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Use of Ammonium Sulphamate as Flame Retardant Paint Additive

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Abstract: Flame retardant paints were prepared by incorporating ammonium sulphamate into emulsion and gloss paints. Wood splints were coated with these paints and the effects on ignition time (IT), flame propagation rate (FPR) and after-glow time (AGT) were studied. It was observed that whereas time of ignition was extended, flame propagation rate and after-glow time were drastically reduced. These observations were attributable to the fact that at flaming heat, the additive decomposes into non-combustible gases which reduced oxygen concentration in the combustion zone, ie, paints act as flame retardant by the gas phase mechanism.

Key words: Ammonium sulphamate · AGT · FPR · IT · Flame retardant and timber

INTRODUCTION

Wood is an indispensable material used in building, construction and making other manufacturing products. It consists of some 50% cellulose, which makes it highly degradable by heat/fire. It ignites easily and burns vigorously, constituting a serious fire hazard [1,2]. Since it is prone to fire, it is thus, not surprising that a lot of energy and time has been devoted to study how cellulose burns and how its combustibility could be controlled. Flame retardancy is a technique of treating materials so that their combustibility will be reduced or totally stopped. A fire retardant chemical when incorporated into a material substantially suppresses the ease of ignition and /or flame propagation [1, 3- 5]. This can be achieved by coating with a flame retardant paint.

Fire is a rapid but persistent chemical reaction accompanied by emission of heat and light. This reaction is self-sustaining unless extinguished or if fuel concentration falls below a minimum value. Flame however, is the visible manifestation of fire which results from heating to incandescence of minute particulate matter composed principally of incomplete burnt fuel [5, 6]. The burning process is an exothermic reaction initiated by external heating. Pyrolysis or degradation of the burning material, eg wood occurs when the external temperature progressively increases beyond a point when enough thermal energy has been imbibed as to break bonds [1]. The products of pyrolysis, the pyrolysates, include combustible and non-combustible gases as well as carboneous char. Char is the concentration of the carbon skeletal reminants of the pyrolysis. The pyrolysis of cellulose is represented as:

$$(C_6H_{10}O_5)n \xrightarrow[\text{Tpy}]{\text{heat}} (C + 5H_2O)n$$

Tpy is the pyrolysis temperature. The burning process does not stop at pyrolysis; its product would be rapidly oxidized if: -(a). sufficient quantity of oxygen is available. (b). a high enough temperature for the oxygen-fuel mixture is available (c). flammable volatiles are present. Ignition occurs if the igniting source raises the temperature of the oxygen-fuel mixture to temperature of oxidation (Tox), whereas, combustion occurs when the heat of oxidation of the pyrolysate (ΔHox) is greater than the heat of pyrolysis (ΔHpy) i.e. ΔHcombustion = ΔHox - ΔHpy

Under ideal condition however, pyrolysis and combustion of flammable volatiles occur at the same time and no char is produced, because there is sufficient amount of oxygen [1].

For combustion not to be extinguished, certain requirements are necessary (a) a fuel supply (b) a means of gasifying the fuel (c) a means of mixing the gaseous product with oxygen in the presence of heat. The burning process therefore consists of heating the decomposition or gasification products, combustion and flame propagation [1]. The burning of cellulose can be shown as:

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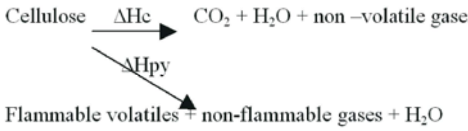

The overall burring of fuel can thus be illustrated as:

$\text{Fuel} + O_2\ CO + CO_2 + H_2O + \text{light} + \text{heat}$

The above reaction proceeds by discrete stages e.g.

