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Effects of APP on the Fire-retardant and Mechanical properties of Wood-flour/HDPE Composite

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1 Introduction

Background of this Research

- **WPC industry is growing fast**

Production of WPC in China mainland:

200 000 – 250 000 t/a, 2006

5 000 – 10 000 t/a, 2001

WPC in Olympic Park, Beijing

1 Introduction

Background of this Research

- **Interior application of WPC is promising**

  WPC almost releases no VOCs

  WPC is a good way to use the wastes of wood processing

  WPC is excellent in dimensional stability concerning moisture

  WPC is environment friendly



1 Introduction

Background of this Research

- **The fire of WPC is more destructive than wood fire**

Polyolefin-based WPC:

The HRR is at least 2 times the value of wood

PVC-based WPC:

The smoke generation is much heavier than wood

The smoke is very corrosive to metals

1 Introduction

Background of this Research

- **Research of fire retardant WPC is demanding**

  No fire retardants are effective for both of wood and plastic

  Effective fire retardants for polyolefin are either containing halogen element or need high loading

- **Opportunities for fire retardant WPCs of high wood content (e.g. WF-HDPE)**

  Use effective fire retardants for wood with higher loading

  Create new fire retardants for plastics

2 Experimental

2.1 Materials and apparatus

High density polyethylene (HDPE), 2200J;

Poplar wood flour (WF), 40-80mesh;

Paraffin (lubricant), melting point 58-60℃;

Maleic anhydride grafted polyethylene (MAPE)，

grafting ratio 0.8%;

Ammonium polyphosphate (APP)，

degree of polymerization ⩾1500;

Profile extruding system:

30mm single-screw/45mm twin-screw extruder;

FTT standard cone calorimeter

2 Experimental

2.2 WF-HDPE composites preparation

① WF was predried at 103℃ to MC ≤3%

② Mixed with HDPE, PEMA, paraffin and APP by a mixer at 100-110℃ for 10min;

③ Cooled to 50℃;

④ Extruded at 140-175℃ to obtain WF-HDPE composite sheets of 40mm×4mm cross section.

2 Experimental

2.3 Samples preparation and test

① Cut the sheets to get the sample for mechanical test;

② Every 3 shortened sheets were combined together, hot pressed and then cut to samples of the size 100mm*100mm*3mm for cone test.

③ Tensile, bending and impact tests;

④ Cone test, 35 kW/m2, 675℃.

3 Results and Discussion

3.1 Fire retardant properties of WF-HDPE composites

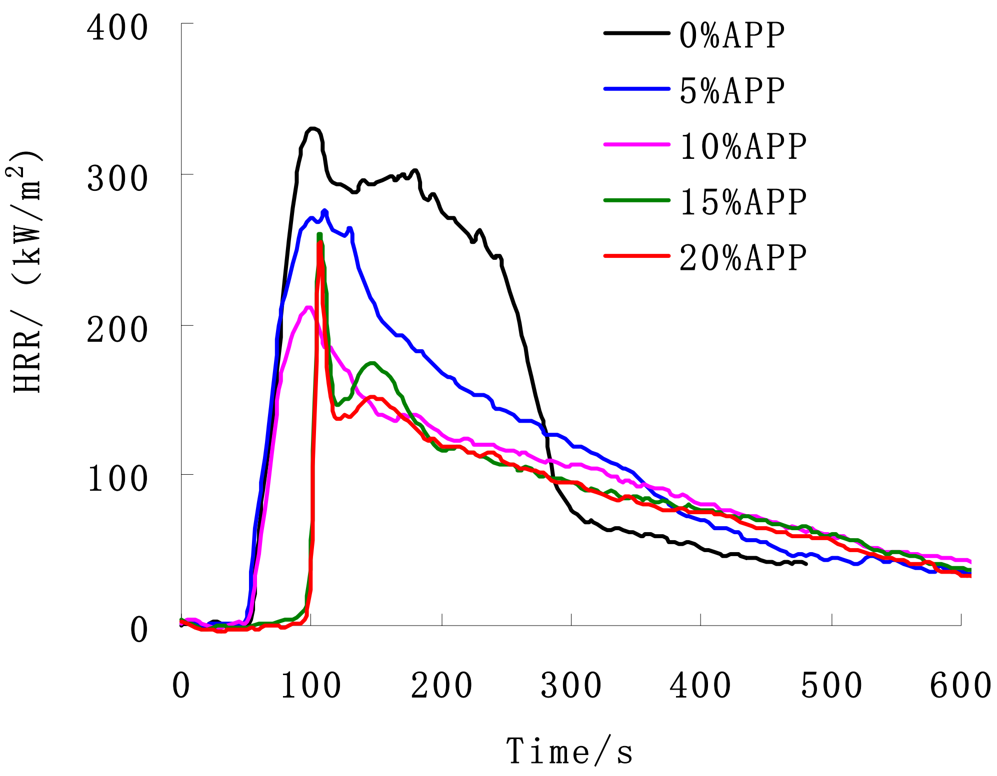
3.1.1 Time to ignition (TTI)

