Study the erosion resistance of hybrid particulate composites

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Dr. Ali Hassan.R.H Al-Azzawi
Physics Department University of Mustansiriyah, /Baghdad.
Email: Dr.alhathal@yahoo.com

Abstract

In this work a hybrid composite materials were prepared containing matrix of polymer blend (Novolac 80% + Epoxy 20%) reinforced by different reinforcing materials (Alumina Powder + Silica Powder + Asbestos short fiber) with two values of volume fraction (30, 40) %.
The hybrid composite materials prepared are:

- H_1 = Blend + Al_2O_3 + AS (30) %
- H_2 = Blend + SiO_2 + AS (30) %
- H_3 = Blend + Al_2O_3 + SiO_2+ AS (30) %
- H_4 = Blend + Al_2O_3 + AS (40) %
- H_5 = Blend + SiO_2 + AS (40) %
- H_6 = Blend + Al_2O_3 + SiO_2+ AS (40) %

Oxy - Acetylene was used to examine erosion .
The sample (H_6) of the volume fraction (40%) showed higher erosion resistance values whereas the sample (H_1) was less in value to resist erosion, the highest rates of erosion. For the (H_1) sample there was high tendency to weight loss with high temperature and less as to the sample (H_6).

دراسة مقاومة التعرية لمواد متراكبة هجينة دقائقية

الخلاصـة

تم في هذا البحث تحضير مواد متراكبة هجينة مكونة من مادة أساس بوليمرية هي عبارة عن خليط بوليمري من راتنجات النوفولاك و راتنجات الايبوكسي ومقواة بأنواع مختلفة من مواد التقوية الدقائقية (السيليكا والالومينا والياف الاسبستوس) وبكسرين حجمين (30% ,40%) .
المواد المتراكبة الهجينة التي تم تحضيرها هي :

- عينات مدعمة بالسيليكا و الاسبستوس وبكسر حجمي 30% ورمزت (H_1) .
- عينات مدعمة بالالومينا والاسبستوس وبكسر حجمي 30% ورمزت (H_2) .
- عينات مدعمة بالسيليكا والالومينا و الاسبستوس وبكسر حجمي 30% ورمزت (H_3) .
- عينات مدعمة بالسيليكا و الاسبستوس وبكسر حجمي 40% ورمزت (H_4) .
- عينات مدعمة بالالومينا والاسبستوس وبكسر حجمي 40% ورمزت (H_5) .
- عينات مدعمة بالسيليكا والالومينا و الاسبستوس وبكسر حجمي 40% ورمزت (H_6) .

تم استخدام طريقة القولبة اليدوية في تحضير العينات المستخدمة في الاختبار.

في اختبار شعلة الاوكسي – استيلينية والتي استخدمت لتحديد وتوصيف خاصية التعرية والتي أعطت العينة H_6 ذات الكسر الحجمي 40% اعلى مقاومة للتعرية مقارنة مع العينة H_1 والتي أعطت اقل مقاومة للتعرية وهذا يعني إن العينة H_1 أعطت اعلى قيمة لمعدل التعرية وهذا يعني قابلية عالية للعينة H_1 على الفقدان في الوزن عند درجات الحرارة العالية مقارنة مع العينةH_6

INTRODUCTION

Composite materials are quite common today and are used in nearly every segment of civilian and military industry. The idea of reinforcement is not new. Over the centuries natural fibers, such as grass or animal hair, have been used to improve the strength and to lessen shrinking of pottery prior to firing and increase the strength in mud houses. This idea in the present form has been exploited with the development of glass, carbon and later of aramid fibers [1].

A composite material can be defined as macroscopic combination of two or more materials (reinforcing elements, fillers, and composite matrix binder), differing in form, or composition on a macro scale. The constituents retain their identities, that is, they do not dissolve or merge completely into one another although they act in concert. Normally, the components can be physically identified and exhibit an interface between one another. A composite material is created from a powder(or reinforcement) and an appropriate matrix material in order to maximize specific performance properties [2].

In 2008 alhathal studied erosion properties of different hybrid composite materials consisting of a polymer blend as a matrix reinforced by different particles and researcher concluded that by increasing the volume fraction of the particles , the rate of erosion will be decreases[2].

Thermal Effect (Ablation Mechanism)

Thermal degradation is the scission of molecular chain at elevated temperatures, so some polymer undergoes chemical reactions in which gaseous species are produced, polymers thermal stability is a measure of its resilience to this decomposition. Thermal stability is related primarily to the magnitude of the bonding energies between the various atomic constituents of the polymer.

