Evaluation of synergistic effect of Borax Decahydrate on flame retardancy of Polypropylene

Yoldas Seki, Mehmet Sarikanat, Lutfiye Altay, Tugce Uysalman, Gozde SevigTantug, Akın İsbilir

Abstract—In order to increase limiting oxygen index (LOI) value of PP, Borax Decahydrate ($Na_2B_4O_7.10H_2O$) was used as synergist for a flame retardant system consisting of ammonium polyphosphate (APP) and pentaerythritol (PER). Borax decahydrate at various weight fractions (1, 2 and 4%) was mixed with APP and PER and compounded with PP by using twin screw extruder. 4 wt% Borax decahydrate addition into mixture increased LOI value from 35 to 59%. Tensile and flexural properties and impact strengths (izod/charpy notched) of PP composites were obtained. Melt flow index, density, and coefficient of thermal expansion of PP and its compounds were also determined. From conducted study, it can be reported that borax decahydrate can be effectively used to increase the LOI value of PP-based composites containing APP and PER.

Keywords— borax, extruder, impact, Limiting oxygen index, mechanical properties, polypropylene, thermal properties

1 Introduction

POLYPROPYLENE(PP), which is commonly used in apparel, floor covering, upholstery, medical, geotextile and automobile, is highly combustible material[1]. Polypropylene's easy flammability, with a limiting oxygen index (LOI) of around 17.5, restricts its range of industrial applications in many fields [3], [4]. Intumescent flame retardants (IFR) are widely used due to their high efficieny, low toxicity, low smoke generation, and halogen-free nature [5], [6]. IFR contains three active ingredients: an acid source, a carbon source and a blowing agent.

One of the most popular IFR formulations for PP is combination of ammonium polyphosphate (APP) and pentaerythritol (PER) [7]. In this IFR formulation, APP acts both as the acid source and blowing agent, and PER acts as the carbon source [8]. However, in order to obtain higher LOI values, greater amounts of FR additives should be added into polymer, which may lead to some drawbacks such as low impact and mechanical properties.

The aim of this study is to increase the LOI of polypropylene containing IFR materials, APP and PER, by using borax decahydrate as a synergist. Flammability of PP and its compounds was characterized with LOI and UL 94 tests. The effect of borax decahydrate on mechanical, impact, density, coefficient of thermal expansion (CTE), and MFI of PP containing APP and PER were also investigated.

2 Materials and Methods

2.1 Materials

Polypropylene (PP) resin (co-polymer, melt flow rate: 8 g/10 min) was used in this study. Ammonium Polyphosphate (APP) (Exolit APP 422 from Clariant) and Pentaerythritol (PER) (from MKS Marmara) were used as flame retardant additives in this study. Borax decahydrate (B) was supplied from ETİMADEN AS., Turkey.

2.2 Manufacturing of Compounds

PP composites containing flame retardant (FR) mixture (22.5 wt%APP and 7.5 wt%PER) and B (1, 2, and 4 wt%) were produced by using twin screw extruder (Leistritz-Model ZSE 27) with a screw speed of 250 rpm. After passing through the extruder, the polymer strands entered a water bath and a pelletizer and 3 mm pellets were produced. The fabricated composites were abbreviated as follows: PP-FR, PP-FR-1B, PP-FR-B2, and PP-FR-B4. Test specimens were obtained from injection molding technique (Bole, model BL90EK, China)

2.3 Characterization of Compounds

Flame retardancy properties of samples were determined according to ASTM D3801 standard by using Atlas HVUL2 Horizontal Vertical Flame Chamber. LOI values of PP and its composites were calculated according to the ASTM D2863-13 standard by using Fire Testing Technology Oxygen Index apparatus. Melt flow index (MFI) values of PP and its compounds were obtained according to ASTM D1238 standard at a temperature of 230°C and a piston load of 2.16 kg. The tensile tests of samples were performed with a Shimadzu Autograph AG-IS Series universal testing machine at a crosshead speed of 50 mm/min according to ASTM D638-10 standard. Three-point bending tests of PP and its compounds were carried out to determine the flexural properties by following the ASTM D790 standard. The impact properties of PP and its compounds were tested by using a pendulum-type tester (Keijan, China) at 23 °C according to ISO 179 and 180 standards. Density values of PP and its compoounds were obtained with respect to ASTM D792 standard. CTEs of PP and its compounds were measured by a thermo-mechanical analyzer (TA Instruments Inc., TMA 400) at a rate of 5 °C min^{-1} with expansion mode.

