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Assessment of Wearing Resistant Property of the Fabricated Polymeric Ceramic Material

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ABSTRACT:
Background: A specific kind of substance in a polymeric material acts as a supporting framework, and the ceramic fragments enclosed within it are called a polymer-matrix ceramic composite. Due to the way distinct layers of composites attach to each other, the failure of composites varies from the characteristics of normal materials, and their efficacy is determined based on their wear-resistant properties.
Purpose: The aim of the study is to investigate the wear-resistant behaviors of commonly used composite materials.
Methods: Al_2O_3 and ZrO_2 are the ceramic materials chosen for the investigation, while epoxy (formaldehyde and phenol) is the polymer chosen. By altering the weight proportion of the ceramics in the matrix of polymers, the study evaluates the outcomes of wear resistance.
Results: The results show that up to 30% of the time, the zirconia composites wore out more quickly than the alumina composites.
Conclusions: The study focuses on determining the wear-resistant behavior of zirconia and alumina composites, providing insights into their use in weight-sensitive applications.

Keywords: Wearing Resistant, Polymeric Ceramic material, Alumina Composites, Zirconia Composites

1. Introduction

Wear mechanisms such as wear and tear, stress, binding, exhaustion, deterioration, and other tribochemical reactions are all included in material wear processes, either alone or in combination. To minimize structural degradation or loss from wear, wear-resistant polymers have been worked out or produced. One of the best ways to lessen wear is through surface engineering since it is a surface phenomenon, and the wear condition of materials is correlated with their surface characteristics and structures. It includes a number of surface and subsurface physical and/or chemical modification procedures, while the bulk structures and attributes remain unchanged [1]. By reducing the impact of the usually complicated metallic matrix (high-speed steel, Al alloys, Mg alloys), the effect of the ceramic particles on the wear behavior of particulate composites was examined. For this, a soft, uniform polymer matrix with extremely low wear resistance was used in place of the metallic matrix. Thus, simulated composites based on polymers were produced [2]. In recent years, alumina-mullite-zirconia composites have drawn a lot of interest for structural uses at high temperatures. Such composites are known for their exceptional thermal stability, appropriate mechanical qualities, and high resistance to thermal shock. According to Khorsand et al., [3] these effective composite materials have also been acknowledged as promising options for wear-resistant parts, including tubes, O-rings, nozzles, and the glass industry. Excellent characteristics of zirconium dioxide include high strength, high fracture toughness, high hardness, effective wear resistance, and high resistance to chemical substances. Therefore, ZrO_2 nanoparticles seem like a desirable choice for reinforcing polymers to create composites with improved performance. Certain nanoparticles, such as titanium dioxide, aluminum oxide, and silicon dioxide zinc dioxide have recently been investigated as fillers in epoxy resins. They have been proven to be effective in improving the mechanical properties of epoxies, and in some situations, their toughness in particular [4]. The fundamental materials of two distinct polymer lattice ceramic composites—alumina and zirconia—are examined in this work. The tearing rates between the two ceramics at various combinations are computed and compared when both materials are exposed to heat and pressure at various combinations in the polymer lattice in order to determine the optimal aggregation for each composite. To determine whether ceramic produces more advantageous modifications in substances, the results of the two ceramic-based composites must be compared.

2. Review of Literature

Uyar et al., [5] Aligned fibers are arranged layer by layer with various configurations and have a spherical or crossing pattern. A fiber load of 0.25% or more yields the maximum flexural strength.Polymethylmethacrylate (PMMA) is ate that common foundation acrylic material for dental appliances. However, because of its poor strength, it might lead to problems with fracturing or breaking in the prosthetic medical specialty. Paz et. al [6] Nanopowders of graphene and graphene chemical compounds were employed as reinforcing agents in acrylic bone cement. The nanocomposites' mechanical and thermal essences were described. Because of the variations inside the crack fronts and the impeded crack propagation, the results indicated better mechanical proficiency, especially fracture toughness and fatigue proficiency, at subdued loadings ($\leq 0.25wt\%$). Xie et al., [7] Involve in developments in employing graphene and its derivatives to improve the bioactivity and essences of biomaterials are covered. To affect stem cell development and enhance the qualities of biomaterials, they have a vigorous specific area and mechanical strength. Along with safety concerns for its use in medical, regenerative, and rehabilitative applications, Moldovan et al., [8] Synthesized was used to create graphene oxide-SiO2 by using Ballroom dancing and decreased graphene oxide-SiO2 composites. Wet chemical methods were used to create hydroxyapatite-SiO2- SiO2 and thermally conditioned hydroxyapatite-SiO2 composites. Alp et al., [9] Three distinct brands of prepolymerized CAD-CAM PMMA and a common heat-polymerized PMMA dental appliance base material were used to create six disk-shaped specimens. A noncontact spectroradiometer was used to calculate color coordinates and evaluate facade roughness three times before and after CTC. CIEDE2000 color distinction and RTP formulae were used to compute color variations and relative semi-transparency parameter (RTP) values.

