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USING OF HYBRID FLAME RETARDANTS TO INCREASE THERMAL EROSION RESISTANCE FOR ADVANCED COMPOSITE MATERIALS

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ABSTRACT:- This research aims to attainment two essential purposes : first, using of inorganic flame retardant which represent zinc borate to increase the flame retardancy for advanced composite material consist of araldite resin (CY223) reinforced by hybrid fibers from carbon and Kevlar fibers as a woven roving (0º - 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 gas flame (2000ºC) with different flame exposure distances (10 mm, 20mm), and study the range of resistance of retardant material layer to the flames and protected the substrate . Second, forming a hybrid flame retardant by added antimony trioxide to zinc borate with various amount(10%,20%,30%) to enhance the retardant action of this material to flame and exposure this hybrid material to same flame temperature and exposure distances and time periods (5-60 sec) and (5-95 sec). 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 Flame Retardant, Composite Material, , Inorganic Retardants .

1- INTRODUCTION

Fire safety is an integral part of precautions. Fire precautions have the objective to minimize the number of and damage from measuring hindering their initiation, limiting their propagation and if possible excluding flash-over. Preventing fires or delaying them makes escape possible over a longer period of time. As a result, life, health, and property are efficiently protected [(1)]. Since plastics are synthetic organic materials with carbon and often high hydrogen contents, they are combustible. For various applications in the building, electrical, transportation, mining, and other industries, plastics have to fulfill flame retardancy requirements laid down in mandatory regulation and voluntary specification. The objective in flame retarding polymers is to increase ignition resistance and reduce rate of flame spread [2].

One way to better protect combustible materials against initiating fires is the use of flame retardants , which are substances that can be chemically inserted into the polymer molecule or be physically blended in polymers after polymerization to suppress , reduce , delay or modify the propagation of a flame through a plastic materials.

There are several classes of flame retardants; halogenated hydrocarbons (chlorine and bromine containing compounds and reactive flame retardants): inorganic flame retardants (boron compounds, antimony oxides, aluminum hydroxide, etc); phosphorus containing compounds; nitrogen containing flame retardants. Depending on their nature, flame retardants can act physically or chemically [3]. Few inorganic compounds are suitable for use as flame retardants in plastics, since such compounds must be effective in the range of decomposition temperature of the plastic, mainly (150ºC - 400ºC). Inorganic flame retardants don't evaporate under the influence of heat ; rather they decompose ; giving off non-flammable gases like water , carbon dioxide , sulphur dioxide , hydrogen chloride , etc. mostly endothermic reaction . in the gas phase , these act by diluting the mixture of flammable gases and by shielding the surface of the polymer against oxygen attack [4] .

The inorganic flame retardants act simultaneously on the surface of the solid phase by cooling the polymer via endothermic breakdown process and reducing the formation of pyrolysis products. In addition , as in the case of inorganic boron compounds , a glassy protective layer can form on the substrate , fending off the effect of oxygen and heat [5] .As example to inorganic flame retardants is zinc borate , aluminum hydroxide , magnesium hydroxide , and antimony oxides . Zinc borate is an effective inorganic flame retardant and it possesses characteristic properties of flame retardancy (FR), smoke suppression, promoting charring, etc. particularly important according to new fire standards. Zinc borate is commonly used as multifunctional flame retardant in combination with other halogenated or halogen free flame retardant systems to boost FR properties. Its efficacy depends upon the type of halogen source (aliphatic versus aromatic) and the used polymer. The zinc borate can generally display synergistic effects with antimony oxide in fire retardancy [6]. Antimony trioxide (ATO) have white color or colorless depended on its structure . antimony trioxide dissolved slightly in water and dissolved in potassium hydroxide , dilute hydrochloric acid and with many organic acids [4]. Figure(1) shows the chemical structure of this oxide .

Composite material is a material consisting of two or more physically and (or) chemically distinct phase, suitably arranged or distributed. A composite material usually has characteristics that are not depicted by any of its components in isolation [6]. Generally, the composite material contains two elements:

1- Matrix material: it is the continuous phase; it may be metal, ceramic or polymer matrix. The polymer matrix is considered the best because of its mechanical and thermal properties, and also it can reinforced by a large fiber volume fraction compared with metal and ceramic matrix. In addition to the low cost and easy fabrication, as example for this materials araldite resin, polyester, and epoxy resin. Araldite resin belong to epoxy group which has excellent thermal and physical properties, and usually used in composite materials for different applications, where it distinct by excellent adhesive capability especially to fibers, also it retain constant dimensions after dryness (7).
2- Reinforcing material: The distributed phase is called reinforcement, many reinforcement materials are available in a variety of forms; continuous fibers; short fibers; whiskers, particles...etc. Reinforcements include organic fibers such as carbon and kevlar fibers, metallic fibers, ceramic fibers, and particles (8).

