cbecimat26
26° Congresso Brasileiro de Engenharia e Ciência dos Materiais
22 a 26 de novembro de 2026
Costão do Santinho
Florianópolis-SC

Study of the flame-retardant performance of high-impact polystyrene compounded with a halogenated masterbatch in combination with zinc borate.

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Introduction

Polymeric materials are highly flammable, which can limit their use, as thermal degradation during combustion releases volatile compounds that fuel the flame. Consequently, the use of flame retardants is necessary to reduce or delay burning; these can act either in the gas phase or the condensed phase. Furthermore, the concentration of these additives is of critical importance, as high concentrations can compromise mechanical properties and processability, while also significantly increasing the cost of the material.

Objectives

In this study, the flame-retardant effect on high-impact polystyrene (HIPS) was evaluated using a commercial halogenated compound additive—in the form of a masterbatch (MTB/MB)—combined with zinc borate (BZ), a smoke suppressant.

Methodology

In this study, high-impact polystyrene (HIPS), a masterbatch (MTB), and zinc borate (ZB) were used—all supplied by a manufacturer of polymer compounds (the company's name cannot be disclosed at this stage of the project due to confidentiality). Formulations were prepared following a 2^2 factorial experimental design with 3 center points, varying the mass of MTB from 16% to 26% and ZB from 2% to 10%. Three additional formulations—consisting of pure HIPS, HIPS/MTB, and HIPS/ZB—were also prepared. The compounds were characterized using Fourier-transform infrared spectroscopy (FTIR), differential scanning calorimetry (DSC), and thermogravimetric analysis (TGA).

The mixtures were processed in an initial batch using a single-screw extruder (L/D = 28; D = 14 mm) with four heating zones (180 °C, 195 °C, 190 °C, and 190 °C) and a rotation speed of 45 rpm; they were subsequently analyzed for their flame-burning behavior in accordance with the UL 94 standard, using vertical burning tests.

The samples classified as V0 and V1 were subjected to further processing in a twin-screw system, including granulation, with the objective of improving homogenization. A co-rotating twin-screw extruder (NZ Philpolymer brand, model SJSL-20) was used, with an L/D ratio of 32 and a diameter of 25 mm. The operating parameters included a screw speed of 81 rpm and the following temperature profile (ºC): Z1: 175, Z2: 183, Z3: 187, Z4: 190, Z5: 195, Z6: 199, Z7: 200, and Z8: 200. Test specimens for mechanical testing were produced using a 60-ton ROMI injection molding machine, with the specimens molded in accordance with the ASTM D638 standard.

The test specimens were subjected to vertical and horizontal burning tests in accordance with the UL 94 standard. They were also subjected to tensile tests following the ASTM D638 standard.

Results and discussion

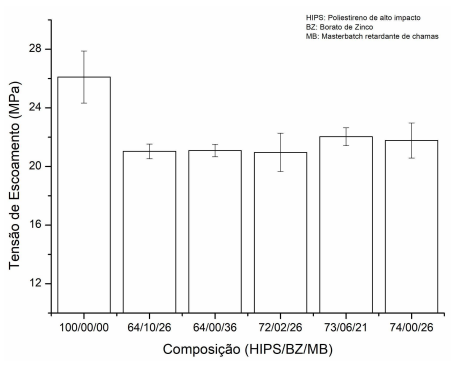
The formulation with 16% masterbatch showed limited performance, with 75% of the samples classified as V-2 and 25% exceeding the maximum burn time, resulting in an overall classification of "not classified" (N.C.). In contrast, the formulation with 26% masterbatch demonstrated superior performance, with 80% of the samples classified as V-0 and 20% as V-1, in addition to rapid flame extinction and the absence of flaming drips in most of the tests.

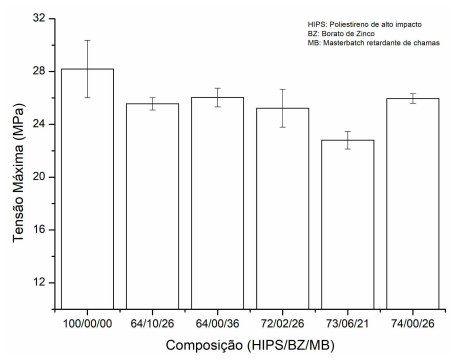
The formulations with the best burning results were processed using a twin-screw extrusion process and subjected to burning and tensile strength tests (Table 1 and Figures 1 (a) and (b)). The results indicate that the addition of BZ and MB reduced the values for Maximum Stress (an average reduction of 11%) and Yield Stress (an average reduction of 16%).

Table 1 - Samples processed using a twin-screw extruder

Norma UL 94			
Amostra	Classificação	Taxa Queima (mm/s)	Fumaça
HIPS 0,64 + BZ 0,10 + MB 0,26	NC	0	Preta+Branca
HIPS 0,73 + BZ 0,06 + MB 0,21	NC	0	Preta+Branca
HIPS 0,64 + MB 0,36	**V0**	**0**	**Branca**
HIPS 0,74 + MB 0,26	**V0**	**0**	**Branca**
HIPS 0,72 + BZ 0,02 + MB 0,26	**V0**	**0**	**Branca**
HIPS	NC	0,53	Preta

Figure 1 - (a) Yield Stress and (b) Maximum Stress.





Conclusions

The results demonstrate that increasing the masterbatch concentration significantly improves the flame-retardant performance of high-impact polystyrene, making it possible to meet the UL94 standard. However, the use of zinc borate did not provide any additional contribution to the flame-retardant effect.

References and Acknowledgments

FENG, C. et al. Influence of zinc borate on the flame retardancy and thermal stability of intumescent flame retardant polypropylene composites. Journal of Analytical and Applied Pyrolysis, v. 115, p. 224 – 232, 1 ago. 2015.

The authors thank UTFPR/CNPq for the undergraduate research scholarship; LCTM/UTFPR-PB and the Central Multiuser Analysis Laboratory at UTFPR-PB for providing the infrastructure; UNOESC for conducting the firing and mechanical tests; and LaTEM-Unochapecó for performing the thermal characterization analyses.