3. Methodology

3.1. Fabrication of Ceramic Composites

Al_2O_3 and ZrO_2 are the ceramic materials chosen for the investigation, while epoxy (formaldehyde and phenol) is the polymer chosen shown in Fig 1. A Borosil hard glass test tube was used to create the composites. The combined mass of epoxy and hardening agent is measured. This experiment uses a 25.00% significant amount of hardening agent. Thus, to produce a weight of 7 grams, 1.75 grams of stiffener and 5.25 grams of epoxy are blended. The overall composition of each ceramic material is then determined by calculating its weight, and it is subsequently stored at 10%, 20%, and 30% in labelled paper packets. To make the ceramic composite, the solution needs to be given time to solidify. The ceramic powder must be dispersed so that much more material is towards the sides because the ends have a greater possibility of being worn out than the inside parts. Therefore, a centrifuge was used to rotate the test tube that contained the epoxy, hardening agent, and ceramic powder at a constant 350 rpm for

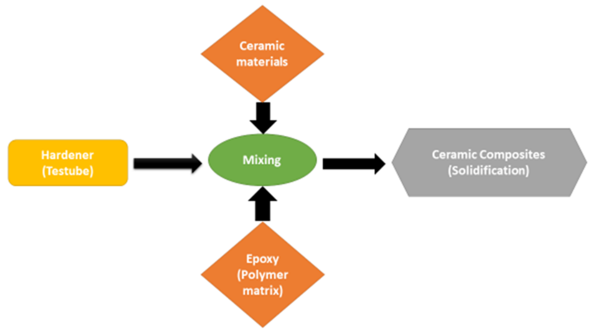

Figure 1: Steps involved in fabrication of ceramic composites

24 hours. The solidified ceramic composite is removed by breaking the glass.

Table 1: Quantity of Ceramic Components For Manufacturing Ceramic Composites

Ceramic material composition (%)	Weight of hardener required (gms)
10.0	0.80
20.0	1.80
30.0	3.20

3.2. *Wear Rate Characteristics*

The ceramic composites are at risk of disintegrating while in use. If the rate of tear is high under working conditions, the material may disintegrate and cause losses to both individuals and assets. Thus, it is essential to look into the tearing of the material. In this case, the tearing characteristics of the ceramic composites are examined using a pin-on-disc wear testing machine, as discussed in article [10]. A rough action is applied by putting the ceramic composite materials in contact with a rotating disc plate and applying the usual pressure to the sample via weight. In this process, the disc plate rotates at different RPMs of 250, 500, 750, and 1000.

4. Results and Discussion

4.1. *Experimental Data*

5. Discussion

The resistance of the surface layer to wear can be substantially higher than that of the underlying substrate when the surface composition and design of a material are carefully tuned. The main cause of this improved wear resistance is the deliberate alteration of the surface's chemical and physical characteristics, such as its coating, hardness, or roughness. These adaptations provide a barrier that shields the substance from wear-causing outside influences. It is impossible to overestimate the significance of optimizing both the interior, or bulk, composition and the surface. It is feasible to improve the component's total wear resistance without sacrificing its inherent mechanical qualities, such as toughness, strength, or flexibility, by carefully managing the bulk material's composition and structural design. This two-pronged strategy guarantees that the bulk and the surface cooperate to deliver enduring performance in demanding applications.