High strength, and high modulus carbon fibers are of about (7-8μm) in diameter and consist of small crystallites of turbostratic graphite, one of the allotropic forms of carbon (9). Kevlar is an organic aramid fiber with (3100 MPa) tensile strength, and (131,000 MPa) elastic modulus. A density approximately one-half of aluminum, good toughness, in addition it is flame retardant (10).

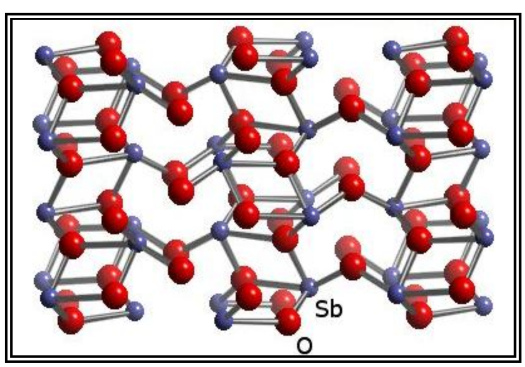

Fig. (1) : Chemical structure of antimony trioxide(4)

2- EXPERIMENTAL WORK

2.1- Materials

There are three types of materials employed in this study:

a. Flame retardant material,

1- Zinc Borate 2335 ($2ZnO.3B_2O_3.5H_2O$) was used as a flame retardant, which supply from C-Tech corporation. Table (1) shows the chemical composition of zinc borate.

2- Antimony Trioxide (Sb_2O_3) : supplied from (BDH Chemical Ltd Pool England) with particle size (2µ) . Table (2) shows the properties of antimony trioxide.

Table (1): Chemical composition of zinc borate.

Compound	Zinc Oxide	Boric Anhydride	Water of Hydration	Impurities
Symbol	ZnO	B_2O_3	H_2O	-
Content(%)	37	47	14	2

Table (2): properties of antimony trioxide [4].

Property	Melting Point(ºC)	Boiling Point(ºC)	Density(g/cm^3)
Value	656	1425	5.67

b. Matrix material, Araldite resin (CY223) with density of (1.15-1.2 g/cm^3) .

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

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

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

2.2- Preparation of Test Specimens:

Specimens of thermal erosion test are a square shape, as shown in figure (2) with dimensions (100 ×100mm), and (10mm) thickness, which it consist of two layers:

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

b. Composite material layer with (6mm) thickness, it contains carbon and Kevlar fibers which used as consecutive layers in araldite resin .

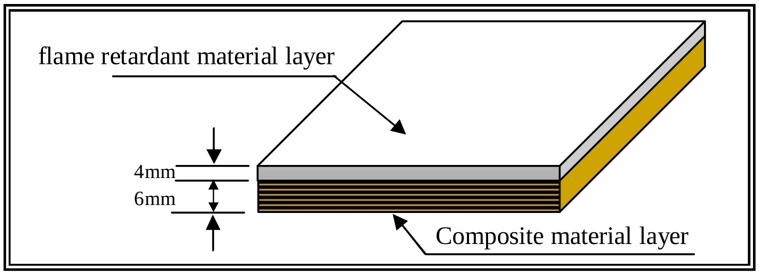

Fig (2): Specimen of thermal erosion test**.**

2.3- Thermal Erosion Test

Flame generated from butane-propane gas(C_3H_8-C_4H_{10}) with temperature (2000ºC) was used in this test. The system (contains flame retardant material and composite material) was exposed to this flame under different exposure distances (10 mm , 20mm). Figure (3) shows the thermal erosion test apparatus, surface temperature method used here to calculate the amount of heat transmitted through flame retardant material and composite material .Temperature monitoring and recording system (Program) was used to observed and saved temperatures measured by thermocouple type-K by entering it in computers by transformation card (AD) .

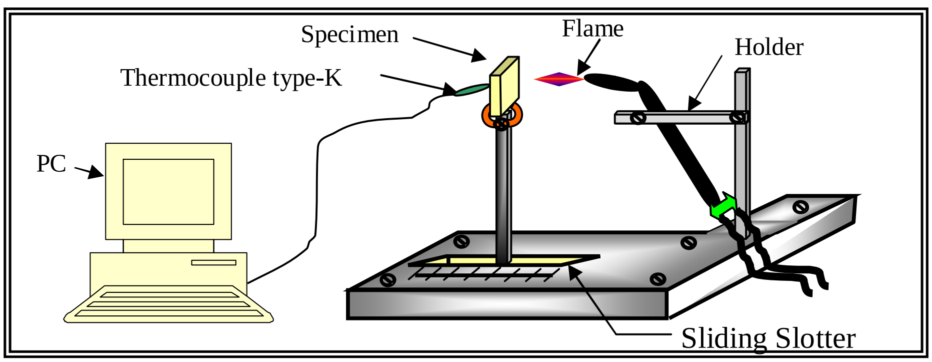

Fig (3): Thermal erosion test apparatus**.**

3- RESULTS AND DISCUSSION

From the results obtained by thermal erosion test, It can be seen :

Figure (4) 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 exposition time to the flame . During this stage , zinc borate has a water of hydration in its chemical structure , therefore , it released this water to extinguish the fire through cooling , in addition , zinc borate will formed glassy coating layer which protecting the substrate (composite material) and the fire spread will decrease. This process of flame retardancy will be increased by addition (10 %) from antimony trioxide because its 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 %) [11].

