Flame retardancy of structural composites

Ali I .Al-Mosawi[1,a] , Haider K. Ammash[2] , Ali J. Salaman[3] , Ali R. Yousif[4] , Muslim M.Ali[5]
[1,3,4,5] Machines and Equipments Depart. ,Technical Institute- Babylon ,IRAQ
[2]Engenering College ,Al-Qadisiya University ,IRAQ

Abstract :

The safety of structural composite**s** have a greatest importance to workers in this field to minimize and eliminated the losses caused by fires or completely removes through resist the flame generated from fires and terminated its activity . In this paper ,zinc borate was used to coating structural composites consist of araldite resin reinforced by carbon and Kevlar fibers to increase the flame retardancy for these structures , where a surface layer from zinc borate was used as a coating layer of (4mm) thickness .Then, this system was exposed to a direct flame generated from Oxyacetylene torch with different flame exposure distances (10,15, and 20mm) For enhance the action of zinc borate, a hybrid flame retardant was formed by added antimony trioxide with amounts (10%,20%, and 30%) to zinc borate 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 determine 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 .

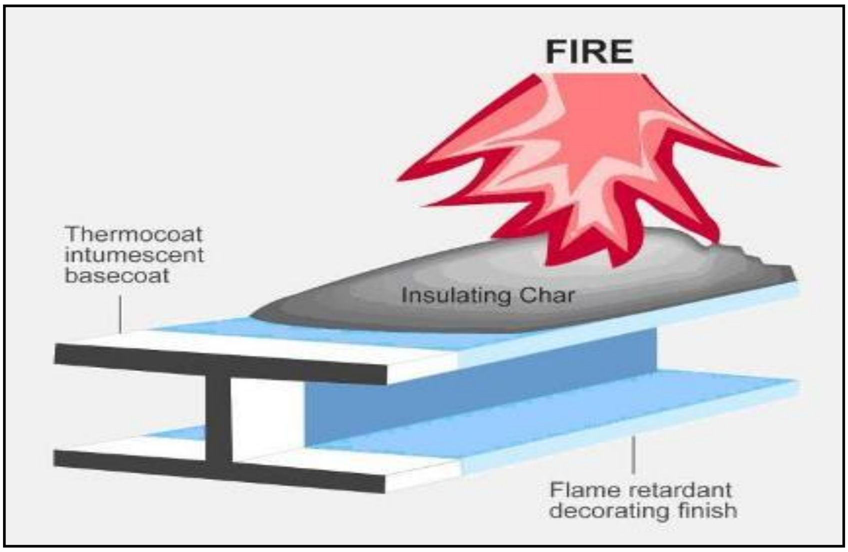
Keywords: Structural composites , Flame retardants .

1. Introduction

Flame retardants (FRs) given flammable polymer flame of functional additives; under way into flame retardant application and reactive flame retardants. Flame retardant directly mixed with resin or plastic materials, processing convenience, wide adaptation, the main flame retardants. Often as a reactive flame retardant monomer bonded to the polymer chain, on the product properties of small and durable flame-retardant effect [1]. According to the composition of flame retardant include inorganic flame retardants, halogen flame retardants (chlorinated organic compounds and organic bromide), phosphorus flame retardant (red phosphorus, phosphate, and halogenated phosphate) and nitrogen flame retardant, etc.. Reactive flame retardant and more reactive functional group-containing organic halide and organic phosphorus in the monomer. In addition, smoke suppression effect with molybdenum compounds, tin compounds and iron compounds, such as the scope is also flame retardant [2]. Mainly used for flame retardant plastics demand, delay or prevent the plastic, especially the burning of plastic polymer type. Time to ignite growth, fire extinguishing, difficult to ignite. General, such as PP, PA, PE, PS, ABS, EVA and PET, PBT and other flammable polymer plastics both need to add special-purpose flame retardant .

