DOWNSIZING FIRE: NOVEL METHODS FOR INVESTIGATING FIRE BEHAVIOR OF MATERIALS

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Abstract
Scale reduction of fire scenarios is examined in the paper. The effect of electric current in simulated cables upon burning and intumescent plastics in extreme fire conditions are investigated. It is shown that selected formulations exhibit an enhanced behavior (high time to piercing at the burnthrough test and resistance to high current).

Introduction
Fire testing for evaluating the reaction and resistance to fire of materials is generally time-consuming and expensive. Due to the complexity of fire phenomenon, full-scale tests are still the main and the most credible tool for investigating fire-related issues. However, the cost of those tests significantly increases with scale. The purpose of this paper is to examine the scale reduction and to mimic fire scenarios at the small scale. Our motivation is to develop new methods at the reduced scale to investigate material undergoing specific fire constraint. It is expected to get more understanding on the mechanism of action of fire protective materials. In this paper, two approaches are presented: (i) the effect of the electric current on the fire behavior of flame retarded polymers and (ii) intumescent polymers undergoing extreme fire behavior.

Results and discussion
a) *Effect of electric current*
There are many circumstances that can lead to an electrical fire. It is then helpful to reproduce those circumstances in laboratory conditions to duplicate real-life fire scenarios in order to increase knowledge and to develop safer and more fire-resistant materials and electrical systems. The electric current produces an overheated condition in the presence of some type of combustible material (e.g. polymeric materials constituting the jacket of the cable) and so, the decomposition and the fire behavior of the material can be modified. Moreover, a developing fire can produce an arcing event in the energized electrical cable. A flame spread test was developed to investigate the flame spread of the polymer around a copper wire (an electric current up to 32 A can be delivered in the wire during the test). In this work, ethylene-vinyl acetate copolymer (EVA) containing aluminum trihydroxide (ATH) as flame retardant (FR) and hereafter called EVA/ATH, and EVA/ATH/Zinc borate (BZn) were selected as model systems mimicking formulations of cable sheath. The materials were evaluated by our flame spread test in horizontal and vertical position (Figure 1). The influence of the electric current at 32 A is only detected on virgin EVA in horizontal position on the propagation rate which jumps from 3 to 5 cm/min. In the vertical position, EVA ignites rapidly and the propagation along the simulated cable is too fast to be correctly estimated. In the case of the FR formulations, their fire behavior is similar and a protective ceramic is formed in the two cases. In the horizontal position, there is no ignition and hence no flame spread: the ceramic is formed where the burner is applied. In the vertical position, the protective ceramic is formed at the bottom of the simulated cable and because of heating, EVA melts causing a partial delamination of the plastic around the copper wire for the formulation without zinc borate while it is not observed with zinc borate. Once again, no flame spread is observed. According to this test, it is clearly evidenced the effect of the flame retardant in EVA and the benefit of incorporating zinc borate in EVA/ATH.

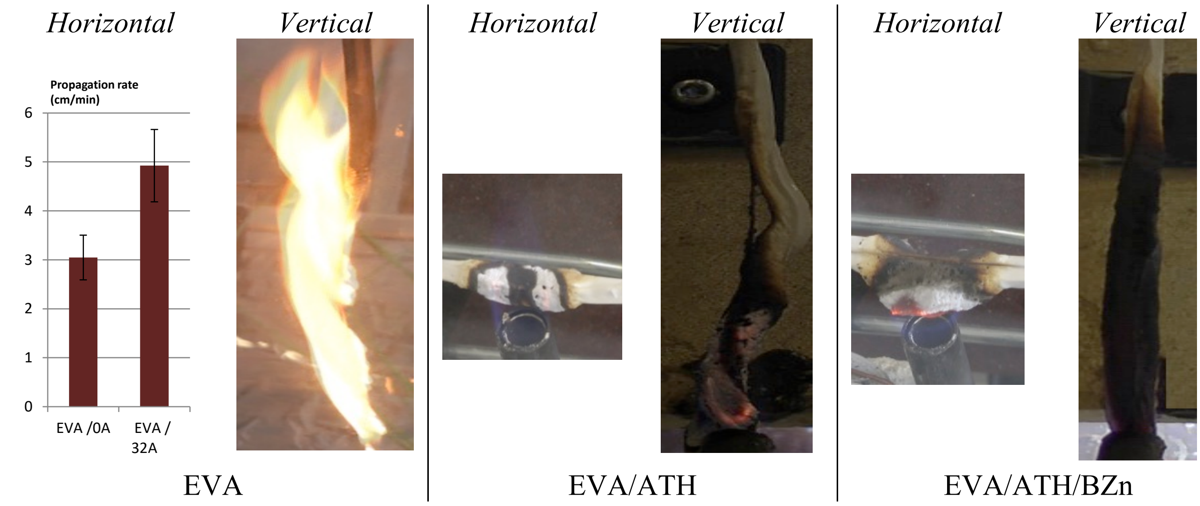

Figure 1. Flame spread tests of EVA and FR EVA in horizontal and in vertical position with and without electrical current

b) Intumescent polymers in extreme fire conditions

Intumescent thermoplastics are not used in the case of resistance to fire, i.e. in fire scenarios corresponding to burn-through, jetfire or structural response to fire. Indeed, they are not designed for this because they soften upon heating and fire can spread out. However, intumescent coatings applied on steel or composite act as efficient fire barrier. In this part, the fire behavior of intumescent polypropylene (PP) undergoing extreme fire (burn-through test at reduced scale designed to deliver heat flux higher than 100 kW/m²) is examined. The purpose of this unusual approach is to explore the possibility to design intumescent plastic (here PP) resisting to burn-through test. A combination of commercial intumescent flame retardants (ammonium polyphosphate-based compounds containing a char former; AP766 (AP) and FlameOff (FO) with zinc borate or Kemgard (combination of BZn and molybdate; KZ)) was incorporated in PP. The use of BZn and KZ as synergists in FO formulations increases dramatically the time of piercing at the burn-through test (heat flux = 116 kW/m², propane burner) from 80 s without BZn or KZ up to 280 s with KZ while the combination with AP does not show any benefit. Chemical analyses of the residues obtained at different times of combustion by solid state nuclear magnetic resonance (NMR) of ^{31}P, ^{11}B and ^{13}C show the formation of borophosphates creating a glass reinforcing the intumescent char. This acts as a 'glue' providing flexibility and cohesion to the char leading to better fire resistance to burn-through.

Conclusion

Scaling reduction permits to successfully build several bench-scale tests mimicking different fire scenarios and providing appropriate and reliable results. Those benches were used to examine the effect of electric current upon burning of simulated cables and the fire behavior of intumescent PPs in extreme conditions.

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