$HO^0 + CO\ CO_2 + H^0$
$RCH_3 + HO^0\ RCH_2 + H_2O$
$RCH_3 + O_2\ RCHO + HO^0$
$H^0 + O_2\ HO^0 + O^0$

Since a flame retardant is a substance which when added to a combustible material hinders ignition [1, 5]. The efficiency depends on its ability to reduce burning when incorporated to materials or sprayed over a burning medium. Therefore, modern-day flame retardants are efficient for use for reducing fire hazards, by interfering with the flame, inhibiting the free radicals that propagate flame reaction. Some flame retardant chemicals upon their decomposition, form new catalytic active surface which are effective at destroying the free radicals required for flame propagation. Some have cooling effect and blanketing property [7]. Flame retardants also have the property of minimizing the formation of volatile flammable products and increasing the amount of water and solid char formed. They induce less exothermic combustion (absorption of energy) incapable of maintaining its self and example is the formation of carbon monoxide instead of carbon dioxide. For instance [8],

a.$C(s) + O_2(g)\ CO_2(g)$?H = -4.76KJmol^{-1}
b.$C\ (s) + ½O_2\ CO(g)$?H = -1.31KJmol^{-1}

Considering “a” and “b”, CO_2 releases more heat than CO.. This serves to slow up or hinder the ignition or growth of fire.

At the surface of a burning polymer, heat is gained from the external source causing combustion and from the burning mass which redirects some heat [1]. Consequently, heat is lost from the gasification of the polymer and other processes like conduction, convection, radiation etc. When the total heat gained is higher than the total heat lost, combustion is self-sustained. Flame retardants do not seek to promote combustion at any stage and therefore act by interrupting pyrolysis or combustion at any stage resulting in total heat lost being greater than total heat gained and thus flame extinction.. In the present work ammonium sulphamate act as a flame retardant by decomposing at high to gaseous species that dilute oxygen concentration.

Experimental

Materials: The timbers were obtained from theTimber Market at Awka and identified by Botany Department.

Table 1: The woods used for this study.

Botanic name	Trade name
Gmelina arborea	Gmelina
Chlorophora excels	Iroko

Ammonium sulphamate, the flame retardant used was procured from BDH Ltd, Poole, England.. The white emulsion and gloss paints were purchased from Citizen’s Chemical Industry, Obosi in Anambra State.

Sample Preparation

Wood Preparation: The timbers (Gmelina and Iroko) were cut into splints of uniform sizes of length 60cm, width 0.8cm and thickness 0.4cm. They were oven-dried for 2 hours at 120^{0}C. Three splints of each wood type were prepared for each concentration of ammonium sulphamate, for both the emulsion and gloss paints.

Preparation of the Flame-Retardant Paint: Flame retardant paint was prepared by mixing each 80cm^3 of white emulsion paint with varying concentrations (00, 0.10, 0.20, 0.50, 1.00, 3.00 and 5.00g) of ammonium sulphamate ($NH_4OSO_2NH_2$). The mixture was stirred thoroughly for even distribution. Each concentration was used to evenly coat three splints. The same method was adopted for gloss paint. These splints were allowed to dry for 2 weeks at room temperature.
The painted wood splints were characterized by:

Determination of the Flame Properties of the Painted Splints.

Determination of Ignition Time: The method applied was as in Ref [9]. This was performed by bringing the ignition source in contact with the base of the wood splint and noting the time interval between this contact and the onset of combustion.

Determination of Flame Propagation Rate (FPR): This was carried out by igniting a vertically clamped splint at the base with a cigarette lighter flame. The distance travelled by the char front and the time taken for the flame to traverse that distance, was measured.

$$FPR = \frac{\text{distance travelled by the char front (cm)}}{\text{Time taken (sec)}}.$$

Determination of After-Glow Time: After-glow time was measured by noting the time between flame extinction and the last visually perceptible glow i.e. the time between flame-out and the last glow.

RESULTS AND DISCUSSIONS

Ignition is initiation of combustion [1]. In other words, the time any combustible material catches fire (i.e. starts to burn).

In Figure.1, it is observed that as the concentration of $NH_4OSO_2NH_2$ increases the ignition time also increases. It is evident that even very low concentrations of the flame retardant lead to substantial increases in ignition time. Furthermore, it was observed that these effects are higher for the emulsion paint than for the gloss variety. It can be deduced that non-flammable gases evolved by $NH_4OSO_2NH_2$ inhibits ignition, thus, increasing the ignition time. Comparison of emulsion gloss paints show that wood treated with gloss paint ignite faster than the one treated with emulsion paint. This could be attributed to paint components, such as water in emulsion.

