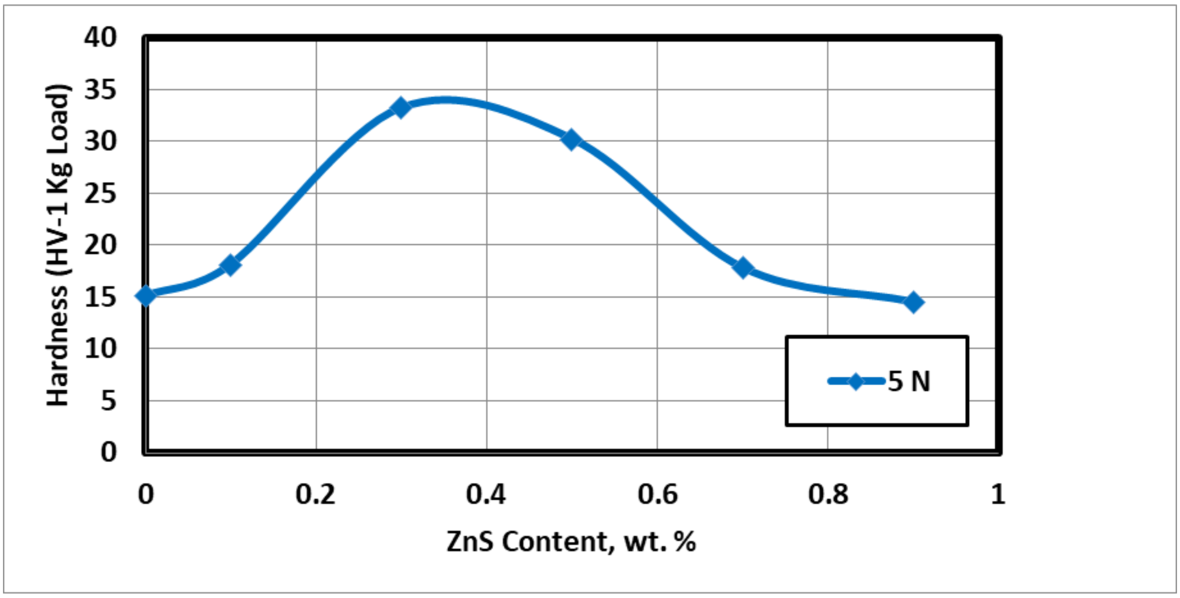


**Fig. 6 The hardness of Epoxy composites reinforced by varying ZnS nanoparticles concentrations at normal load of 5 N.**

