

## Effect of triammonium orthophosphate on fire retardation of Epoxy resin reinforced with wood flour

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### Abstract :

Epoxy resin reinforced by 30% of wood flour was prepared as a composite . Triammonium orthophosphate as a flame retardant was added to composite at weight percentages of ( 0 , 2 , 3 , 5 , 7 , and 10 ) % . Hand lay-up technique was used to prepare sheets from that composite. The results indicated that the rate of burning decreases with increasing the weight percentage of that flame retardant. And the limiting oxygen Index (LOI ) increases with increasing concentration of that flame retardant .

**Key words :** Epoxy resin , wood flour , Reinforced Epoxy resin composite , flame retardant

### Introduction:

The growing industrial activities create continuous demand for improved materials which satisfy the increasing stringent requirements , such as higher strength , modulus , thermal and electrical conductivity and fire resistance [1,2] .

Fire needs : Fuel , oxygen and ignition source , Low- temperature pyrolysis , giving volatile , flammable products , precedes ignition , flame propagation is maintained by diffusion of fuel and oxygen to the combustion zone as well as by production of heat in excess of losses .Combustion process can be retard by : [3]

Formation of protective layer (coating) which reduce heat transfer and diffusion of oxygen from reaching solid-phase and prevent fuel from reaching gas-phase (e.g. phosphorus compound) , Dilution of combustion gases : (such as evaluation of carbon dioxide or nitrogen), Cooling the substrate to a temperature below that required for sustaining the combustion process , Free- radical mechanism by reaction in the gas phase(such as

halogenated flame retardants , Promoting formation of incombustible materials by reaction in the solid phase ( e.g. ammonium phosphate ) .

All organic polymers burn and thus entail measure of fire hazard in some situation [4] . , therefore , many studies were performed to reduce flammability of polymeric materials by using flame retardants .

Fame retardants are defined as a chemical compounds that modify pyrolysis reaction of polymer or oxidation reactions implied the combustion by slowing them down or by inhibiting them , flame retardants are divided into additive , reactive flame retardants [5] .

Known flame retardants can be classified into organic and inorganic compounds [4,6]

A- Organic compounds include : Compounds of phosphorus , generally solid-phase retardants , Compounds of halogens which have effectiveness in the order  $F < Cl < Br < I$  , Compounds containing both phosphorus and halogen . B- Inorganic compounds

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include: Antimony compounds which are used synergistically with halogens containing flame retardant, Hydrates which decompose endothermically releasing water vapour into gas-phase (e.g.  $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ ,  $\text{Mg}(\text{OH})_2$ ), Acid and forming salt such as: ammonium salts, sulfure acid, phosphoric acid, and boric acid which act as a solid first-phase retardant. Many studies showed that a large variety of organic and inorganic phosphorus compounds has been as being useful in reducing the flammability of different polymeric materials, from these studies: red phosphorus with polyethelene terphthalate [7], Diammonium phosphate with Epoxy resin and polyester resin [8], ammonium polyphosphate with polyesters and Epoxies[9]. Ammonium polyphosphate with wood plastic composites [10], reactive phosphorus with Epoxy resin [11], alkyl phosphonium and alkyl ammonium with Epoxy resin-clay non composite materials [12]. In this study, triammonium orthophosphate was used to retardance flammability of wood flour-reinforced Epoxy resin.

## Materials and Methods:

### Materials

The materials one used in this study include:

Epoxy resin 105 (which has low viscosity, supplied from industrial chemical and resin, Jordan/the Jordian Swiss. Company for manufacturing and marking construction chemicals Ltd.), wood flour (in length 0.5 – 1 mm) and triammonium orthophosphate (which supplied from England).

### Sample Preparation:

Hand lay-up technique was used to prepare the sheets by using the cast mould. Cast mould include: A glass plates of dimensions (300 x 300 x 6) mm used as a mould stage, glass strips

of dimensions (200 x 20 x 3) mm., used as boundaries for cast mould. The specimens of Epoxy resin containing additive with weight percentages of (0, 2, 3, 5, 7, 10) and reinforced with 30% wood flour were prepared in the form of sheets of (18 x 18 x 0.3) cm.

### Technique of measurements:

The flammability of the sample was determined in term of:

1. The rate of burning, Extent of burning and time of burning according to ASTM: D635, in this method specimens ( $130 \pm 0.1$ ) (mm length, ( $13 \pm 0.1$ ) mm width and ( $3 \pm 0.1$ ) mm thickness), were clamped horizontally and flame applied to free end of the specimen for a given time, they were termed (self-extinguishing if flaming did not continue when the test flame was removed [13]).
2. The oxygen index according to ASTM D-2863, in this method, the limiting oxygen Index (LOI) is the volume concentration of Oxygen which allows the test specimen to burn for at least 3 min and is calculated as:

$$\text{LOI} = \frac{[\text{O}_2]}{[\text{O}_2] + [\text{N}_2]}$$

Where  $[\text{O}_2]$  and  $[\text{N}_2]$  are the volume concentration of oxygen and nitrogen in the test atmosphere [14].

## Results and Discussion:

### Rate of burning

The results of test of burning rate for wood flour / Epoxy resin composite with triammonium orthophosphate are listed in table (1) and illustrated in figures (1).