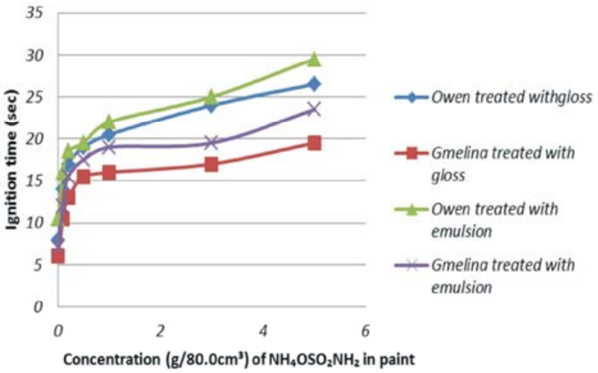

Fig. 1: Effect of ammonium sulphamate flame retardant on the ignition time of painted wood splint.

It is clear in Figure 2 that FPR decreased as the concentration of $NH_4OSO_2NH_2$ increases in both emulsion and gloss paints, indicating that the salt is a good flame retardant.The non-flammable gases suppressed the combustion, as the concentration increases,i.e more gas is evolved leading to decreased FPR. The emulsion treated paint gave lower FPR than that for gloss paint. Water being one of the major components of emulsion paint may have absorbed heat thereby reducing the FPR while solvent used in the production of gloss paint might have contributed to its increase in FPR.

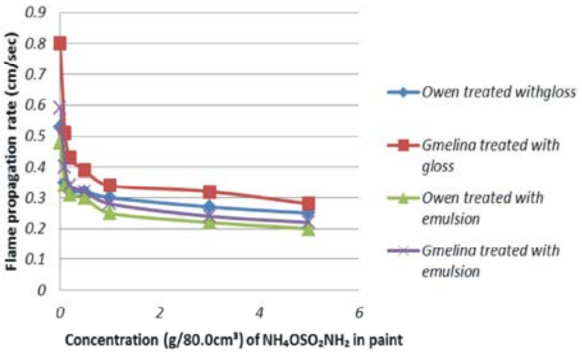

Fig. 2: Effect of ammonium sulphamate flame retardant on flame propagation rate of painted wood splint.

Glow is the visual evidence of combustion of carbon in the char layer of burning wood. When the flaming of the released combustible gases has ceased, the glowing of the char is known as after-glow [1].Consideration of Figure.3 shows decrease in after-glow time with increase in $NH_4OSO_2NH_2$ concentration. In effect, the flame retardant (FR) reduces the after-glow time by forming a seal of gas around the cellulose, thus minimizing the amount of heat reaching the timber.

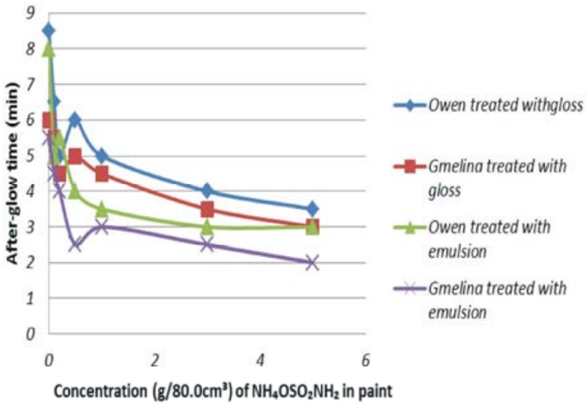

Fig. 3: Effect of ammonium sulphamate flame retardant on the after-glow time of painted wood splint.

From the foregoing results, the ammonium sulphamate treated paint is evidently a flame suppressant. At flaming heat this compound decomposes as in the equation: $NH_4\text{-}OSO_2NH_2$? $2NH_3 + SO_3$. The two non-combustible gases act as oxygen concentration diluents, thereby inhibiting the attainment of the right fuel-oxygen ratio necessary for combustion to occur or be sustained. Thus, by this mechanism the flame retardant paint reduces or retards the combustion of the timber where it is applied. The fact that flame retardant emulsion paint is more effective is attributable to the presence of water molecules in this variety.

CONCLUSION

The painting of wood splints with both emulsion and gloss paints mixed with different concentrations of $NH_4OSO_2NH_2$ considerably reduced the FPR, AGT and increased the ignition time. The results portray ammonium sulphamate is a good additive for flame retardant paints.

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