Hybrid fire retardants to increasing combusting resistance for fibers-reinforced composites

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Abstract

   This research aims to attainment two essential purposes : first, using of inorganic fire retardant which represent zinc borate to increase the flame retardancy for advanced composite material consist of araldite resin (AY103) reinforced by hybrid fibers from carbon and Kevlar fibers as a woven roving (0 º - 45º), by using a surface layer from zinc borate as a coating layer of (4mm) thickness .Then, this system was exposed to a direct flame generated from Oxyacetylene torch (3000ºC) with different flame exposure distances   [10,15,20mm], and study the range of resistance of retardant material layer to the flames and protected the substrate . Second, forming a hybrid fire retardant by added antimony trioxide with various amount (10%,20%,30%) to zinc borate for enhance the action of this material to react flame and exposure this hybrid material to same flame temperature and exposure distances. Method of measuring the surface temperature opposite to the flame was used to determined the heat transferred to composite material . the best results was obtained with large exposed distance and large percentage from protective layer which is zinc borate with (30%) antimony trioxide .

Keywords: Hybrid Retardant, Composite Material, , Inorganic Retardants .

:

(AY103)

(45º - 0º)

. (4mm)

[10,15,20mm]   (3000ºC)

.

(30%,20%,10%)

.

.

(30%)   .

Introduction

Fire retardants (FRS) comprise a diverse group of chemicals which are widely used at relatively high concentrations in many applications, including the manufacture of electronic equipment, textiles, plastic polymers and in the car industry [1]. The use of (FRS) is primarily to protect materials against ignition and to prevent fire-related damage. Room combustion tests comparing FR plastics with non-FR plastics conducted by the National Bureau of Standards (The National Institute of Standards and Technology) have shown that FR materials allow longer escape time, less heat release, less smoke and release of a lower concentration of toxic gases. These effects are due to a decrease in the amount of burning materials [2]. Fire retardants commonly divided into four major groups : Inorganic FRS, Organo phosphorus FRS, Nitrogen-containing FRS and Halogenated organic FRS. Depending on their nature, fire retardants can act physically or chemically [3].

Inorganic FRS comprise metal hydroxides (e.g. aluminum hydroxide and magnesium hydroxide), ammonium polyphosphate, boron salts, inorganic antimony, tin, zinc and molybdenum compounds, as well as elemental red phosphorous. Inorganic FRs are added as fillers into the polymers and are considered immobile, in contrast to the organic additive FRS[4] . **fig(1)** shows the mode action for inorganic FRS .

Polymeric plastic combustion occurs in the vapor phase. When a plastic is exposed to increased temperatures, the plastic undergoes pyrolysis. Potentially combustible vapors are slowly released at first. Since many polymers are substituted, the increase in surrounding temperatures can cause variations in connectivity among the monomer units. Often, these variations in connectivity result in an overall weakening of the polymer structure and can encourage the release of more vapors and liquids, both flammable and non-flammable. As the heat source persists, the temperature of the polymer increases steadily [5].

Volatile vapor release rates increase and hydrogen and hydroxide radicals diffuse out of the material. The radicals can combine to propagate the flame spread. Re-radiation from combusting vapors effectively increases the polymers' temperature. During this process a char layer forms on the surface of the plastic which serves to inhibit flame spreading. If there is enough char barrier, the flame will slowly extinguish. Otherwise, heat will continue to be released at higher rates and the pyrolysis-combustion process continues. So the flame retardants used with these materials to inhibiting combustion process [6].
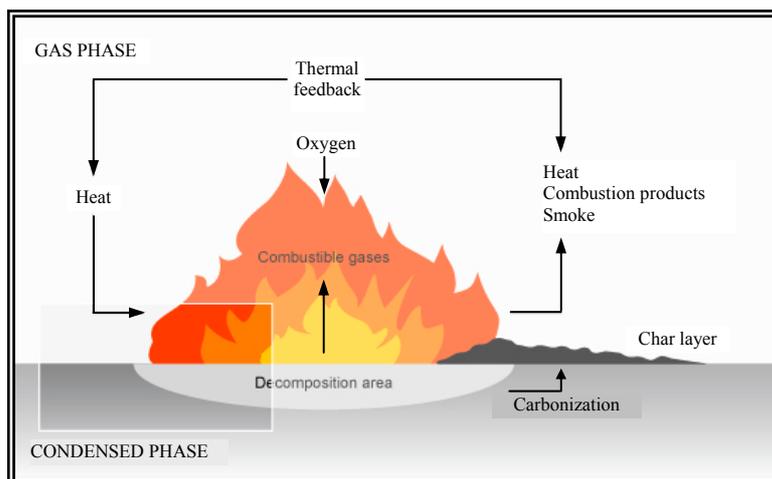
Fig(1) : Mode of action for inorganic FRS