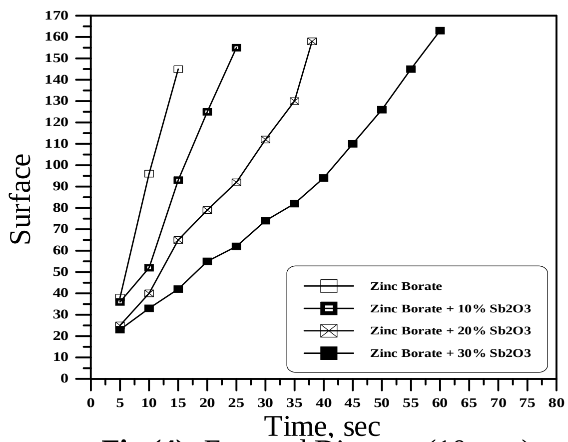

Fig (4): Exposed Distance (10 mm) .

Figure (5) the thermal erosion test for composite material with retardant surface layer with exposed distance(20mm) . As a result, when the exposed distance to flame increased to (20mm), the time necessary to break down of flame 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. All that will rise the time of break down for zinc borate- antimony trioxide layer and substrate composite material. From figureures , the better results obtained with large exposed distance and large percentage from protective layer which is antimony trioxide (30%)[12].

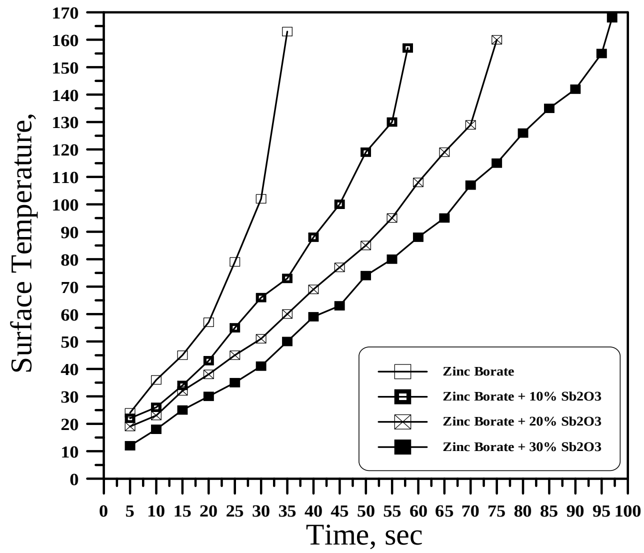

Fig (5): Exposed Distance (20mm).

4- CONCLUSIONS

From this study, we concluded that:

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 .
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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إستخدام المثبطات الهجينة للّهب لزيادة مقاومة التعرية الحرارية للمواد المتراكبة المتقدم

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الخلاصة

يسعى هذا البحث إلى تحقيق غرضين أساسيين: الأول،هو إستخدام مثبط لهب لاعضوي متمثل ببورات الزنك لزيادة تثبيط اللهب لمادة متراكبة متقدمة مكونة من راتنج الإرلدايت (CY223) الذي تم تقويته بألياف الكاربون وألياف كيفلار الهجينة بشكل حصيرة (0° - 45°) حيث تم إستخدام طبقة سطحية من بورات الزنك كطبقة طلاء سمكها (4mm) . بعدها تم تعريض هذا النظام للهب مباشر متولد من شعلة غازية درجة حرارتها (2000°C) وبمسافات تعرض مختلفة للّهب (20mm,10mm) ودراسة مدى مقاومة طبقة المادة المثبطة للهب ومدى حمايتها للطبقة التي تحتها . الهدف الثاني ، تكوين مثبط لّهب هجين بإضافة ثالث أُوكسيد الأنتيمون إلى بورات الزنك بكميات متنوعة (30%,20%,10%) لتحسين فعل تثبيط اللهب لهذه المادة وتعريض هذه المادة الهجينة لنفس درجة حرارة الّلهب ومسافات التعرض ولفترات زمنية (5-60 ثانية) و(5-95 ثانية) . تم إستخدام طريقة السطح المعاكس للشعلة لقياس الحرارة المنتقلة للمادة المتراكبة . أفضل النتائج المستحصل عليها كانت مع أكبر مسافة تعرض ونسبة من الطبقة الحامية الهجينة والتي هي بورات الزنك مع (30%) ثالث أُوكسيد الأنتيمون .

الكلمات الدالة : مثبط لّهب هجين ، مادة متراكبة ، المثبطات اللاعضوية.