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3 RESULTS AND DISCUSSIONS

Fig. 1. and Fig. 2. show density and MFI values of PP and its compounds, respectively. As can be seen from Fig. 1, density value of PP increased with addition of FR mixture and Borax. As can be seen from Fig. 2, FR mixture increased MFI value of PP, which may be due low relatively low melting temperature of PER. Borax addition decreased the MFI value of PP-FR.

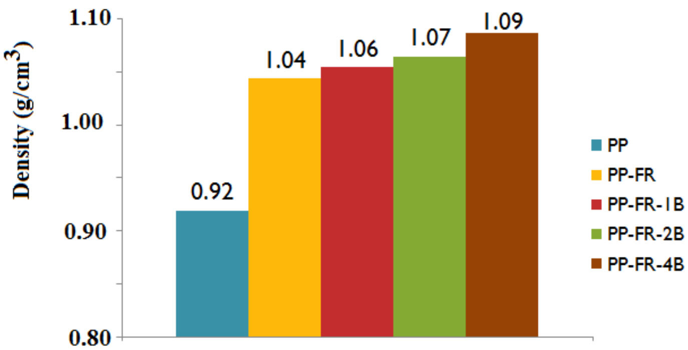

Fig. 1. Density values of PP and compounds

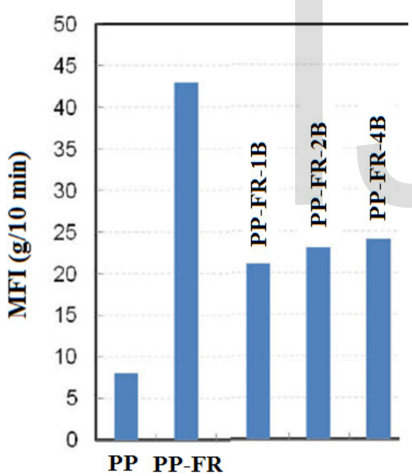

Fig. 2. MFI values of PP and compounds

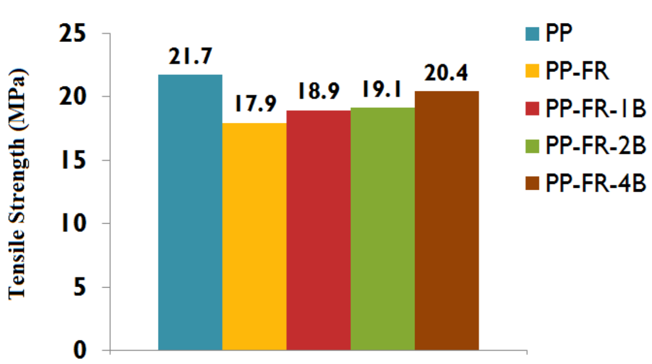

Fig. 3. Tensile Strength values of samples

Tensile and Flexural strength values of PP and its compounds are shown in Fig. 3 and 4, respectively. While FR addition into PP decreased the tensile strength of PP, Borax addition increased the tensile strength of PP-FR slightly. FR and Borax addition has not led to considerable increase in flexural strength values.

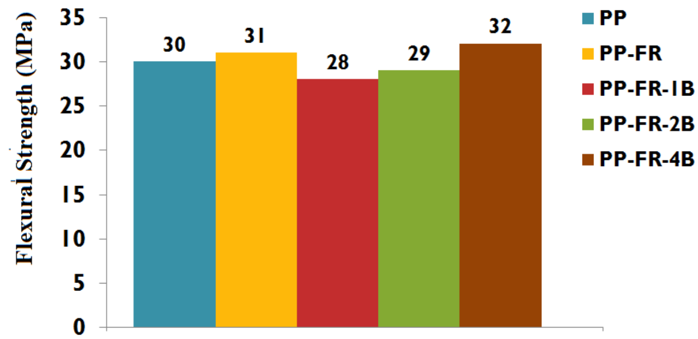

Fig. 4. Flexural strength values of PP and compounds

Izod notched and charpy notched impact strengths of PP and its FR compounds is shown in Fig. 5 respectively