Flame retardant present mainly organic and inorganic, halogen and non-halogen [3]. Is brominated organic, nitrogen line and red phosphorus and compounds represented by some of the flame retardants, inorganic mainly antimony trioxide, magnesium hydroxide, aluminum hydroxide, silicon and other flame retardant system. In general, organic flame retardant has very good affinity in plastics, brominated flame retardants in the organic flame retardant system, position of absolute dominance, although the issue of environmental protection, "criticized" many, but there are other flame retardant system has been difficult to replace [4] . In the non-halogen flame retardants in the red phosphorus is a better flame retardant, have to add less, flame retardant, high efficiency, low smoke, low toxicity, wide range of uses, etc; red phosphorus and aluminum hydroxide, expansion of graphite inorganic flame retardants such as the use made of composite phosphate / magnesium; P / Al; P / graphite and other non-halogen flame retardants, flame retardants can be used is greatly reduced, thus improving the performance of plastics processing and mechanical properties [5]. But the ordinary red phosphorus easily oxidized in air, moisture, easily lead to dust explosion, transportation difficulties, and poor compatibility with the polymer material defects, application has been limited.

To make up for this lack of red phosphorus in order to expand the range of applications, we have adopted the advanced technology microcapsules, making micro-encapsulated red phosphorus. Micro-encapsulation red phosphorus red phosphorus than to overcome the drawbacks inherent in things, and has high efficiency, low smoke, in the process does not produce toxic gases, their dispersion, physical, mechanical properties, thermal stability and flame retardant properties are increased and improvement [6]. **Fig(1)** shows the work way of FRs .



Fig(1) : Work way of FRs

2. Experimental Work

1- Materials used .

a. Fire retardant material:

1- Zinc Borate 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: High molecular weight Araldite resin GT 7077 (BPA type 7) .

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 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.

3- Thermal erosion test .

This test was done according to ASTM E 162 standard using a radiant heat source for surface flammability 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). A transformation card (AD) which called Thermal monitoring and recording system (see **Fig (2)**) was used to observed and saved temperatures with time (in seconds) .

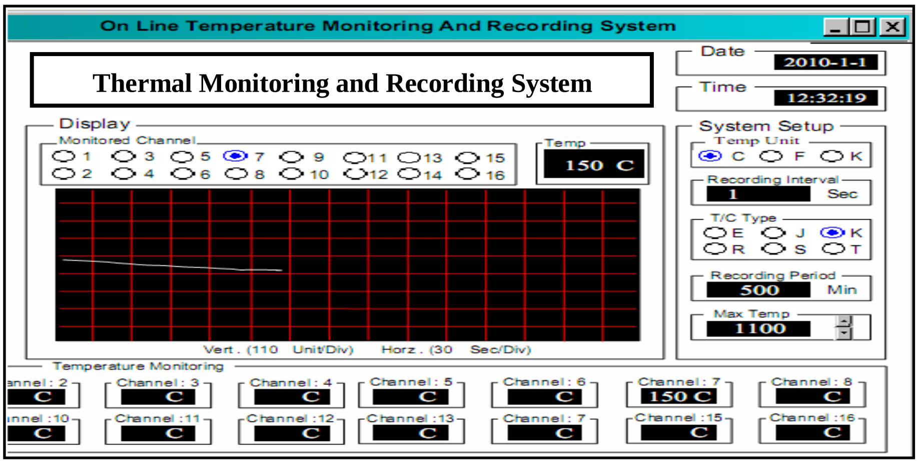


Fig (2): Thermal monitoring and recording system

3. Results and Discussion

Fig (3) 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 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 (4) 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 (5)** ,and this will rise the time of break down for zinc borate- antimony trioxide layer and substrate composite material [7] . From figures, the better results obtained with large exposed distance and large percentage from protective layer which is antimony trioxide (30%).

4. 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.