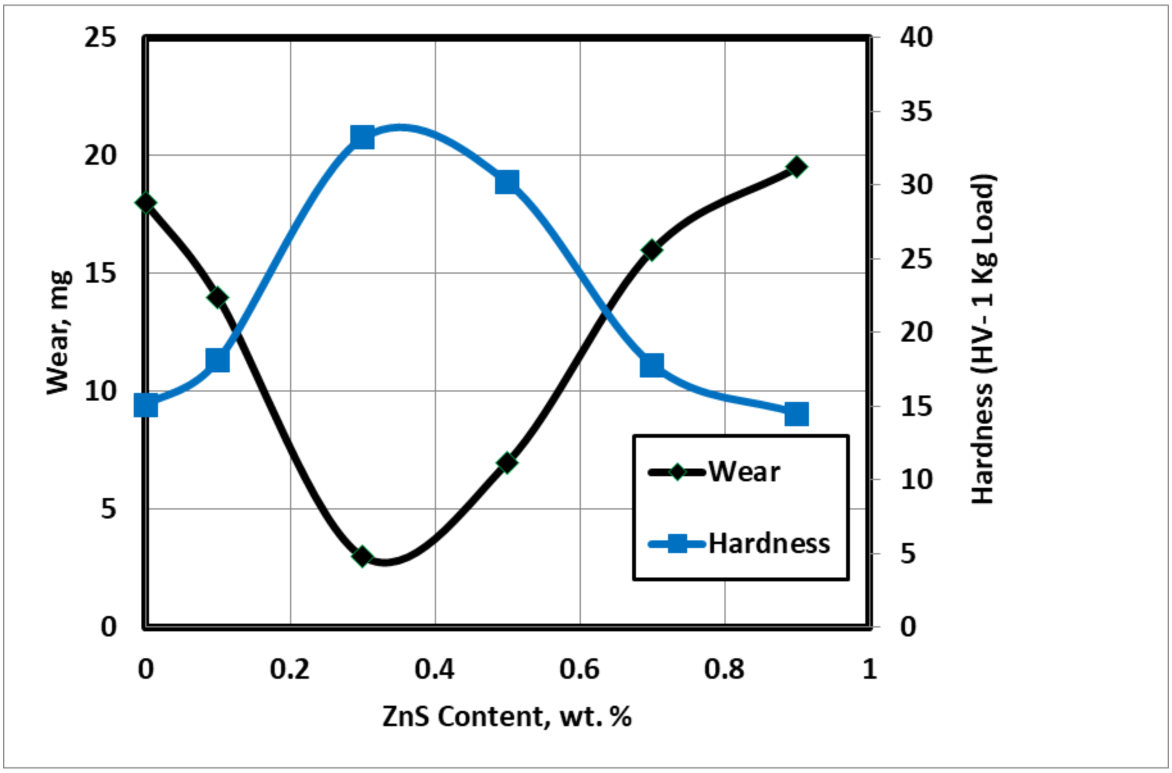


**Fig. 7 The wear and hardness of Epoxy composites reinforced by varying ZnS nanoparticles concentrations at normal load of 5 N.**

**Scanning electron microscopy (SEM) photographs of the worn surfaces of epoxy composite reinforced with 0.9 weight percent ZnS at 5 N normal load at various magnifications are displayed in Figure 9. As can be seen in the pictures, both the a and b SEM micrographs show scratches as well as surface fragments and plastic flow of the material surfaces.**

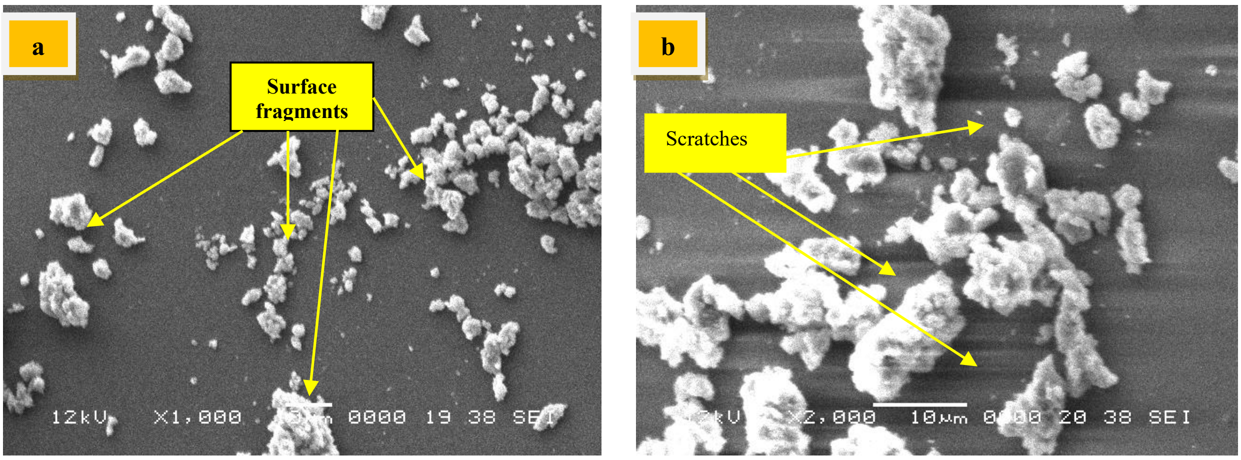


**Fig. 8 SEM images of the worn surfaces of Epoxy composite reinforced by 0.9 wt. % ZnS at 5 N normal load at different magnifications a (x1000) and b (x2000).**

## CONCLUSIONS

**The zinc sulfide nanoparticles improved the epoxy composites' hardness, wear, and friction, according to the results, which made them appropriate materials for a variety of tribological applications. Hardness and wear are inversely correlated; the harder the composite, the less wear it endures. The epoxy composite containing 0.3% nano zinc sulfide recorded the maximum hardness value (33.3%) and the lowest wear value (3 mg). Highest wear value (19.5 mg) and lowest hardness value (14.5) were found in epoxy composite containing 0.9% nano zinc sulfide. The addition of nano zinc sulfide has improved the mechanical and hardness characteristics of the epoxy composite. The dispersion of ZnS nanoparticles has a significant impact on the hardness of epoxy composites. A hardener epoxy composite is produced when fine granules are evenly distributed throughout the material, and vice versa. For improved dispersion and great hardness in the composite, we advise researchers to utilize only extremely fine zinc sulfide nanoparticles.**

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