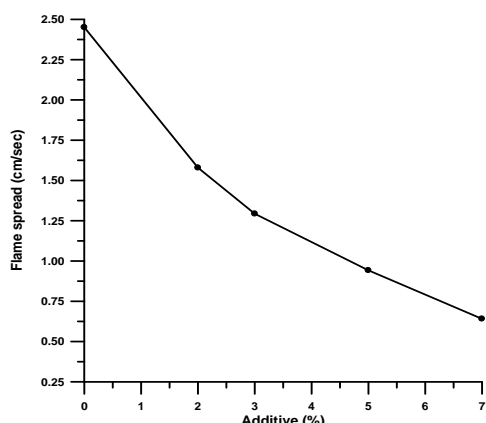
The results showed that rate of burning of specimens decrease with increase in amount of incorporation of the additive

, the self-extinguishing occurred in specimens of test at weight percentages , (3 % ) , (5 %) and (7 %) and the flame spread at these percents are (1.293) , (0.942) , and (0.641) , respectively as shown in table (1). at weight percentage of (10%) the specimens were non burning, according to figure (1), the curve shows great reduction in rate of burning with increase of additive weight % , the results obtained shows that the additive is effective flame retardant for the composite , because it reduce the contribution of hydrocarbon fuel and produce a more carbonaceous char [15,16] as shown in figure (2), the char acts as an insulator to decrease heat transfer to the condensed phase and as a barrier to prevent the volatile fuel from reaching the gaseous [15,17]

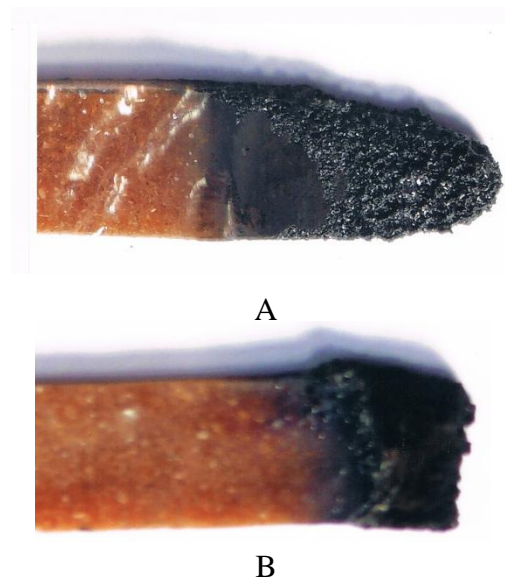
**Table (1) Rate of burning (R.B) test for EP reinforced with wood flour + different weight percentages of tri ammonium orthophosphate**

Additive	0%	2%	3%	5%	7%	10 %
AEB cm	10	10	6.7	2.1	0.5	-
ATB min	4.08	6.33	5.18	2.23	0.78	-
R.Bcm/m in	2.45 1	1.57 9	1.29 3	0.94 2	0.64 1	-
S.E	-	-	yes	yes	yes	yes
N.B	-	-	-	-	-	yes

AEB : Average extent of burning  
 ATB : Average time of burning  
 RB : Rate of burning  
 SE : Self-extinguishing .  
 NB : Non burning .



**Fig. (1): Variation of flame spread with additive weight (%) for EP reinforced with wood flour.**



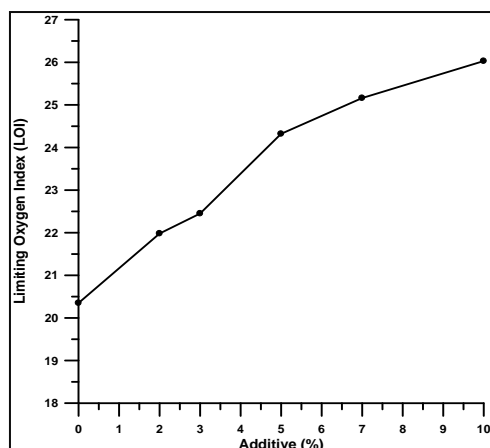
**Fig. (2) A- pure specimen, B- with additive**

**Limiting oxygen index ( LOI )**

The effect of triammonium orthophosphate on (LOI ) values of specimens is indicated in table ( 2 ) , the results obtained for (LOI ) test shows that the values of (LOI ) increase with increase in concentration of the additive . The variation of (LOI ) with the weight percentages of additive for specimens tested are shown in figure ( 3 ) , Results of (LOI ) test shows that there is good agreement with the results of test of rate burning .

**Table ( 2 ) limiting oxygen index for Epoxy resin reinforced with wood flour + different weight percentage of triammonium orthophosphate**

Additive %	LOI
0	20.35
2%	21.98
3%	22.45
5%	24.32
7%	25.16
10%	26.03



**Fig. (3): Variation of LOI with additive weight (%) for EP reinforced with wood flour.**

### Conclusion :

Results showed that the self-extinguishing occurred at the weight percentage 3% , 5% and 7%, no burning happened at 10% . Triammonium orthophosphate has high efficiency as a flame retardant for Epoxy resin reinforced with wood flour , this flame retardant can be used at low weight percentages . The ideal weight percentage is 7 – 10 % .

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## تأثير ثلاثي أمونيوم أورثو فوسفات على مقاومة الاحتراق لراتنج الايبوكسي المسلح بنشارة الخشب

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### الخلاصة :

تم دراسة تأثير اضافة ثلاثي أمونيوم اورثو فوسفات على لهوية راتنج الايبوكسي المسلح بـ 30% من نشارة الخشب . استخدم المضاف بنسب مئوية % ( 0 , 2 , 3 , 5 , 7 , 10 ) . ثم حضر صفائح من المتراكب بالطريقة اليدوية لصب مكبوسات .  
قد اظهرت النتائج ان معدل احتراق العينات يتناقض مع زيادة النسب المئوية للمضاف وان معامل الاوكسجين المحدد ( LOI ) يزداد مع زيادة تركيز المضاف .