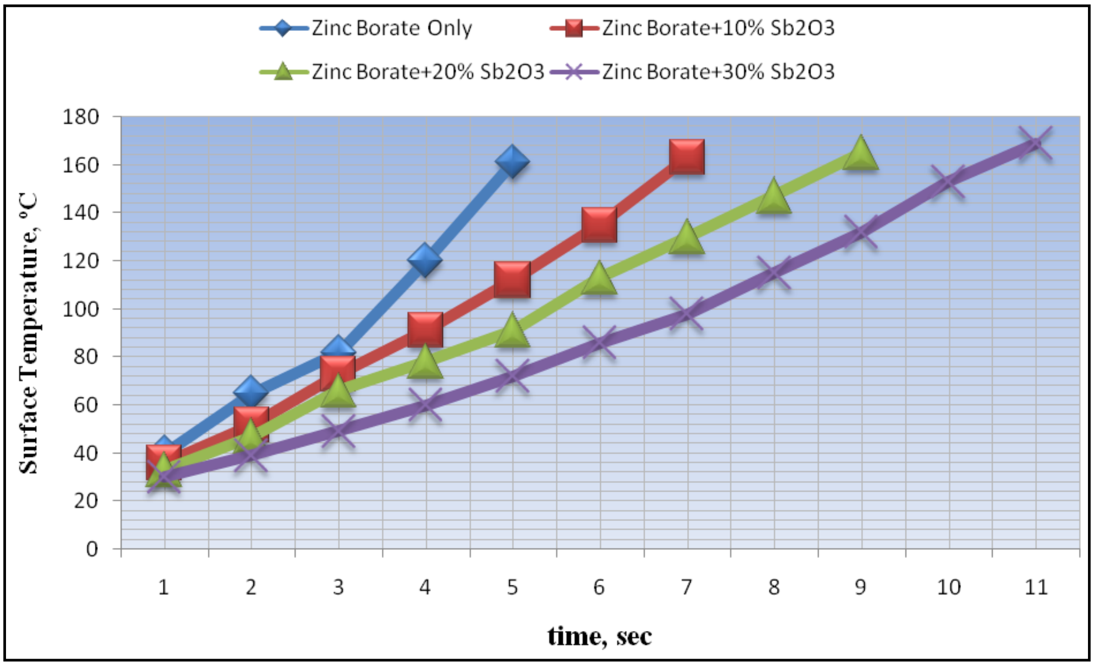


Fig (3): Thermal erosion test with (10 mm) exposed distance

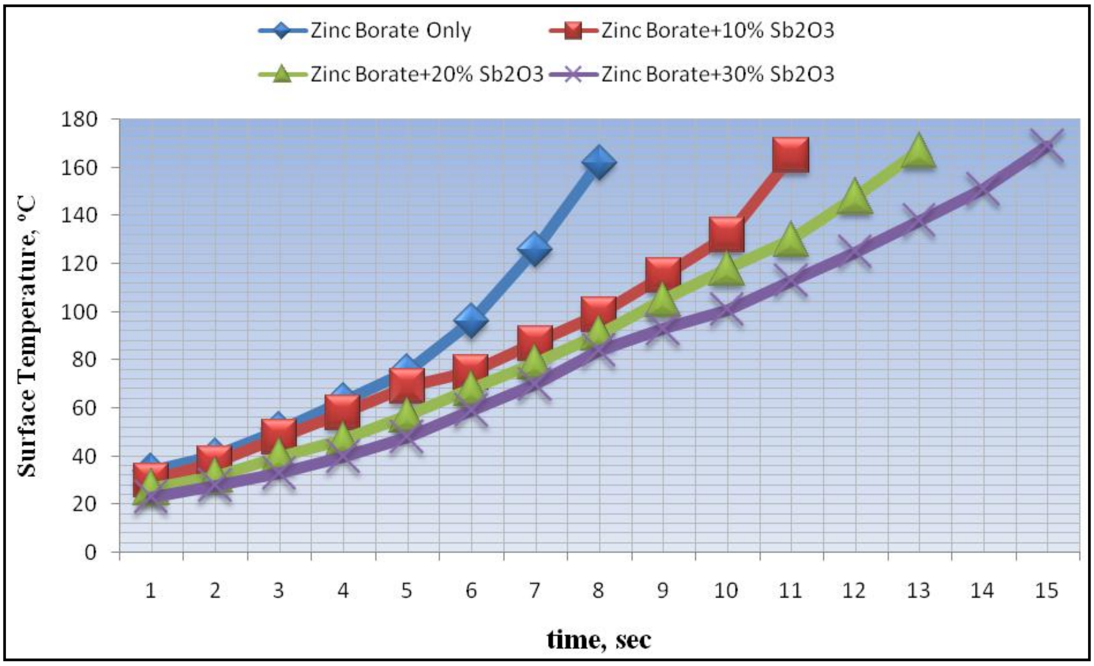


Fig (4): Thermal erosion test with (15 mm) exposed distance

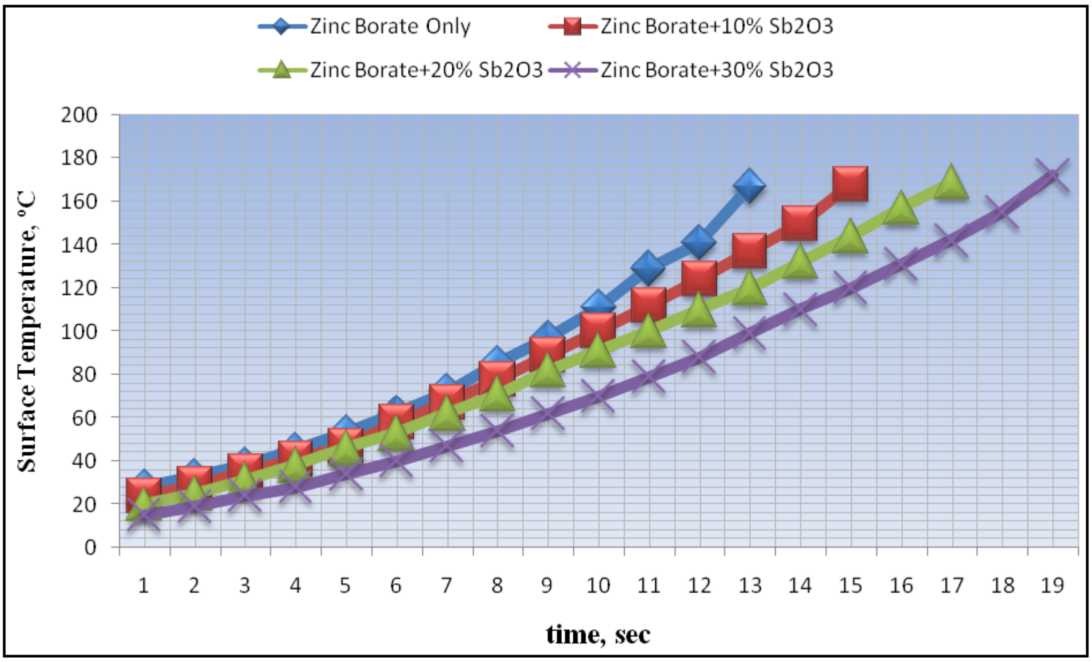


Fig (5): Thermal erosion test with (20 mm) exposed distance

5. References

1. Ping'an Song, Youming Yu, Tao Zhang, Shenyuan Fu, Zhengping Fang, and Qiang Wu "*Permeability, Viscoelasticity, and Flammability Performances and Their Relationship to Polymer Nano composites* " , Ind. Eng. Chem. Res., 51 (21), 2012, pp 7255–7263 .

2. Takashi Kashiwagi, Fangming Du, Jack F. Douglas, Karen I. Winey, Richard H. Harris, Jr and John R. Shields "*Nanoparticle networks reduce the flammability of polymer nanocomposites* " ,Nature Materials ,4, 2005, pp. 928 – 933 .

3. Horrocks, A.R.; Price, D. " *Fire retardant materials* " , Taylor and Francis Group, LLC ,2010
