Eng. & Tech. Journal ,Vol.29, No. 11, 2011

Reducing of Flammability for Polymeric Composite Material by Using Flame Retardants Coating

Ali Ibrhim Al-Mosawi

Received on: 17/2/2011
Accepted on: 5/5/2011

Abstract

The low thermal resistance of polymeric materials to high temperatures considered the main limitation to used these materials in such applications required high thermal resistance ,so ,the present research aimed to study the possibility to increasing flame retardancy of advanced polymeric composite materials reinforced by fibers by coating by a flame retardant layer represent antimony tetroxide (Sb_2O_4) as a coating layer (4mm) thickness to react and prevent spread of flame on surface of composite material consist of araldite resin(AY103) reinforced by woven roving carbon - Kevlar fibers (0°-45°) and exposed this coating layer to direct flame generated from oxyacetylene flame with different exposure distances (10mm,15mm,20mm) and study the range of resistance of flame retardant material layer to the flames and thermal resistance and flame retardancy after coating by antimony tetroxide as well as rising flame resistance increased exposure distances to flame .

Keywords: Hybrid Composite Material, Flame Retardancy, Thermal Resistance

إختزال قابلية الإشتعال للمواد المركبة البولميرية بإستخدام الطلاء بمعيقات اللّهب

الخلاصة

تعتبر مقاومة المواد البولميرية المنخفضة للحرارة العالية المحدد الأساسي لإستخدامها في التطبيقات الصناعية التي تتطلب مقاومة حرارية عالية ،لذلك يهدف البحث الحالي إلى دراسة إمكانية زيادة إعاقة اللّهب للمواد المركبة البولميرية المتقدمة المقواة بالألياف بطلائها بطبقة مكونة من مادة معيقة للّهب متمثلة برابع أوكسيد الأنتيمون (Sb_2O_4) كطبقة طلاء بسمك (4mm) لإعاقة اللّهب وإنتشاره على سطح المادة المركبة المكونة من راتنج الإرلدايت (AY103) المقوى بألياف الكاربون- كيفلار الهجينة بشكل حصيرة (0º-45º) وتعريض هذه الطبقة من الطلاء إلى لهب مباشر متولد من الشُعلة الأوكسي أستلينية وبمسافات تعرض مختلفة (20mm,15mm,10mm) ودراسة مدى مقاومة هذه الطبقة للحرارة ومدى حمايتها للطبقة التحتية .أظهرت نتائج الإختبارات العملية زيادة كبيرة في المقاومة الحرارية وإعاقة اللّهب للمادة المركبة بعد طلائها برابع أوكسيد الأنتيمون إضافة إلى إرتفاع مقاومة اللّهب مع زيادة مسافة التعرض للشُعلة الحرارية .

الكلمات الدالة : مادة مركبة هجينة ، إعاقة اللّهب ،المقاومة الحرارية .

1- Introduction

Flame retardants are chemicals which are added to many materials to increase their fire safety. For example, many plastics are highly flammable and therefore their fire resistance is increased by adding flame retardants in order to reduce the risk of fire. Flame retardants work through a number of different mechanisms. The ultimate goal is to decrease the potential of ignition or to delay the spread of a flame over the body of material the retardant is protecting. This is accomplished by increasing the combusting resistance of the materials to continue burning [1]. Flame retardants are applied in a number of different methods.

*Technical Institute -Babylon, Foundation of Technical Education/ Babylon

https://doi.org/10.30684/etj.29.11.10
2412-0758/University of Technology-Iraq, Baghdad, Iraq

They can be impregnated into plastics during processing, blended with insulation materials during application, used as treatments on shingles and decks and applied on the surface of materials as coatings or paints [2].

Some flame retardants cause a treated material to char thus inhibiting the pyrolysis process. Others remove flammable gases by reacting with the hydrogen and hydroxide radicals in the air. There are four primary substances which work to retard fire in different ways. These families include halogenated, phosphorus, nitrogen and inorganic flame retardants [2].

2- Inorganic Flame Retardants

There are a few different inorganic substances that are effective at retarding flames in the temperature range that plastics decompose, between (150 and 400)°C. The most commonly used flame retardant is aluminum hydroxide , magnesium hydroxide , zinc borate , and antimony oxides (trioxide ,tetroxide ,pentoxide) [3]. Antimony tetroxide is an inorganic compound with the formula Sb_2O_4 **(fig(1))** , which used as a flame retardant in engineering plastics due to its stability in high temperatures . Sb_2O_4 has a white color when cold but reversibly yellows upon heating[4]. The material forms when Sb_2O_3 is heated in air:

$$Sb_2O_3 + 0.5\ O_2 \rightarrow Sb_2O_4 \quad \Delta H = -187\ \text{kJ/mol}$$

At 800 °C, antimony pentoxide loses oxygen to give the same material:

$$Sb_2O_5 \rightarrow Sb_2O_4 + 0.5\ O_2 \quad \Delta H = -64\ \text{kJ/mol}$$

3- Composite Materials

A composite is commonly defined as a combination of two or more distinct materials, each of which retains its own distinctive properties, to create a new material with properties that cannot be achieved by any of the components acting alone. Using this definition, it can be determined that a wide range of engineering materials fall into this category. For example, concrete is a composite because it is a mixture of Portland cement and aggregate [5]. Fiberglass sheet is a composite since it is made of glass fibers imbedded in a polymer. Composite materials are said to have two phases. The reinforcing phase is the fibers, sheets, or particles that are embedded in the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Typically, reinforcing materials are strong with low densities while the matrix is usually a ductile, or tough, material [6].