Plastics can be protected from thermal degradation by incorporating stabilizers into them.

The aim of this work is Study the adhesion properties of the different material, Choosing the best composition for adhesion properties of hybrids composites and developing a thermosetting net work .

Polymer matrix composite (PMC) materials are increasingly being used in all aspects of our society, from transportation (trains, autos and airplanes) and civil engineering (bridges, wall reinforcement,) to electronics and sporting goods. The aerospace military industry has been using these materials for more than 40 years, principally due to their demand for low weight structures [2].

Materials

Phenol Formaldehyde Resin (novolac type)

Phenol Formaldehyde (novolac type) is most widely utilized since it is cheap polymer resin. This matrix material is used primarily with carbon fiber, glass fiber composites, and alumina, silica powder.

Commercial phenolic resins provided from Iran novolac type (Bazerkane), mixed with weight fraction of (11-13) % hexametheltitramine (HMTA) of yellow color powder of density 0.91g/cm^3 are used.

Epoxy Resin (EP)

Epoxy resin (type Conbextra EP10) was used in this research; it is a liquid with moderate viscosity and capable to be converted to solid state by adding the solution (Metaphenylene Diamine, MPDA) as hardener. This hardener is a light liquid with yellowish color, the ratio of this hardener to the epoxy is about (1:3). This resin also has applicable technical specification such as, high adhesion to fibers and low shrinkage during solidification.

Asbestos Fiber(As)

Chrysotile known as white asbestos was used, Chrysotile is hydrated silicates are found in certain types of rocks, known for its snake-like, curly appearance, soft, flexible, strong, durable, and resistant to heat and fire, its density is 2.4 g/cm^3 [4] .

Alumina powder (Amphoteric nature)

A white powder Al_2O_3 of density (3.89) g/cm^3 and of particle size less than 250 μm was used .It is useful at high temperature and has a high dielectric strength, excellent electrical resistance [3].

Aluminium oxide is an amphoteric substance, meaning it can react with both acids and bases, such as hydrofluoric acidand sodium hydroxide, acting as an acid with a base and a base with an acid, neutralising the other and producing a salt.

Silica powder

After oxygen, silicon is the most plentiful element on the earth's cust. It occurs as its oxide either free or combined with metallic oxides as silicates.

Silica crystallizes in different forms at different temperatures, but as the changes are slow, the unstable form occur naturally , as well as the farmore common stable from which is α– quartz [5].

Silicate materials are basic raw materials for much of the ceramic industry. Silica is non – plastic raw materials which provide strength [5]. It is widely used because it is inexpensive, hard, chemically stable and relatively infusible.

Preparation methods for hybrids composites materials

1 - The novolac was mixed with methanol (1/2 weight of solvent to novolac) .
2 – The novolac liquid mixed with (HMTA) hardener (11-13) % powder[6].
3 - Epoxy resin mixed with (33) % hardener.
4 – The mixture in the step (2) mixed with the mixture in the step (3).

(80% Novolac + 20% Epoxy) in order to prepare the polymer blend (Inter pentrating polymer net work) .
5 – The polymer blend in the step (4) reinforced by different types of particles (Al_2O_3, SiO_2) and asbestos fibers with two values of volume fraction .
6 – Six hybrids composites materials prepared:
H_1 = Blend + Al_2O_3 + As (30) %
H_2 = Blend + SiO_2 + As (30) %
H_3 = Blend + Al_2O_3 + SiO_2+ As (30) %
H_4 = Blend + Al_2O_3 + As (40) %
H_5 = Blend + SiO_2 + As(40) %
H_6 = Blend + Al_2O_3 + SiO_2+ As (40) %
7 – For all cases, this was calculated by applying the relation ship: [2]

$$\Phi = \frac{1}{1+ ((1-\psi)/\psi) \times (\rho_f / \rho_m)} \quad \dots \quad (1)$$

Where:
Φ, ψ are the volume and weight fractions of the reinforcements respectively.
ρ_f , ρ_m are the density of reinforcements and matrix respectively.

Oxyacetylene standard flame tests are one of the most important standard tests of ablative materials. The test apparatus is made according to the American Standard, ASTM-E-285-80. This test is used in order to find out how the hybrid composites behave at very high temperature (rapid heating).The percentage of oxygen to acetylene is 1/1.2 with rate of flow 60 F^3/min and the distance between the center of the flame and the specimens is 18 mm. Note that the degree of the temperature of the flame is about 3000 ^oC. The specimens in these conditions and the time intravel for the flame enter and just passing a decent thickness of specimens was measured.

