THE EFFECT OF ADDING ALUMINA AND GRAPHITE PARTICLES TO IMPROVE THE MECHANICAL PROPERTIES OF COMPOSITES [+]

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Abstract:

This research aim to study the effect of adding alumina and graphite particles on the mechanical and tribological properties of composite material based on an epoxy resins. The epoxy matrix was reinforced with (10-40) (wt %) of alumina particles to improve its mechanical and tribological properties.

Measurement of density, friction compressive strength and hardness revealed that the properties of the prepared composite were enhanced by the addition of the alumina particles. These improvements in the physical and mechanical properties lead to decrease the coefficient of friction, which is the tribological property we were aiming to decrease. (20%) alumina was found the best.

In order to enhance the friction property of the composite, some (wt %) of graphite powder was added to 20wt % alumina-epoxy composite. In fact this was the case; the coefficient of friction was decrease further more, and also the other physical and mechanical properties except hardness (which is considered as a surface property) giving a possibility of using the prepared composite in many different applications.

المستخلص:

تم في هذا البحث دراسة تأثير إضافة الالومينا والكرافيت لتحسين الخصائص الميكانيكية لراتنجات الايبوكسي بسبب الحاجة الى هذا النوع من المواد وعليه تم اختبار(١٠–٤٠)% وزنا من الالومينا كمادة داعمة للايبوكسي لمعرفة النسبة الافضل للاستخدام.

تم إجراء مجموعة من الاختبارات الميكانيكية والفيزياوية والترابولوجية للمادة المركبة المحضرة حيث اجري اختبار الانضغاط والصلادة كاختبارات ميكانيكية بينما تم اجراء اختبار الاحتكاك واختبار الكثافة كاختبارات ترابولوجية وفيزياوية على التوالي بعد تحضير العينات الخاصة بكل اختبار في محاولة للحصول على أفضل النسب والتي كانت بحدود ٢٠% من الالومينا. ولتقليل معامل الاحتكاك تم اضافة ٥% من الكرافيت وأجريت الاختبارات ثانية و وجد أن معامل الاحتكاك يقل إضافة إلى الخواص الأخرى ما عدا الصلادة والتي تعتبر كخاصية سطح. مما يفسح المجال أمام هذه المواد للتطبيقات المختلفة.

Introduction:

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The scientists of the material science noticed that there are differences in material types, properties, behaviors and applications. This result is reached because of the large need for many types of materials to be used in different applications to comply with the industrial development and growth [1].

Composites, are simply a result of uniting mainly two different materials, one of them is called matrix while the other is called reinforcing material. By using composites, the engineers can improve the physical and mechanical properties [2] of materials.

THEORETICAL PART:

Tribology

The concept of tribology is probably initiated in the year 1966 at the instigation of the JOST committee [3]. Tribology has been defined as the science and practice of interacting surfaces in relative motion. It encompasses, in addition to other topics, three classical subjects/disciplines, friction, wear and lubrication. Friction is usually classified as a branch of physics or of mechanical engineering. Wear is often considered to be a part of metallurgy or mechanical engineering. Lubrication and lubricants, which affect friction and wear, may come under the heading of chemistry. However, the surface interaction phenomena are so closely related that it is difficult to isolate one from another. This makes the study of tribology a multi-disciplinary concept [3].

Thus, for any tribological study the examination of its friction, wear and lubrication aspects are essential.

Figure (1) shows the interactions between friction, wear and lubrication. The shaded portion in the figure is considered as tribology. Thus, for any tribological study, the examination of its friction, wear and lubrication aspects are essential [4].

