Study some thermal properties for hybrid composite reinforced with particales

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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 (type α) + Silica Powder + Asbestos short fiber) with two values of volume fraction (30, 40) %.

The hybrid composite materials prepared are:
- \( H_1 = \text{Blend} + \text{Al}_2\text{O}_3 (\alpha) + \text{AS} \ (30) \%
- \( H_2 = \text{Blend} + \text{SiO}_2 + \text{AS} \ (30) \%
- \( H_3 = \text{Blend} + \text{Al}_2\text{O}_3 (\alpha) + \text{SiO}_2 + \text{AS} \ (30) \%
- \( H_4 = \text{Blend} + \text{Al}_2\text{O}_3 (\alpha) + \text{AS} \ (40) \%
- \( H_5 = \text{Blend} + \text{SiO}_2 + \text{AS} \ (40) \%
- \( H_6 = \text{Blend} + \text{Al}_2\text{O}_3 (\alpha) + \text{SiO}_2 + \text{AS} \ (40) \%

All samples related to mechanical, thermal, electrical and physical tests were prepar by hand lay up process. The tests can be classifi into four groups: For the \( (H_i) \) samples, there was high tendency to loose weight with high temperature and less as to the samples \( (H_6) \).

Keyword: Thermogravimetric analysis (TGA), Alumina (AL\(_2\)O\(_3\)), Silica (SiO\(_2\)), asbestos short fiber (As).

دراسة بعض الخواص الحرارية لمتراكبات هجينة مقواة بالدقائق

الخلاصة
تم في هذا البحث تحضير مواد متراكبة هجينة مكونة منمادة أساس بوليميرية هي عبارة عن خليط بوليمري Novolac 80% + Epoxy 20% مع مكونات مختلفة من مواد الفئة (مسحوق الألومينوم نوع الفا + مسحوق السيليكا + ألياف الأسيبستوس المقطعة العشوائية) وكمركزين حجم (40%, 30%).

المواد المتراكبة الهجينة التي تم تحضيرها هي:
- عينات مدمجة بالألومنيا والاستيبستوس وبكسر حجمي 30% ورمزت (\(H_1\))
- عينات مدمجة بالسيريكا والاستيبستوس وبكسر حجمي 30% ورمزت (\(H_2\))
- عينات مدمجة بالألومنيا بالسيريكا والاستيبستوس وبكسر حجمي 30% ورمزت (\(H_3\))

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All samples related to mechanical, thermal, electrical, and physical tests were prepared by hand lay up process. The tests can be classified into four groups: For the \( (H_i) \) samples, there was high tendency to lose weight with high temperature and less as to the samples \( (H_6) \).

Keyword: Thermogravimetric analysis (TGA), Alumina (AL\(_2\)O\(_3\)), Silica (SiO\(_2\)), asbestos short fiber (As).
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 [1,2].

In 2006, Das [3] prepared novolac composites from Bamboo strips, using bamboo strips that were treat with varying concentrations of sodium hydroxide solution. Mechanical properties of various composites (flexural modulus, toughness, tensile strength, and elastic modulus) were determined. The physical characteristics, such as the wetting ability of the alkali treated reinforcements, were increas because of alkali treatment, with increasing concentrations of alkali. The mechanical properties were increas with increasing mercerizing strength. Maximum improvement in properties was achiev with 16-20% of caustic treated reinforcements.

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) % hexamethenitramine (HMTA) of yellow color powder of density 0.91g/cm³ 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 (Metaphenylenediamine, 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

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/cm³ [4,5].
Alumina powder
A white powder $\text{Al}_2\text{O}_3$ of density (3.89) g/cm$^3$. It is useful at high temperature and has a high dielectric strength, excellent electrical resistance [6, 7].

Silica powder
After oxygen, silicon is the most plentiful element on the earth's crust. 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, [8, 9]. Silicate materials are basic raw materials for much of the ceramic industry. Silica is non-plastic raw materials, which provide strength to the dried and fired wares [10, 11]. 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) [12].
2 - The novolac liquid mixed with (HMTA) hardener (11-13) % powder [13].
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) [14].
5 - The polymer blend in the step (4) reinforced by different types of particles ($\text{Al}_2\text{O}_3$, $\text{SiO}_2$) and asbestos fibers with two values of volume fraction (30, 40) %.
6 - Six hybrids composites materials prepared:
  $H_1 = \text{Blend} + \text{Al}_2\text{O}_3 + \text{As} (30)$ %
  $H_2 = \text{Blend} + \text{SiO}_2 + \text{As} (30)$ %
  $H_3 = \text{Blend} + \text{Al}_2\text{O}_3 + \text{SiO}_2 + \text{As} (30)$ %
  $H_4 = \text{Blend} + \text{Al}_2\text{O}_3 + \text{As} (40)$ %
  $H_5 = \text{Blend} + \text{SiO}_2 + \text{As}(40)$ %
  $H_6 = \text{Blend} + \text{Al}_2\text{O}_3 + \text{SiO}_2 + \text{As} (40)$ %
7 - For all cases, this was calculatby applying the relation ship:

\[
\Phi = \frac{1}{1+ ((1- \psi)/ \psi) \times (\rho_f / \rho_m)}
\] ...

