Experimental study of Wear Rate Behavior for Composite Materials under Hygrothermal Effect

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Abstract

The behavior of wear for composite materials with effect of hygrothermal was investigated experimentally. The pin-on-disc wear rig was manufacturing. The wear parameters, distance, humidity, applied load, temperature, and speed on the wear behavior was investigated. These composite materials consist of (fiberglass and polyester resin), with (40%) volume fraction. The results give the increasing of humidity and, or temperature causes increasing in glass-fiber/polyester composite's wear. Also, increasing the load, distance and sliding speed, will be led to an increase in the wear of glass fiber/polyester.

Key Words: composites, Hygrothermal, Wear.

1. Introduction

The wear occurs through the interaction between surfaces, causing the material to be deformed on the surface as a result of the mechanical work of the corresponding surface [1]. In the wear, dimensional loss of plastic deformation may result from the interference between two sliding surfaces. Composite materials are distinguished by their high strength at low specific weight; therefore, they are more preferred than steels and other metals. The many researchers studied the behavior of wear to increasing the resistance of wear for composites materials due to importance of the tribological properties [2]. Hygrothermal is the change in properties due to moisture absorption and temperature change or relating to a combination of heat and moisture. Effect of hygrothermal caused the polymer degradation resulting from exposure to moisture absorption and high temperatures in the composite materials causes expansion of the fiber inside the matrix resulting in severe internal stresses. I.C. Visconti et.al [3], observed at different values of pressure and sliding speed, the variation of wear behavior of the composite materials. It was found that for all the materials examined the wear rate increases as the normal load increases, but not linearly. N. Tosun [4], used a block-on-disk wear device to study the behavior of wear for composite (glass-fiber-polyester) at two different loads (500 and 1000 g) and speeds (500 and 710rpm). The load effect is more than speed effect on the wear behavior of the specimens. A. Babilius [5], investigate the effect of temperature and speed on the adhesive wear. The wear was also studied for several different temperatures at various sliding speeds and constant 90 N load. Also note that the wear rate
was increased due to a decrease in speed from 0.3 m/s to 1.5 m/s. Kwon-yeong Lee et al. [6] evaluated the effects of distance and temperature on the metal-to-metal wear behavior of (Fe-20Cr-1.7C-1Si) in the distance up to 18 m at 300 and temperature range from 25 to 450 °C. The wear rate increased significantly from the beginning of the wear test and became almost saturated over the 3.6 m distance. S. Narendranath et al. [7], investigated the applied load effect on dry sliding wear property of aged TiNiCu alloy. It was found that increasing the aging temperature leads to an increased wear rate. This is due to a decrease in hardness of the Ti50Ni45Cu5 alloys. Abrasion, adhesion, brinelling and surface fatigue are main mechanisms that they have important contributions to the wear characteristics of the aged Ti50Ni45Cu5 alloys. The main objective of this work is to determine the effects of hygrothermal on the wear behavior of composite materials. To accomplish this goal, the process is the experimental work, which is included designing and construction of the wear test rig (pin on disc) and a hygrothermal chamber.

2. Experimental Work
2.1. Materials
In this paper the wear test samples were manufactured from composite materials. These samples are made up of fiber glass and polyester with (40%) volume fraction. The dimensions of wear test samples are 1 cm diameter, 4 cm length [8,9] as shown in figure (1).

![Figure (1) Desired Samples](image_url)

2.2. Device of Wear Measurement
The (pin on disc) is a device used to measure wear rate that was manufactured according to ASTM G-99 standards [10]. Figure (2) shows (pin on disc) device schematic diagram. Figure (3) shows the device used in this work (pin on disc).

2.3. Chamber of Hygrothermal
Chamber of hygrothermal effect was used in this work to investigate the hygrothermal effect of composite materials. Figure (4) shows (chamber of hygrothermal) schematic diagram and figure (5) shows (chamber of hygrothermal) photograph [11].
Figure (2) (Pin on Disc) Schematic Diagram

Figure (3) (Pin on Disc) Device Photograph
2.4. Plan of Experiments

The plan of experimental was formulated considering five parameters and three levels. The five parameters are (temperature, sliding speed, load, humidity, and distance). Table (1) shows the parameters and used in this work. [12,14]

| Levels | Sliding speed, (rpm) | Load (N) | distance, (m) | Temp C° | Humidity % |
|--------|----------------------|----------|---------------|---------|------------|
| 1      | 100                  | 10       | 500           | 25      | 50         |
| 2      | 200                  | 20       | 1000          | 40      | 75         |
| 3      | 300                  | 30       | 1500          | 60      | 95         |

Figure (4) (Chamber of Hygrothermal) Schematic Diagram

Figure (5) (Chamber of Hygrothermal) Photograph
3. RESULTS AND DISCUSSION

The aim of experiments was to study the effect of applied load (A), speed (B), distance (C), temperature (D) and humidity (E) on the dry sliding wear of the composite materials.