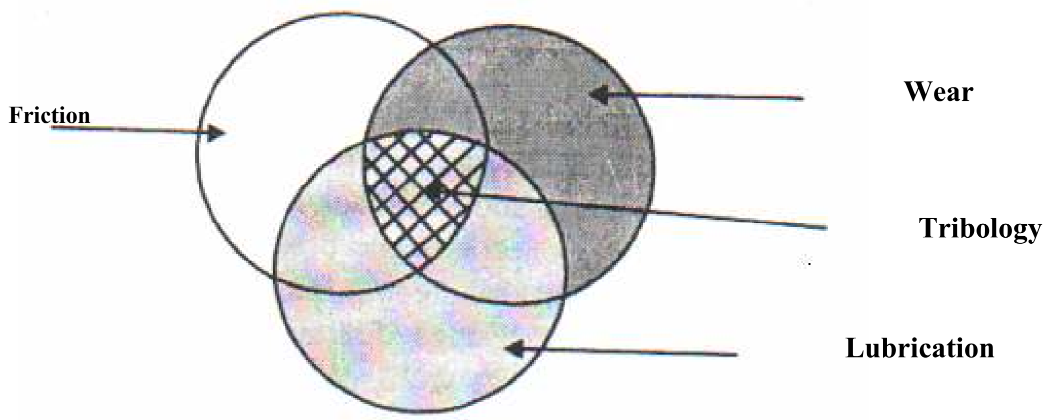

Fig. (1): Tribology

Etiology is truly an interdisciplinary science and is very useful for its practitioners, even though they may be trained in only one of related classical disciplines. It involves, principally, mechanical engineering, production engineering, fluid dynamics, chemistry and chemical engineering, material science and other related topics. It can be considered as heart of engineering [4].

Friction:

In its simplest form, friction may be defined as the resistance to motion, which exists when a solid object is moved (tangentially or otherwise) against the surface of another object with which it touches or when an attempt is made to produce such a motion [4]ز

Wear:

Wear has been defined in different ways by different persons such as:

a) Damage or loss of quality by usage

b) The destruction of material, produced as a result of repeated disturbance of frictional bonds.

c) Removal of material from surface in a relative motion by mechanical or chemical processes [3].

Lubrication:

Lubrication is the most important component of tribology. The primary objective of lubrication is to reduce the severity of friction and wear [3].

Bearings as a Tribological Component:

A bearing is a machine element which support another moving machine element known as journal it permits a relative motion between the contact surfaces of the members, while carrying the load a little consideration will show that due to the relative motion between the contact surfaces. Certain amount of power is wasted in overcoming frictional resistance. If the rubbing surfaces are in direct contact, there will be rapid wear. In order to reduce frictional resistance and wear and in some cases to carry away the heat generated a layer of fluid (known as lubricant)may be provided the lubricant used to separate the journal and bearing is usually a mineral oil refined from petroleum, but vegetable oil, silicon oils, grease...etc, may be used [4].

EXPREMENTAL WORK:

Materials:

Matrix:

The matrix material used in this work is epoxy resin, which is a thermoset resins type Nitofill EPLV.

Reinforcing material:

The reinforcing material used in this work is aluminum oxide powder manufactured by (MERK) with grain size 106-150 µm. It was added to matrix resin with (10-40 wt %) weight fraction.

Graphite as a lubricant:

The lubricant material used in this research is graphite with average grain size 12 µm. It was added as (5 wt %).

Preparation techniques:

The molding technique used in preparing composites is hand lay-up technique. It is used as follows:

- Powders are prepared after weighing the required weight fractions of alumina. Then, they are added to epoxy (which is prepared previously) gradually to prevent bubbles forming.
- The third type of specimens is prepared using the same procedures well as adding 5% weight fraction of graphite.
- After pouring process, the molds were left for 24 hours for the solidification of the specimens. Then, the specimens are taken from molds. Therefore, they are now prepared for testing.

RESULTS AND DISSCUSSION:

Measurement of compressive strength

Compression behavior of composite materials is one of the important mechanical properties which are studied thoroughly by scientists and researchers. The test proves that the compression strength is increasing with the increase in the particle weight fraction and that the epoxy resin has the lowest compression value as clarified by table (1).

The behavior of the composite is changed depending on the (wt %) percentage of alumina. It is clear that the yield points of the composite are gradually increasing from its lower points (pure epoxy).It can be specified from the curves that as long as there is addition of alumina particles, there is increasing towards brittleness (See fig.(2)).

The toughness of any material depends mainly on the defects, which, the material contains. This toughness can be controlled by controlling the flaw-initiation characteristics. The scientists found that there are two theories for compression failure, which is buckling mode, and shear mode, which grows across the internal layers within composite material, which leads to consequent failure [5]. This failure is due to these defects, which become as regions of stress concentration. So, the addition of particles to the resin may lead to the increase of these obstructions, which impede the growing of these defects. Therefore, these particles work as impeding or hindering points to crack propagation and consequently failure. There is another reason for the increase in compression strength, which is the good bondability and good adhesion between matrix and reinforcement.