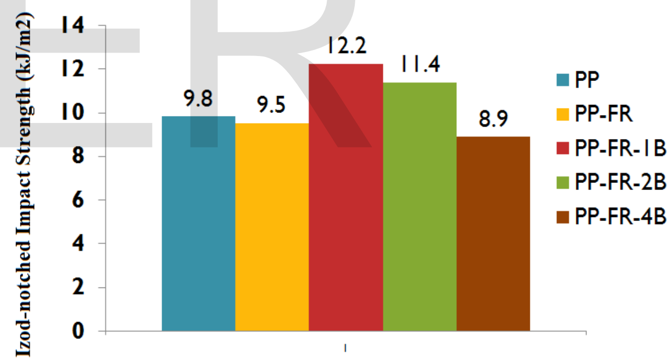

Fig. 5. Izod notched impact strength values of samples

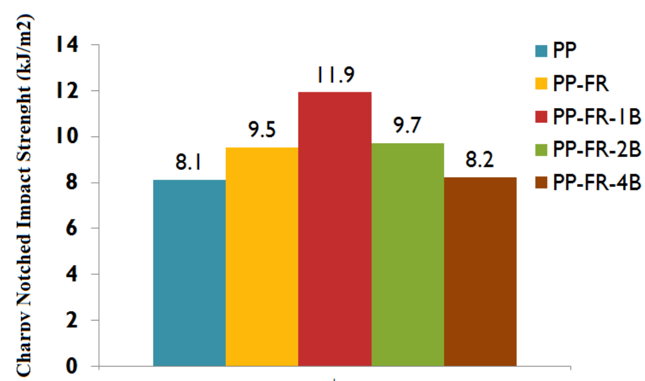

Fig. 6. Charpy notched impact strengths of samples

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As can be seen from impact strength values, 1 wt% Borax added FR-based PP compound exhibited the greatest izod and charpy notched impact strength values. However 2 and 3 wt% Borax addition decreased the notched impact strength values.

Izod and charpy unnotched impact strength values of PP and its compounds are shown in Fig. 7 and Fig. 8, respectively. As can be seen from Fig. 7, izod unnotched impact strength of PP, PP-FR, PP-FR-1B, PP-FR-2B are close each other. However 4wt% Borax addition decreased izod unnotched impact strength considerably. As shown in Fig. 8. Charpy unnotched impact strength values of PP and its compounds followed almost a similar trend as izod and charpy notched strength. The highest charpy unnotched impact strength value was observed by adding 1 wt% Borax into FR mixture. Adding greater amount of borax (2 and 4 wt%) led to drops in the charpy unnotched impact strength. 1 wt% Borax addition into FR mixture increased charpy unnotched impact strength of PP-FR by about 25%. It is possible that Borax at low weight fraction (1 wt% in this study) may have acted a nucleating agent and this may improve the impact strength of sample.