Experimental Work
1- Materials Used .

There are three types of materials employed in this study:

a. Fire retardant material:

1- Zinc Borate $(2ZnO.3B_2O_3.3.5H_2O)$ was used as a fire retardant, which supply by Akrochem corporation. Zinc borate, however, is water-insoluble and is mostly used in plastics and rubber products. It is used either as a complete or partial replacement for antimony oxide in PVC, nylon, polyolefin, epoxy, EPDM, etc. In most systems, it displays synergism with antimony oxide.

2- Antimony Trioxide (Sb_2O_3) : produced by NL Industries with particle size (1μ) . Antimony trioxide are cubic phase (Senarmontite) which colorless and Orthorhombic phase (Valetinite) which have white color

b. Matrix material: Araldite resin (AY103) which hardening with (HY956) .

c. Reinforcing fibers: Two types of fibers were used as consecutive layers :

1- Carbon fibers, A woven roving fibers(0 º - 45 º) with density of $(1.75 \ g/cm^3)$.

2- Kevlar fibers, A woven roving fibers(0 º - 45 º) with density of $(1.45 \ g/cm^3)$.

2- Preparation of Test Specimens.

Specimens of thermal erosion test shown **fig (2)** have a square shape, with dimensions (100 ×100×10mm).These Specimens consist of two layers:

a- Fire retardant material layer with (4mm) thickness represented by zinc borate.

b- Composite material layer with (6mm) thickness.
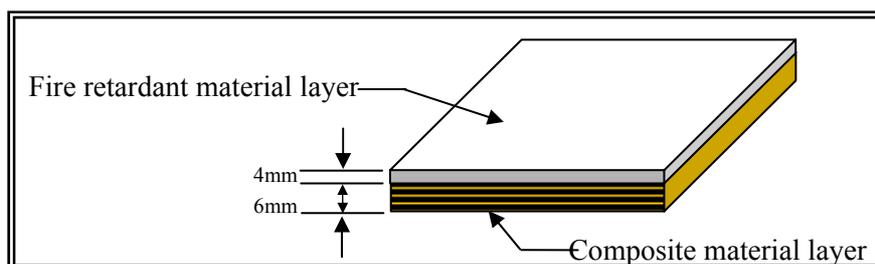
Fig (2): Specimen of thermal erosion test

3- Thermal Erosion Test .
Flame generated from Oxyacetylene torch with temperature (3000ºC) was used in this test. The system (contains fire retardant material and composite material) was exposed to this flame under different exposure distances (10 ,15, 20mm). **fig (3)** shows the mechanism of thermal erosion test,