Table (1): Compressive strength of composites havingdifferent alumina weight fractions

Alumina percentage (wt%)	Compressive strength(MPa)
0	59.24
10	63.185
20	67.13
30	71.1
40	79

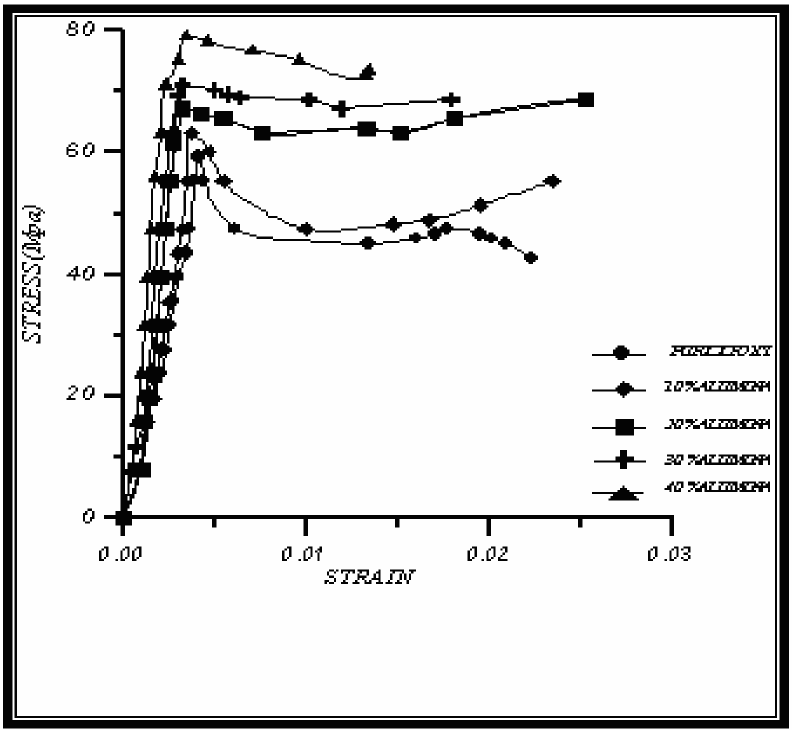

Fig. (2): Stress-Strain curve of different epoxy reinforced with different weight fractions of alumina particles.

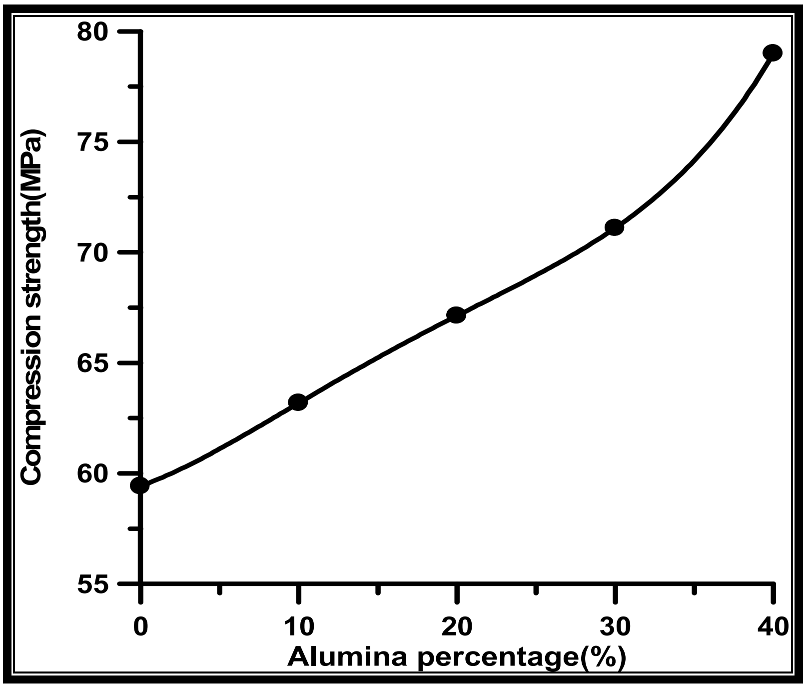

Fig. (3): Compressive strength versus alumina (wt %)

Measurement of hardness:

Result of this test proves that there is a clear increase in the hardness number with the increase in particle weight fraction and the lowest value of hardness is the value of epoxy resin. The behavior of material depends on the role of particles as reinforcement. These particles may affect the bonds between the matrix and the reinforcement causing it to become stronger, as a result the hardness is increased. The researcher Wasan in University of Technology studied the influence of adding alumina particles as a reinforcement to epoxy matrix. The results of this study clarifies that the hardness of composite is increased with addition of alumina particles [6].