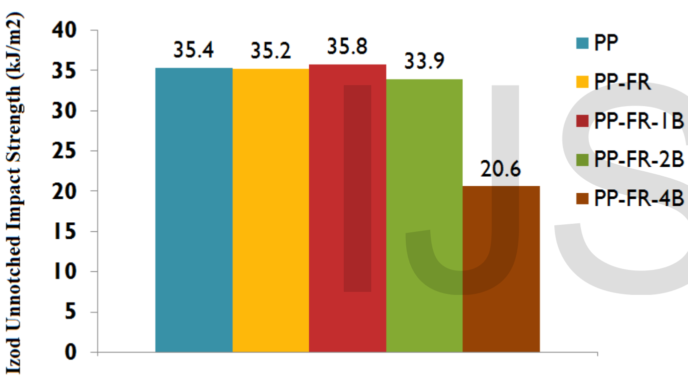

Fig. 7. Izod unnotched impact strength values of samples

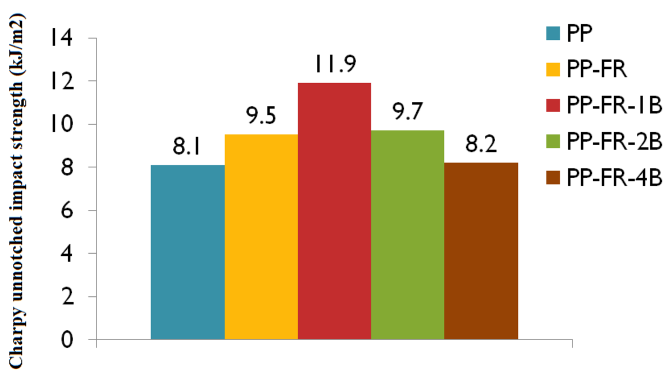

Fig. 8. Charpy unnotched impact strength values of samples

The variation of CTE values of PP and FR-based compounds is shown in Fig. 9. Both FR and Borax addition decreased the CTE value of PP considerably. It can be also noted that higher Borax addition (4 wt%) has not led to so much variation in the CTE value. It is known that one of the main drawback of thermoplastic matrix is their high CTE values [9]. FR addition (a total weight ratio of 30 wt%) into PP decreased CTE value of PP by about 15%. However 1 wt% borax addition into FR mixture decreased the CTE value of PP compound by about 16%. This result indicates that borax decahydrate is fairly efficient to decrease the CTE value of PP containing APP and PER. To decrease CTE value of PP may be an important issue for many applications in industry.

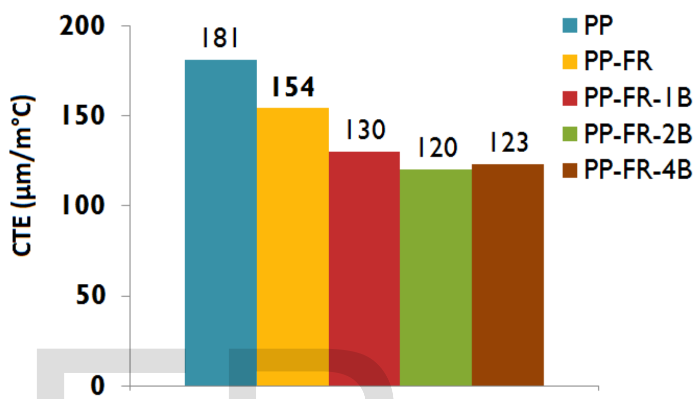

Fig. 9. CTE values of PP and its composites

According to UL 94 test, PP-FR, PP-FR-1B, PP-FR-2B, PP-FR-4B exhibited V0 classification for the thickness of 1.6 mm. LOI values for PP and its compounds are shown in Fig. 8. LOI values of PP-FR, PP-FR-1B, PP-FR-2B, and PP-FR-4B were obtained to be 35.4, 48.4, 56.3, and 59.1, respectively. 30 wt% FR addition into PP increased the LOI value by about twice. It is seen that low amount of borax increased the LOI value considerably.

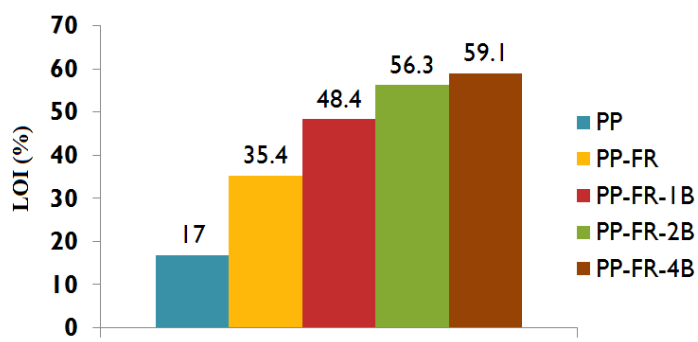

Fig. 8. LOI values of PP and its compounds.

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4 Conclusion

Borax decahydrate can be effectively used to increase the LOI value of PP containing APP and PER without degradading the other properties considerably. 1 wt% Borax addition increased the LOI value from 35.4 to 48.4%. Besides, izod and charpy notched impact strength values increased by 28 and 25%, respectively. However flexural strength values decreased by about 10%. From the conducted study, it can be reported that synergism between borax decahydrate and FR additives (APP and PER) for PP was observed.

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