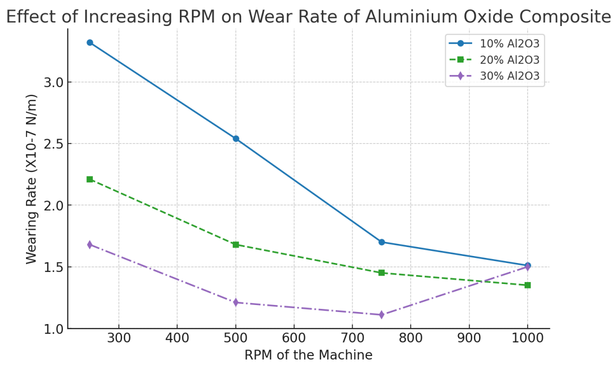

Figure 2: Wearing Rate of Aluminum Oxide Composites

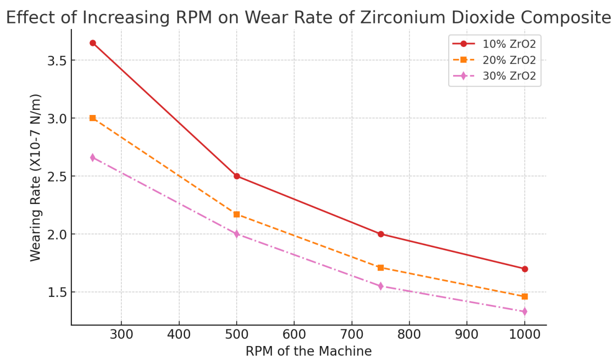

Figure 3: Wearing Rate of Zirconium Dioxide Composites

Added to that, experimental data from graphical representations show that the wear rate of materials like zirconia and alumina is drastically affected by the metallic disc's rotating speed (rpm) in a pin-on-disc wear testing system. In particular, the wear rate for both zirconia and alumina exhibits a declining tendency as the metallic wheel's rpm rises. According to this inverse connection, the frictional heat produced at greater speeds may cause surface smoothing or the

Table 2: Experimental Data for Zirconia Composites for 3.6 kg load and time=4 min 50 sec

Composite	RPM of the Machine	Initial Weight (gms)	Final Weight (gms)	Weight Loss (gms)	Sliding Distance (m)	Wearing Rate ($\times 10^{-7}$ N/m)
10% Al_2O_3	250	1.58	1.57	0.02	590	3.32
	500	1.56	1.53	0.03	1179	2.54
	750	1.54	1.50	0.04	1768	1.70
	1000	1.51	1.49	0.02	2356	1.51
20% Al_2O_3	250	1.48	1.45	0.03	589	2.21
	500	1.46	1.42	0.03	1178	1.68
	750	1.45	1.40	0.02	1768	1.45
	1000	1.40	1.36	0.04	2357	1.35
30% Al_2O_3	250	1.36	1.35	0.01	589	1.68
	500	1.35	1.32	0.02	1178	1.21
	750	1.33	1.31	0.02	1767	1.11
	1000	1.31	1.30	0.02	2356	1.50

Table 3: Experimental Data for Zirconia Composites for 3.6 kg load and time = 4 min 50 sec

Composite	RPM of the Machine	Initial Weight (gms)	Final Weight (gms)	Weight Loss (gms)	Sliding Distance (m)	Wearing Rate ($\times 10^{-7}$ N/m)
10% ZrO_2	250	2.23	2.20	0.02	589	3.65
	500	2.20	2.16	0.03	1177	2.50
	750	2.16	2.13	0.04	1767	2.00
	1000	2.13	2.08	0.04	2357	1.70
20% ZrO_2	250	1.58	1.56	0.02	589	3.00
	500	1.55	1.54	0.03	1178	2.17
	750	1.54	1.51	0.03	1766	1.71
	1000	1.50	1.47	0.04	2356	1.46
30% ZrO_2	250	1.92	1.90	0.02	589	2.66
	500	1.90	1.88	0.02	1179	2.00
	750	1.89	1.85	0.03	1767	1.55
	1000	1.86	1.82	0.03	2356	1.33