Table (2): Hardness No. for different additives of alumina epoxy resin.

Alumina percentage (wt%)	Hardness No.
0 %	127.4
10 %	140.41
20 %	166.51
30 %	186.43
40 %	220

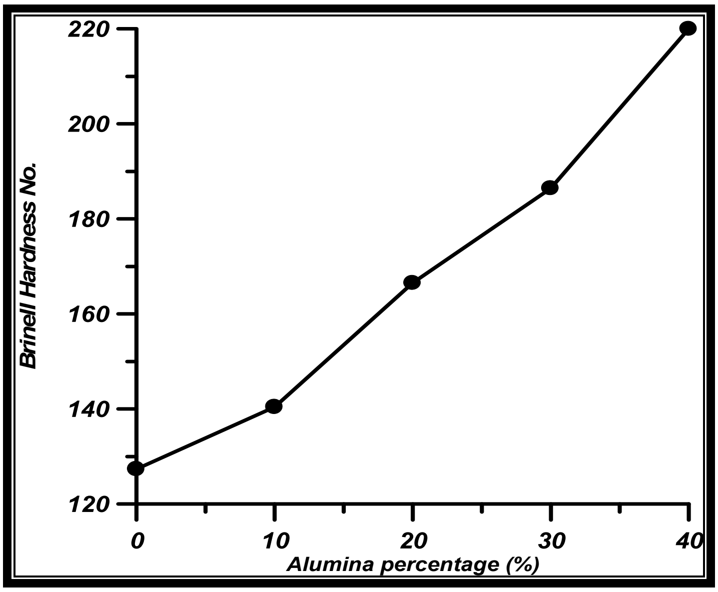

Fig. (4): Effect of different wt% alumina on the hardness no. of the composites.

Measurement of coefficient of friction:

Friction is expressed as a force and frictional force is the force exerted by either of two contacting bodies tending to oppose relative tangential displacement of the other.

The results of friction test clarifies that there is increase in coefficient of friction (μ) with the increase in particles weight fraction and that the lower (μ) is in epoxy resin .The interpretation of this behavior is that the epoxy resin has a lubricant effect which leads to decrease friction while the alumina particles have an abrasive effect. Polymers generally show better sliding conditions as compared to metals [3] because the naked surfaces of the most polymers, which do not react with oxygen, or moisture of the air do not form oxides and contamination on surface is of less importance, and also the absorbed films do not affect the frictional properties much. When a non-metal is sliding over a metal or another non-metal ,the frictional properties tend to be of those of softer material as the harder material get covered with the particles of the softer material. Melting occurs on the surface of the polymers more than metals surface because metals have much higher thermal conductivity than polymers. The molten polymers films often act as a lubricants .With the addition of the ceramic particles (alumina), the behavior is different because ceramics are hard materials and they wear /abrade other materials which get (μ) to be higher to some extent because ceramics also get worn out to some extent. These results are shown in table (3) and Fig. (5). Sung Won Han and Thierry Blanchet studied the possibility of adding hard fillers inside polymer matrices in order to improve their tribological properties and finding an equations for simulation of their behavior. These equations describe wear behavior as a function of composite characteristics such as filler and matrix bulk volume fractions and specific wear rates, thus providing predictive capability as well as insight into the improvement of composites [8, 9].

Table (3): Coefficient of friction values of composites reinforced with different alumina percentages