Result and discussion

Figure (1) represent the erosion resistance of hybrids composites materials and from this figure the following results can be concluded:
1 - The values of (Erosion rate) decrease with increasing the volume fraction.
$H_3 > H_6$, $H_2 > H_5$, $H_1 > H_4$.
2 – Specimens that contain only (SiO_2) give (Erosion rate) lower than the (Erosion rate) of the specimens that contain only (Al_2O_3) Because of the small size of the silica particles compared with alumina particles which leads to homogeneity and overlap between the silica particles with asbestos fibers and therefore more diffusivity of silica in the matrix
$H_1 > H_2$, $H_4 > H_5$.
3 – Specimens that contain both (Al_2O_3 + SiO_2) give (Erosion rate) lower than the specimens that contain only (Al_2O_3) or specimens that contain only (SiO_2) .
$H_1 > H_3$, $H_2 > H_3$, $H_4 > H_6$, $H_5 > H_6$.
4 – H_1 shows high erosion rate while H_6 shows low erosion rate.

In this test Oxy-Acetylene flame is used to find out the degree of thermal insulation of polymeric materials and also to study the behavior of the material when exposed to ablative environment, which is useful for insulation of exit cone of solid-propellant [4,9].

In this test the heat flux of temperature ~ 3000 ^{O}C is imposed on the surface of the prepared hybrids. Thermal degradation happen by continuous exposure to the heat flux, gases released in char regime, as the heat flux continues to fall on the surface of the material, the degradation becomes large and gases continue to burn, and remain inside the char regime. This leads to increase the external pressure, this pressure continues to increase until reaching its maximum values, after that the thermo-chemical expansion takes place and the gases are released and are able to pass through the material leading to an attenuated thermal energy reaching the pyrolyzed zone by convection

The type of the reinforcement can also influence the fire performance. Fig (1) shows variation in erosion rate for the prepared hybrids composites. The result shows that the better erosion resistance is obtained in hybrids (H_6). The type of reinforcement influences the performance of the composites and (SiO_2) act to dissipate the heat in the material faster than the (Al_2O_3). The asbestos in these hybrids make the material more stable and have better resistance to high temperature.

Conclusions

This work has reached to the following conclusions:

In the erosion test which include (OSF), the hybrid samples (H_6) gives high values of erosion resistance (low values of erosion rate) while the hybrid samples (H_1) gives low values of erosion resistance (high values of erosion rate) because of the homogeneity between the three reinforcing materials in addition to that increase volume fraction less than the rate of erosion.

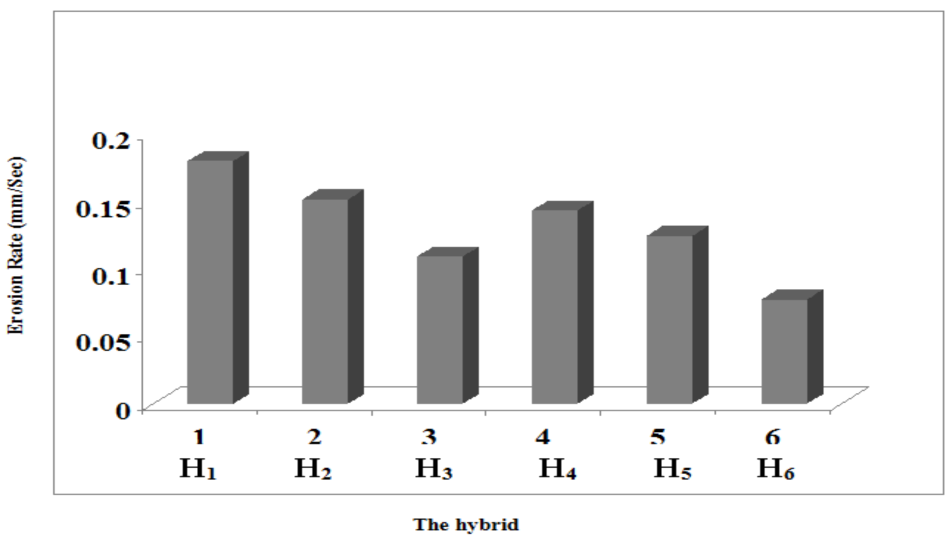

Figure (1) Systematic diagram illustrating different extents for erosion rate of prepared hybrids composites.

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