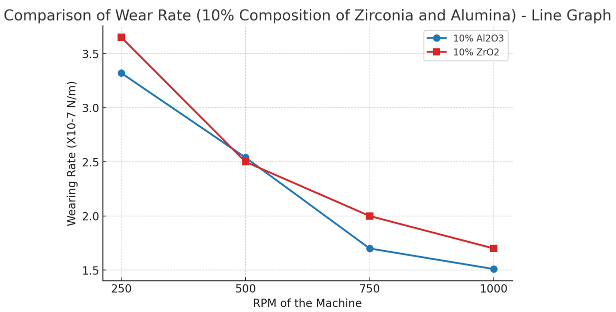

Figure 4: Comparison of wearing rate of 10% composition of Zirconia and Alumina

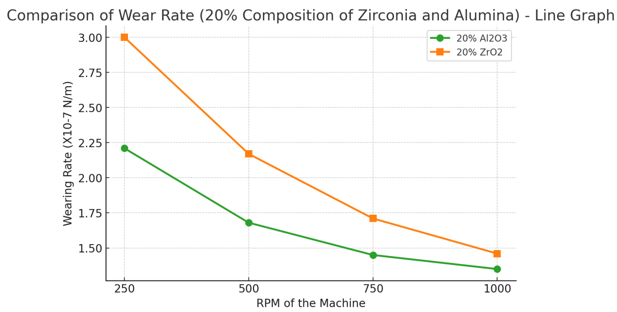

Figure 5: Comparison of wearing rate of 20% composition of Zirconia and Alumina

development of protective oxide layers, which prevent more wear. Figure 2 illustrates how increasing RPM affects the wear rate of composites made of aluminum oxide (AlO_3) at varying compositions (10%, 20%, and 30%). The impact of RPM on the wear rate of ZrO_2 composites, for varying compositions, is depicted in Figure 3. It is clearly apparent from the examination of Figures 4, 5, and 6 that zirconia and alumina composites behave quite differently in terms of wear. Zirconia composites wear more quickly than alumina composites up to 30% of the time. This discovery draws attention to the fundamental variations amongst these two ceramics' compositional and microstructural

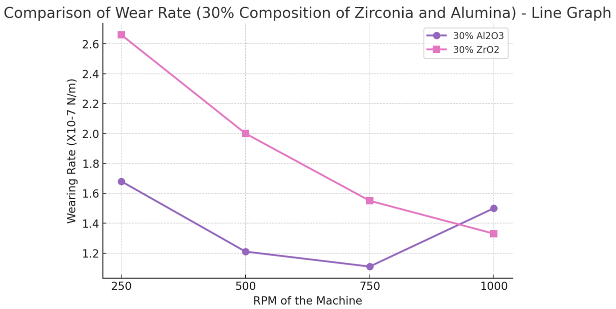

Figure 6: Comparison of wearing rate of 30% composition of Zirconia and Alumina

characteristics. Although zirconia is renowned for its remarkable toughness and capacity to convert under stress, under some circumstances, its decreased hardness relative to alumina may cause it to wear more quickly. Applications where abrasive wear is common are better suited for alumina because to its greater hardness and more brittle character. The disparity in wear rates emphasizes how crucial it is to choose the right ceramic material for a given industrial application based on operating parameters including load, speed, and environmental influences.

6. Conclusion

By changing the percentage of each composition (10.0%, 20.0%, and 30.0%) according to the weight of the ceramic material, several ceramic composites of zirconium dioxide (Zirconia) and aluminium oxide (Alumina) were produced in test tubes using the casting technique. We analysed at, compared, and showed the wearing characteristics of zirconia and alumina. The following conclusions came from the experiment's findings.

I The wearing rate decreases with increasing sliding distance. As sliding distance increases, the wearing rate varies for both zirconia and alumina.

II The wearing rate for alumina decreased as the ratio of the component by alumina weight increased around 30.0%.

III The wearing rate for zirconia decreases when the percentage of zirconia by weight increases to about 30.0%.

Aluminum oxide is a ceramic composite material that is more resilient to wear over zirconium dioxide due to the fact it deteriorates at a slower rate.

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Similarity Index: The authors hereby confirm that there is no similarity index in abstract and conclusion while overall is less than 10% where individual source contribution is 2% or less than it.

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