4. Takashi Kashiwagi , Eric Grulke, Jenny Hilding, Katrina Groth, Richard Harris, Kathryn Butler, John Shields, Semen Kharchenko, Jack Douglas "*Thermal and flammability properties of polypropylene/carbon nanotube nanocomposites*", Polymer, Vol. 45, Issue. 12, May 2004, pp. 4227–4239.

5. Jeffrey W. Gilman , Catheryn L. Jackson , Alexander B. Morgan , and Richard Harris "*Flammability Properties of Polymer−Layered-Silicate Nanocomposites. Polypropylene and Polystyrene Nanocomposites* ", Chem. Mater., 12 (7), 2000,pp 1866–1873.

6. Peter W.Dufton "*Flame Retardants for Plastics*", *Smithers Rapra Press*, 2003 , January 1.

7. C. Formicola, A. De Fenzo, M. Zarrelli, A. Frache , M. Giordano, G. Camino " *Synergistic effects of zinc borate and aluminium trihydroxide on flammability behaviour of aerospace epoxy system* " , eXPRESS Polymer Letters ,3(6) ,2009 ,pp 376–384 .

8. Kashiwagi, T., Danyus, R., Liu, M., Zammarano, M., and Shields, J.R., "*Enhancement of Char Formation of Polymer Nanocomposites Using a Catalyst*" , Polymer Degradation and Stability, Vol. 94, 2009, pp. 2028-2035.