The aim of this research is increasing flame retardancy of composite material by coating it by a flame retardant material represent antimony tetroxide to react and prevent spread of flame on surface of composite material .

[Ali] was used an 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 [7].**[Abbas, Ali, and Mushtaq]** This was investigated possibility to increase the flame retardancy for composite materials by addition of a flame retardant material which represent the zinc borate as a coating layer of (4mm) thickness on the surface of composite material consist of araldite resin reinforced by hybrid fibers from carbon and kevlar fibers as a consecutive layers [8]. **[Ali, Kahtan , Jaleel and Samara]** was studied the compilation between two types of inorganic flame retardants zinc borate and antimony trioxide and study the effect of this compilation on thermal resistance at elevated temperatures for advanced composite material consist from unsaturated polyester resin and glass fibers, where the thermal erosion test at (2000°C) and (3000°C) [9]. **[Mostashari, Nia , and Moafi]** was studied comparative effect of selected hydroxides of groups IA and IIA on the flammability of a cotton fabric [10].

4- Experimental Work

The experimental work includes the following :

1- Materials Used .

Three types of materials were used :

a- Antimony tetroxide -Sb_2O_4: supplied from NL Industries with particle size (2µ) .

b- Araldite resin-(AY103) : supplied by Ciba-Geigy company .

c- Woven roving carbon-Kevlar fibers(0 º - 45 º): The company supplied these fibers is Hyfil ltd , UK .

2- Preparation of Test Specimens.

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

a- Fire retardant material layer with (4mm) thickness represented by antimony tetroxide (Sb_2O_4) .

b- Composite material layer with (6mm) thickness , consist of (60%) fibers and (40%) resin as weight fraction .

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) .

5- Results and Discussion

fig (5) represent thermal erosion test with exposed distance (10 mm) .The temperature of opposite surface to flame begins to increase with increasing time of exposed to flame and during this time , antimony tetroxide absorbed heat and transformed to antimony trioxide which also a flame retardant .This represent endothermic process which decreased surface temperature as well as rise fall down of flame retardant layer and protect the substrate [11].

This state of absorbed heat and transformed to antimony trioxide will improved as the exposed distance increased to (15 mm) as shown in **fig (6)**, where the flame heat reached to antimony tetroxide layer will decreased .So ,the break down of antimony tetroxide will delay and the resistance to heat as a result will rise .After that, antimony tetroxide will decomposed to antimony trioxide and the flame spread will retard by this oxide again ,and all this cause to increase the flame retardancy of composite material [12].

fig (7) represent thermal erosion test with exposed distance (20 mm) . As observed from this figure ,the resistance to flame will increased and the presence of antimony tetroxide will be longer due to decreased amount of heat reached to retardant layer . The endothermic reaction will continue until failure of this protect layer [7]. **fig (8)** represent a comparison between three exposed distance .

6- Conclusions

From the result obtained by thermal erosion test we concluded :

1- increasing flame retardancy of antimony tetroxide layer as increased in exposed distance .
2- break down of antimony tetroxide to trioxide will improved flame retardancy .

7- References

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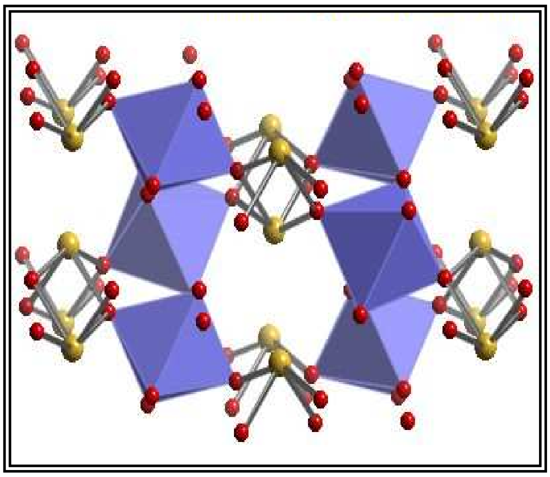

figure(1) : Structure of antimony tetroxide[4]