3.1 Humidity Effect on Wear Rate Behavior

Figure (6) shows the effect of humidity on the wear of glass fiber/polyester at temperature of 25°C, speed of 100 rpm, and load 10N, for (500, 1000 and 1500 m) distance. Also, it is noticed that increasing of the distance cause increased the wear rate. wear of glass fiber/polyester will be increased (53.3%, 62.5% and 57.8%) for distance of (500, 1000 and 1500m) respectively, with the increases in humidity from (50% to 70%). Figures (7) and (8) give same relation as figure (6) for loads of (20 and 30N) and temperatures of (40ºC and 60ºC) respectively, in which both results are similar. From figures (6), (7) and (8) it can be seen that increasing the load causing increased the wear of glass fiber/polyester. This increase is due to the heat generated by friction [14]. Also, increases of the humidity causes increased the wear of glass fiber/polyester.

Figure (9) shows the effect of humidity on the wear of glass fiber/polyester at temperature of 25°C, speed of 200 rpm, and load 10N, for (500, 1000 and 1500 m) distance. Wear of glass fiber/polyester will be increased (17.8%, 10% and 12.1%) for distance of (500, 1000 and 1500m) respectively, with the increases in humidity from (50% to 70%). Figures (10) and (11) gives same relation as figure (9) for loads of (20 and 30N) and temperatures of (40ºC and 60ºC) respectively. It can be indicated from figures (9), (10) and (11) increased the load causes increased the wear of glass fiber/polyester [15]. Also, it can be noted that increased temperature and humidity causes increased the wear of glass fiber/polyester.

3.2 Effect of Temperature on Wear Rate Behavior

Figure (12) illustrates the effect of the temperature on the wear of glass fiber/polyester at 50% (humidity), 100 rpm (speed), 500 m (distance), for (10, 20 and 30N) loads. It can be seen that the increase in temperature leads to increased wear. wear may be expected to increase with increasing temperature due to reduced hardness and yield strength. Therefore; wear of glass fiber/polyester will be increased (85.4%, 40.6% and 30%) for loads of (10, 20 and 30N) respectively, with the increases in temperature from (25°C to 40°C). Figures (13) and (14) give same result found in figure (12) for (200 and 300 rpm) speed and (70% and 95%) humidity respectively, in which both results are similar. From figures (12), (13) and (14) obviously, increasing the speed leads to increased wear of glass / polyester fibers [16].

Figure (15) illustrates the effect of the temperature on the wear of glass fiber/polyester at 50% (humidity), 100 rpm (speed), 1500 m (distance), for (10, 20 and 30N) loads. The wear of glass fiber/polyester will be increased (83%, 13.2% and 6.1%) for loads of (10, 20 and 30N) respectively, with the increases in temperature from (25°C to 40°C). Figures (16) and (17) give same relation as figure (15) for speed of (200 and 300 rpm) and humidity of (70% and 95%) respectively, in which both results are similar [17].
Figure (6) Variation of wear with humidity at 25°C (temp), 10N (load), 100 rpm (speed)

Figure (7) Effect of humidity on the wear at 40°C (temp), 20N (load), 100 rpm (speed)

Figure (8) Effect of humidity on the wear at temp=60°C, (load=30N) and (speed=100rpm)
**Figure (9)** Effect of humidity on the wear at 25°C (temp), 10N (load), 200 rpm (speed)

**Figure (10)** Effect of humidity on the wear at 40°C (temp), 10N (load), 200 rpm (speed)

**Figure (11)** Effect of humidity on the wear at temp=60°C, (load=30N) and (speed=200rpm)
Figure (12) Effect of temperature on the wear at speed=100rpm, (distance=500m) and (humidity50%)

Figure (13) Effect of temperature on the wear at speed=200rpm, distance=500m and (humidity70%)

Figure (14) Effect of temperature on the wear at speed=300rpm, distance=500m and (humidity95%)
Figure (15) Effect of temperature on the wear at speed=100rpm, (distance=1500m) and (humidity50%)

Figure (16) Effect of temperature on the wear at speed=200rpm, distance=1500m and (humidity70%)

Figure (17) Effect of temperature on the wear at speed=300rpm, distance=1500m and (humidity95%)
4. Conclusion:

1. Increasing the sliding speed, distance and load will be led to an increase in a wear of (fiber glass-polyester) composite.

2. The effect of hygrothermal was a great on the wear of (fiber glass-polyester) composite.

3. In composites materials (used in this work), The most influencing factor is applied load compare with other factors.

4. For the purpose of describing wear in composites materials, the experimental method can be used to describe behavior

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