Where:
$\Phi$, $\psi$ are the volume and weight fractions of the reinforcements respectively.
$\rho_f$, $\rho_m$ are the density of reinforcements and matrix respectively.
The density of the prepared hybrids was determined from the equation:
$\rho_m = x_1 \rho_1 + x_2 \rho_2$ ........ (Rule of mixtures)
Where $\rho_m$ : the density of the matrix (polymer blend).
$\rho_1$, $\rho_2$ : the density of the first polymer and the second respectively.
$x_1$, $x_2$ : the percentages of the first polymer and the second respectively.
8 - The metal mould was clean and used for casting the sheet of hybrids composite material.
9 - The fablon was fix on the inner mould faces before casting to facilitate the releasing of casting hybrids and having smooth faces.
Cover plate, with identical dimension of the mould face, was used to apply appropriate load on the casting sheet for releasing voids, bubbles, to have a specified thickness and smooth face.

Casting sheet was left inside the mould at room temperature about (24h).

After solidification, the casting sheets were released from the mould and placed in an oven with (50°C setting temperature) for (3h) to post cure the considered sheets.

The testing samples were obtained by cutting the casting sheets.

Thermogravimetric Analysis (TGA)

This analysis shows how the prepared hybrid behaves as temperature increases from low to high temperature gradually. The thermal oxidative degradation pathways are studied using computerized digital oven Model (Gallenhamp Program Rapid), and the specimens (of weight 100 gm) were put in a porcelain vessel and placed in oven at heating rate 50°C/min in air to various temperature from 25 up to 1000 °C. The temperature was measured with a sensitive ballistic system Model (four digits), as the temperature increased the weight loss occurred.

Results and Discussions

Figures (1) and table (1) represent the relationship between increasing the temperature and the residue weight for hybrids composites materials and from this figure, one can conclude the following results:

1 – H₁ has high ability to residue weight with increasing temperature while H₆ has low ability to residue weight with increasing temperature.

2 - The values of (Residue weight) decrease with increasing the volume fraction.

H₃ > H₆ , H₂ > H₅, H₁ > H₄

3– Specimens that contain only (SiO₂) give (Residue weight) lower than the (Residue weight) of the Specimens that contain only (Al₂O₃).

H₁ > H₂ , H₄ > H₅

4 – Specimens that contain both (Al₂O₃ + SiO₂) give (Residue weight) lower than the Specimens that contain only (Al₂O₃) or Specimens that contain only (SiO₂).

H₁ > H₃ , H₂ > H₅, H₄ > H₆, H₅ > H₆

The polymeric material undergoes many changes when it is heat gradually from low to high temperature at constant rate, during which the material emits gases and liquid, changes occur in shape, color and molecular weight. The ability of polymer to resist these changes at high temperature was called thermal stability [15, 16]. Therefore, TGA measurement is employ to study the thermal-oxidative degradation of prepared hybrids in air. Fig. (1) and Table (1) represent the TGA curves for all samples. These figures show three stages for pyrolysis degradation.

1 – First stage is at temperature range from room temperature up to 300 °C during this interval hybrids releases little gaseous components, therefore the loss in weight in this stage is very small [17].

2 – Second stage is at temperature range from (300-600)°C, heating causes the release vapors of water, CO, phenol. Moreover, weight loss increases at rate more than that at first stage, in this stage thermal degradation occurs with less degradation in density with out shrinkage [18, 19]. This stage also includes broken of molecular chain of polymer.

3 - Third stage is at temperature range from 600 °C and so on, in this stage there is shrinkage with large decrease in weight, heating in this stage causes the release of phenol, H₂O, CH₄, CO₂, Benzene [19].
Results also show that the thermal stability increases in (H₆) compared with other samples, depending on the type and loading ratio of the reinforcements in the hybrids composites. As the loading ratio of \((\text{Al}_2\text{O}_3 + \text{SiO}_2)\) increases the hybrids become more stable compared with hybrids as loading ratio of \((\text{SiO}_2)\) or \((\text{Al}_2\text{O}_3)\) increases as shown in Fig (1).

Conclusions
This work has reached to the following conclusions:
1 – The results show the hybrid (H₁) gives high ability to weight loss with increasing temperature while the hybrid (H₆) gives low ability to weight loss with increasing temperature.
2 - The results show that as the values of volume fraction increases the ability to weight loss with all hybrids decrease also.

Table (1) gives the values of residue weight (%) for prepared hybrids composites

<table>
<thead>
<tr>
<th>Temp(°C)</th>
<th>H₁</th>
<th>H₂</th>
<th>H₃</th>
<th>H₄</th>
<th>H₅</th>
<th>H₆</th>
</tr>
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<tbody>
<tr>
<td>25</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<td>99.006</td>
<td>98.672</td>
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<td>97.553</td>
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<td>98.751</td>
<td>98.110</td>
<td>98.729</td>
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<td>93.175</td>
<td>98.151</td>
<td>97.327</td>
<td>98.197</td>
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<td>97.425</td>
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<td>95.579</td>
<td>94.285</td>
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<tr>
<td>300</td>
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<td>91.487</td>
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<td>88.925</td>
<td>91.044</td>
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<td>400</td>
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<td>75.153</td>
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<td>77.197</td>
<td>70.284</td>
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<td>73.444</td>
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<td>40.151</td>
</tr>
</tbody>
</table>
Hybrid study some thermal properties for Hybrid composite reinforced with particles.

Figure (1) TGA thermal oxidative degradation curves at elevated temperature for all prepared hybrids.

References
[1]. Erin Boutwell, MS; Rebecca Stine, MS; Andrew Hansen, PhD; Kerice Tucker, BS; Steven Gard, "Effect of prosthetic gel liner thickness on gait biomechanics and pressure distribution within the transtibial socket", JRRD Volume 49, Number 2, P. 227–240, 2012.