TTI value of the samples with deferent APP loading:

APP, %	0,	5,	10,	15,	20
TTI, s	59,	50,	54,	98,	99

3.1 Fire retardant properties of WF-HDPE composites

3.1.2 Heat release rate （HRR）



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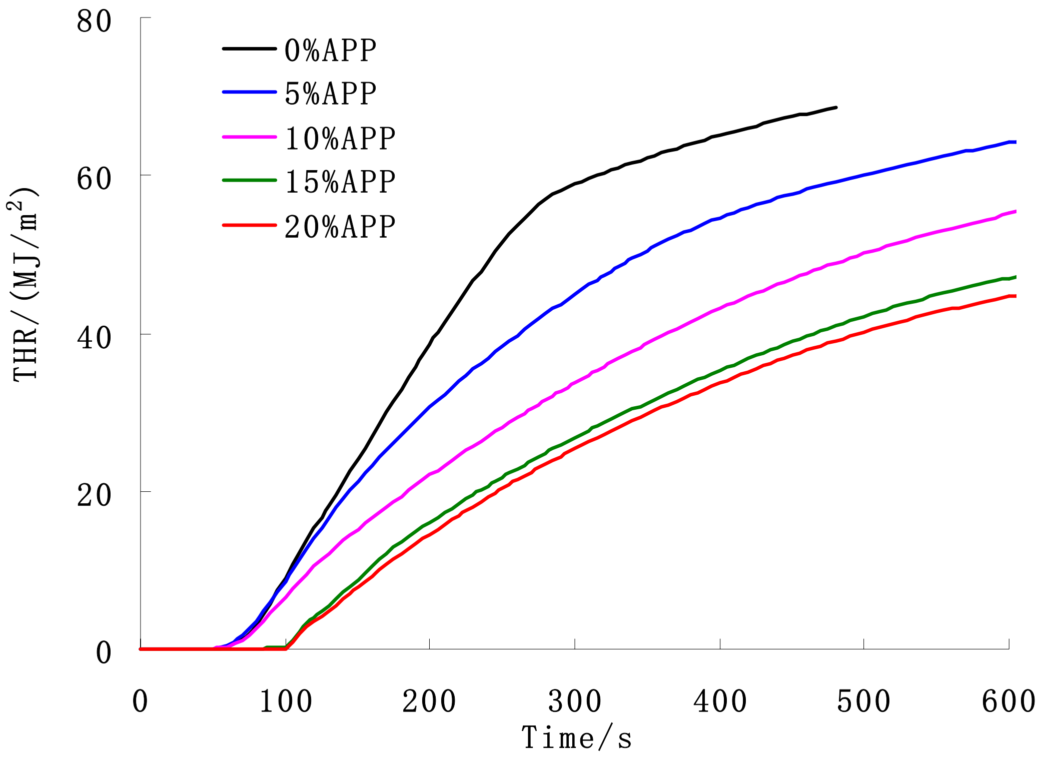
3.1 Fire retardant properties of WF-HDPE composites

3.1.3 Total heat released (THR)



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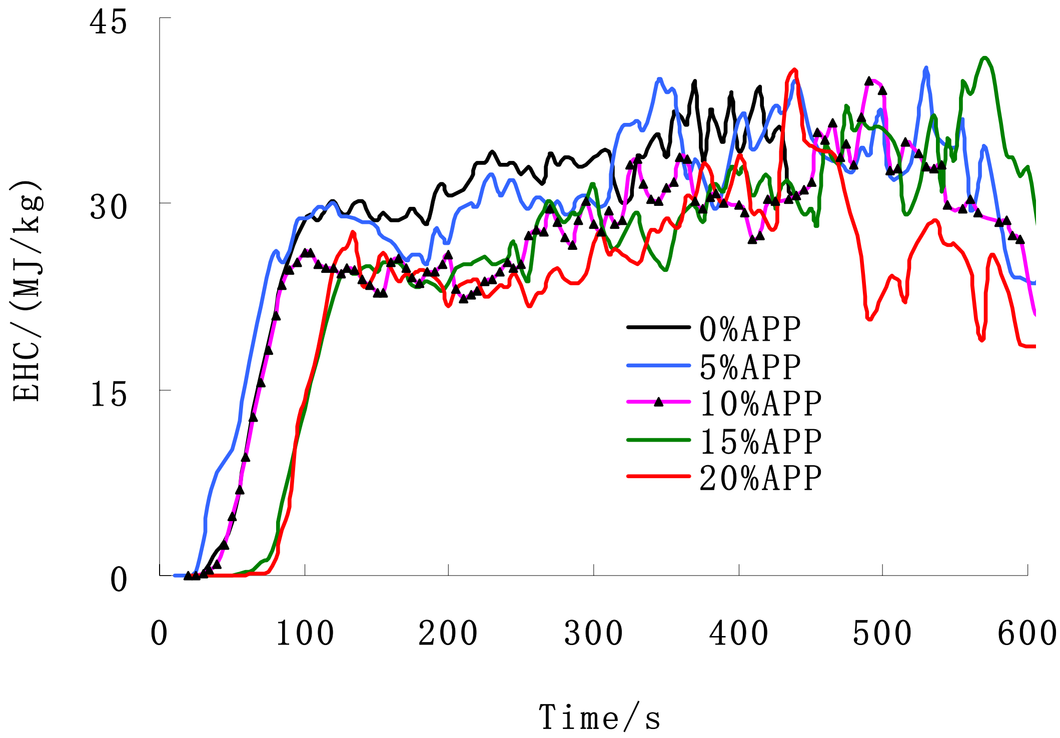
3.1 Fire retardant properties of WF-HDPE composites