Alumina (wt%)	μ
0%	0.156
10%	0.2
20%	0.22
30%	0.297
40%	0.376

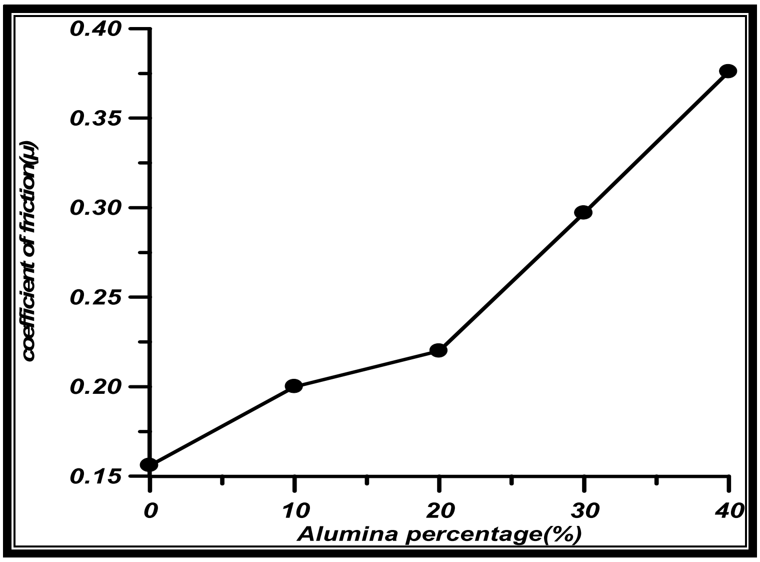

Fig. (5): Effect of different wt% alumina on the coefficient of friction of the composites.

<u>The Effect of the Addition of Graphite 5% on the 20% Composite:</u>

Finally, the addition of 5% graphite decreases the density, coefficient of friction and compression and increase hardness number. The cause of this Behavior is the lubrication effect of graphite .Graphite has a lubricant effect due to its structure (its layers) [9], the bonds between of the matrix and reinforcement and the brittleness property of graphite.

Table (4): Comparison between composite properties with and without graphite.

Property	Value without graphite	Value with graphite

Density(g/cm^3)	1.283	1.251
Compression strength(MPa)	67.13	60.95
Hardness No.	166.51	297.1
Friction (μ)	0.22	0.13

The addition of graphite has a positive effect on some properties while it may have some negative effect on others. It affects hardness positively; hardness No. after the addition of graphite is more than its value before the addition of graphite. This is due to bondability between alumina particles, graphite particles and their matrix. As it is known, if hardness of bearing is high, the fatigue life of the composite may be increased [4]. Therefore, by using a harder material for bearing we can obtain workable bearing. In addition, when a plastic material slides over a metallic or non-metallic material, the frictional properties tend to be of those of softer material as the harder material gets cover with the particles of the softer material. Some other materials like plastics and graphite have very low coefficient of friction. Melting occurs on the surface of the polymer more than surfaces because metals have much higher thermal conductivity than polymers. The molten polymer films acts as lubricants. Therefore, there is a relation between friction, wear, and hardness depending on the material and its contact points with other material hardness is a surface property. It depends on surface roughness. Hardness affected fatigue life. The mechanical properties of the material, which is used as a bearing, should have enough hardness, good compressive strength and low coefficient of friction. The addition of graphite affects the hardness, friction and compression. Hardness No. is increased, coefficient of friction is decreased while the compression strength becomes lower than its value before the addition of graphite. (See above). These results are obtained depending on the bondability of the material particles and the lubricant effect of graphite, while the decrease in compressive strength depends on the brittleness property of graphite, which leads to the advanced failure of compressive specimens. Researchers such as Alstaedt, Werner and Sandler who studied this behavior find that graphite has its lubricant effect on the polymer matrix [10]. Kishore, Sampathkumaran, Seetharamu, Thomas and Janardhana also found that There is an effect of type and content of filler (here they used graphite) in epoxy-glass composite system on the friction and slide wear characteristics by using graphite as a lubricant [11].

Conclusions:

After studying the possibility of making slide bearing from composite consisting of epoxy matrix reinforced with alumina particles, we can conclude the following:
The results of compression test showed that there is increase in compressive strength in company with the increase in alumina weight fractions, whereas in hardness test, it can be concluded that there is an increase in Brinell hardness No. with the increase in alumina weight fractions. In addition, there is an increase in coefficient of friction with the increase in alumina weight fractions.

Therefore, we can conclude that the optimal value to be used in bearing manufacturing is 10-20% alumina weight fractions (depending on the pervious conclusions and on the density test which assist our claim because there is a steady increase in density up to 20% weight fraction whereas it becomes unsteady up to 40% weight fraction). .As a result, we add a predetermined percentage of graphite

(5%) as a lubricant to decrease coefficient of friction and to improve tribological properties of our composite. (See table (4)).

However, the addition of graphite improves the tribological (such as friction, wear and lubrication) properties and some of the mechanical properties such as hardness. It may influence other mechanical properties negatively such as compression.

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