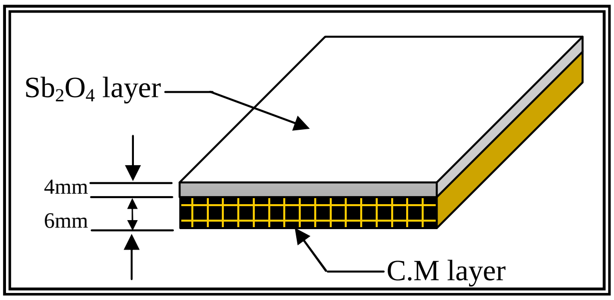

figure (2): Specimen of thermal erosion test

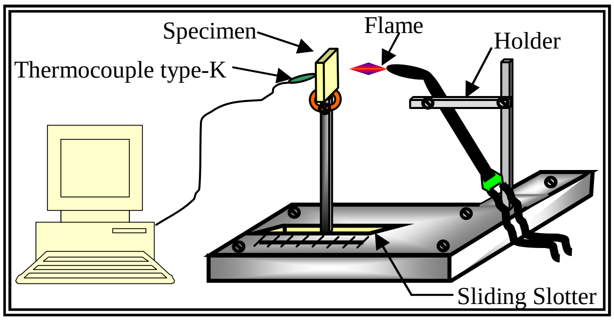

Figure (3): Mechanism of thermal erosion

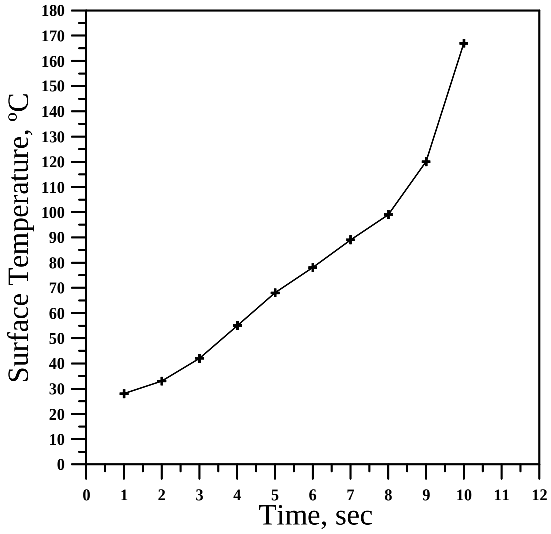

figure (5): Variation of surface temperature Vs time of exposed to flame at exposed distance (10

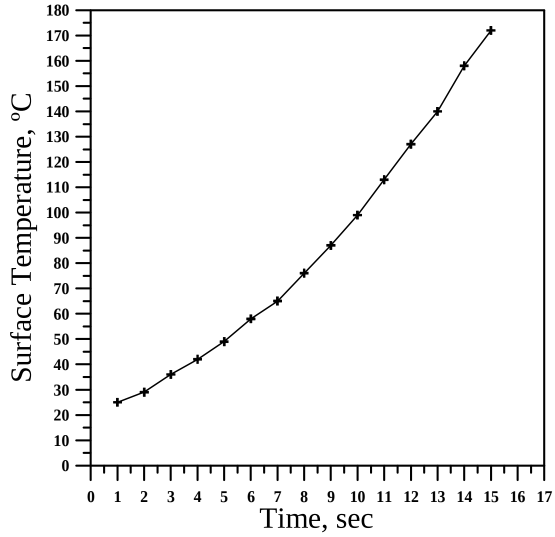

figure (6): Variation of surface temperature Vs time of exposed to flame at exposed distance (15 mm)

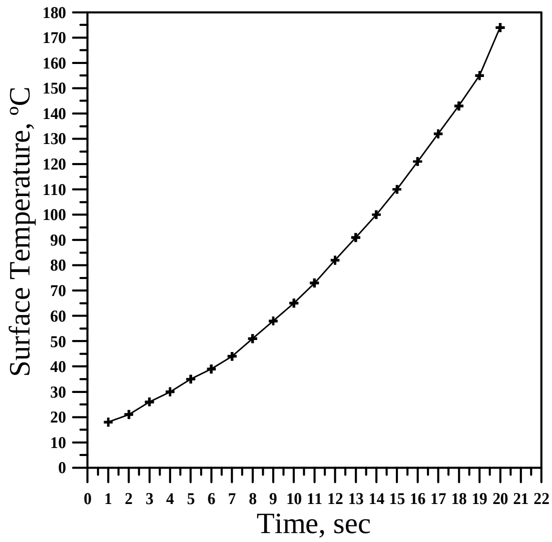

figure (7): Variation of surface temperature Vs time of exposed to flame at exposed distance (20 mm)

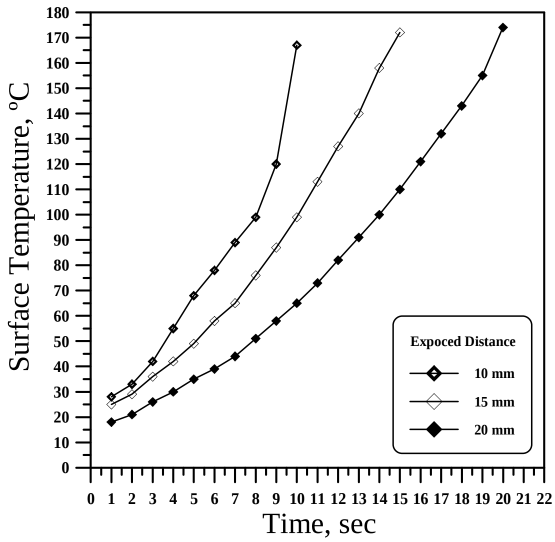

figure (8): Comparison between three exposed distance