surface temperature method used here to calculate the amount of heat transmitted through fire retardant material and composite material. A transformation card (AD) which called Thermal monitoring and recording system (see **fig (4)**) was used to observed and saved temperatures with time (in seconds) .
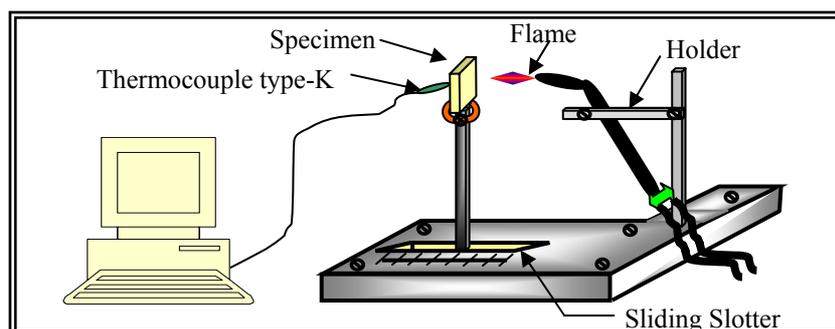
Fig (3): Mechanism of thermal erosion test
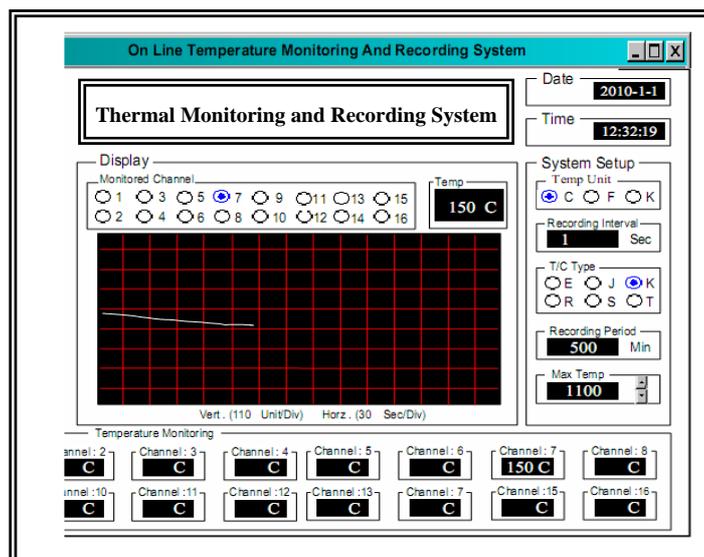
Fig (4): Thermal monitoring and recording

Results and Discussion

Fig (5) represents the thermal erosion test for composite material with retardant surface layer at exposed distance (10mm), the temperature of the opposite surface to the torch begins to increase with increasing the time of exposition to the flame . Zinc borate will form a glassy char at high

temperatures that prevents flame propagation ,It also releases water of hydration from its chemical structure . Therefore, the substrate (composite material) will protect and the fire spread will decrease [6]. This process of flame retardancy will be increased by addition antimony trioxide to zinc borate where zinc borate is a synergist with this oxide , so the combined

ingredient will have better flame resistance than separate materials would have . When added (10 %) from antimony trioxide to Zinc Borate ,the phase transformations happened in internal structure of this oxide which cause with zinc borate enhanced flame retardancy of composite materials , and this retardant action increased with increased antimony trioxide content to (20 %, and 30 %) [7] .
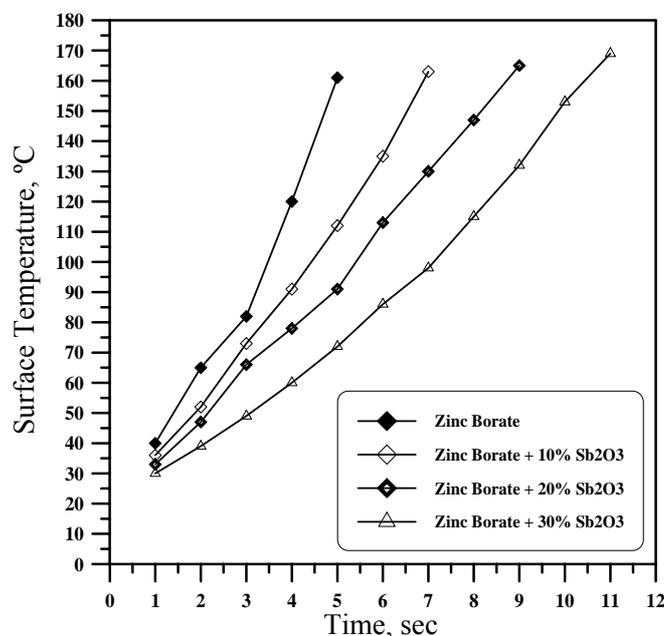
Fig (5): Exposed Distance (10 mm)