3.1.4 Effective heat of combustion (EHC)



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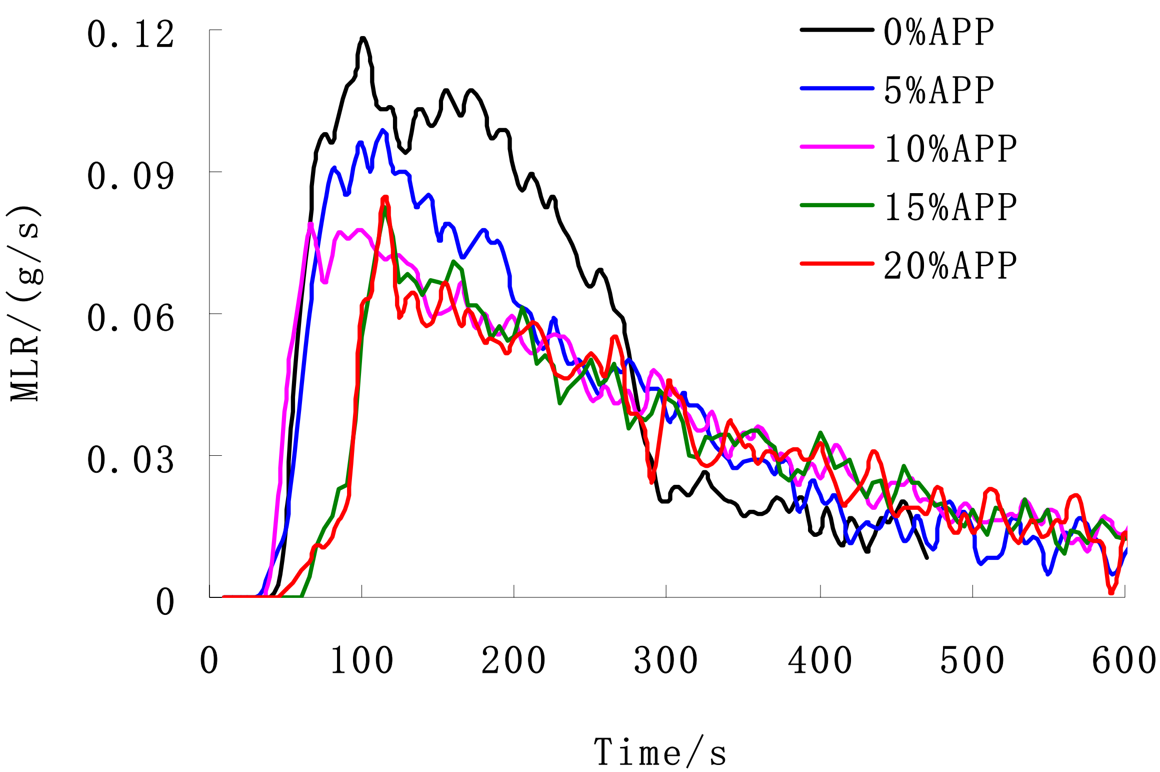
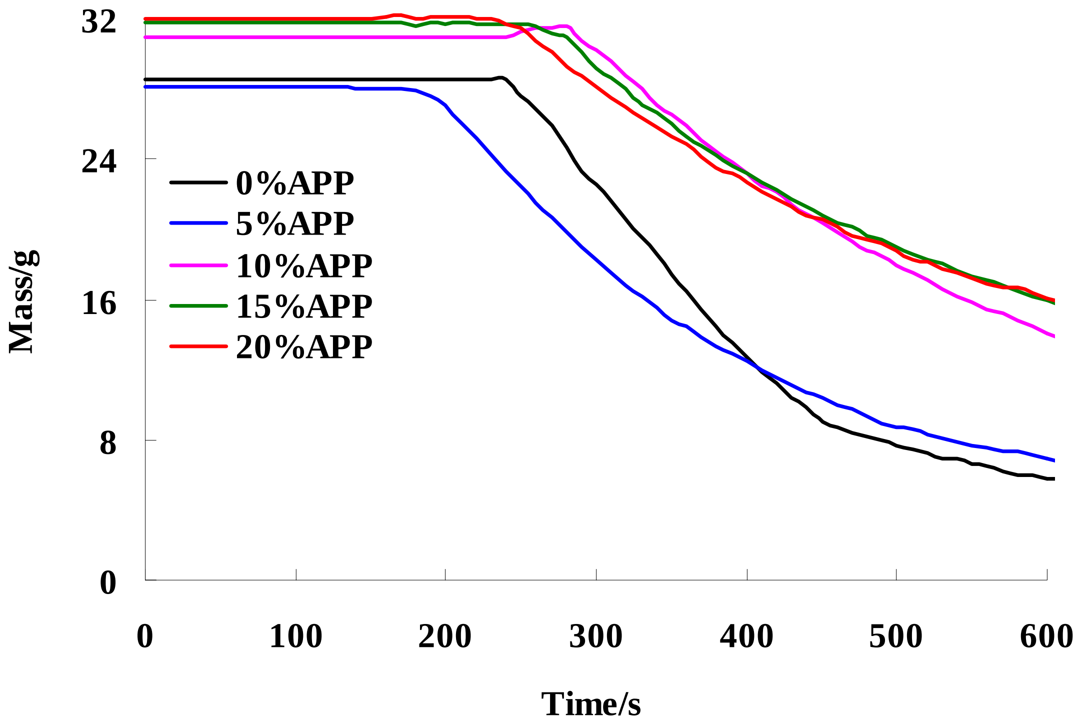
3.1 Fire retardant properties of WF-HDPE composites