Fig (6) the thermal erosion test for composite material with retardant surface layer with exposed distance(15mm) . As a result, when the exposed distance to flame increased to (15mm), the time necessary to break down of fire retardant layer will increase and the combustion gaseous will reduced and there will be a less plastic to burn due to water of hydration and protected glassy coating layer comes from zinc borate, and this protection will improves with addition(10% ,20 %, and 30 %) from antimony trioxide because the mode action of this oxide with glassy coating layer increasing flame retardancy [8] . The improvement in flame retardancy will increased with increased exposed distance to (20mm) as shown in **fig (7)** . All that will rise the time of break down for zinc borate- antimony trioxide layer and substrate composite material [9] . From figures , the better results obtained with large exposed distance and large percentage from protective layer which is antimony trioxide (30%).
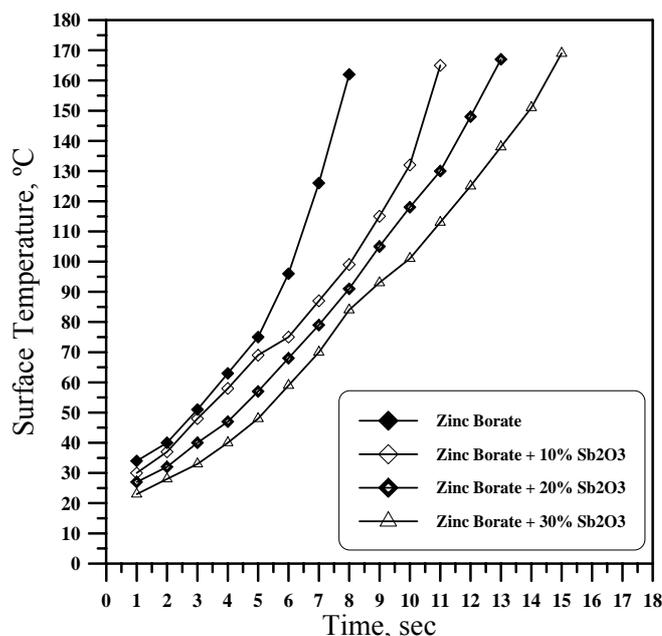
Fig (6): Exposed Distance (15 mm)
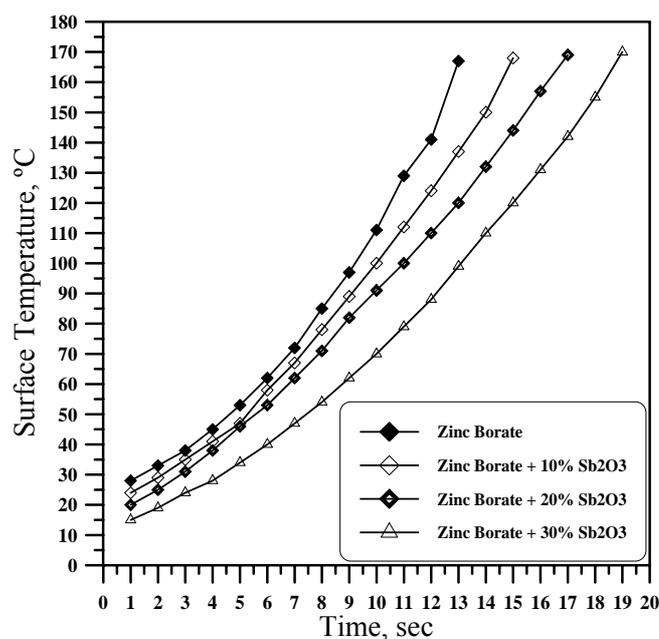
Fig (7): Exposed Distance (20 mm)

Conclusions

From the obtained results we get :

1- Improvement flame retardancy for composite material with added zinc borate as a retardant layer.

2- Increasing the flame retardancy when added antimony trioxide to zinc borate with different percentages and forming hybrid retardant material .

3- The resistance to flame spread will increased with increasing of exposed distance .

4- The flame retardancy is increased as the flame temperature is decreased.

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