3.1.5 Mass loss rate (MLR)



3.1 Fire retardant properties of WF-HDPE composites

3.1.6 Mass



3.2 Combustion reaction kinetics of WF-HDPE composites at constant temperature

In the stable flaming phase (300s-600s), the combustion of WF-HDPE (with or without APP) was found to the first order reaction:

$$\ln(1-\alpha) = -kt + C$$

- α ——extent of reaction (mass loss ratio);
- **k ——the rate constant of combustion reaction;**
- **t ——time of reaction last**
- **C——constant**

Table 1 Kinetic analysis results of WF-HDPE

APP loading/ %	0	5	10	15	20
k / s^{-1}	0.0057	0.0039	0.0025	0.0021	0.0020
r	0.9962	0.9996	0.9992	0.9979	0.9981
$t_{1/2}$ / s	121.6	177.7	277.3	330.1	346.6

3.3 Mechanical properties of WF-HDPE composites

With the addition of APP to WF-HDPE,
Flexural properties was almost unchanged;
Tensile strength was lower while rigidity was higher;
Impact strength was decreased markedly.

Table 2 Results of mechanical tests of WF-HDPE composites

APP loading /%	Tensile MOR /MPa, V/ %	Tensile MOE /GPa, V/ %	Bending MOR /MPa, V/%	Bending MOE /GPa, V/%	Impact strength /(kJ·m^{-2}), V/%
0	34.76，0.09	2.06，5.70	53.74，3.66	2.50， 4.54	22.24, 2.47
5	34.18，3.64	2.11，7.63	52.53，0.41	2.31， 5.42	21.58, 4.11
10	34.27，2.29	2.48，10.6	55.82，1.12	2.83， 3.85	18.44, 6.87
15	32.31，1.47	2.77，9.41	52.84，4.85	2.58， 7.84	13.73, 5.64
20	29.70，2.01	2.72，4.20	53.56，2.32	3.04， 4.62	12.66, 2.37

4 Conclusions

- APP was effective to reduce the heat release of WF-HDPE composites;
- The combustion of WF-HDPE composites was first order reaction, in which the reaction rate constant *k* and half life $t_{1/2}$ are 0.0075 s^{-1} and 121.6s respectively(675℃);

  The value of *k* decreased and *t*1/2 is increased by the addition of APP.
- Adding APP was negative to the impact properties of WF-HDPE composites, while flexural properties and tensile rigidity was basically unchanged, tensile strength decreased to a small extent.
- The suggested loading of APP is 10%-20%, and 15% may be

optimal