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Flammability of Composites Based on Polypropylene and Flax Fibers

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Biodegradability and interesting physical and mechanical properties of polypropylene (PP)/cellulose composites are the essential motive for undertaking fundamental studies of various properties of such materials.

An addition of lignocellulosic particles to polymers results in a change in properties of the product obtained which is a resultant of properties of lignocellulosic material and those of polymer and depends on the proportion of both materials. It is also reflected in the flammability characteristics of the composites.

In this study we have analyzed flammability of PP composites with long flax fibers obtained by compressing. The amounts of natural fibers were 12.5%, 20%, 30% and 40%. The thickness of the investigated samples was 5 mm.

The samples were tested in accordance with ISO 5660 (Cone Calorimeter) at heat flux of 35 kW/m^2. Heat release rate (HRR) and mass loss rate (MLR) curves show that thermal decomposition and combustion of the mentioned samples occur in a different way. When flax fiber content was 12.5%, a reduction in maximum heat released (HRR peak) by about 35% was observed. However, time to sustained ignition of composites was shorter than that of PP. The characteristics of the composite are closer to those of lignocellulosic material. The addition of 12.5% fibers resulted in an increase in fire retardancy of the composite compared to polypropylene alone. The addition of fibers in the amount exceeding 20% made the composite material characteristics similar to those of lignocellulosic materials.

Keywords: flammability; composite; polypropylene; flax fibers; Cone Calorimeter

INTRODUCTION

Polypropylene (PP) belongs to the most frequently used polymers in a wide area of applications. However, as most of man-made polymers, it is not biodegradable and makes potential hazard to the environment. One of the methods of suppressing this disadvantageous property is the preparation materials of a new type - thermoplastic/biodegradable filler composites which can be recycled and have interesting physical and mechanical properties. This fact makes an essential motive for fundamental studies of properties of materials of such a kind [1, 2].

There is a growing interest in composites prepared on the basis of agro-fibers used as a filler and/or reinforcement of polymeric matrix. One of the advantages of the composites based on natural vegetable fibers is a reduction in mass of composite-containing elements because the fibers are characterized by a low density. Among polymers a special role is played by isotactic polypropylene due to its properties and friendly behavior at temperatures of processing of natural fibers. A lot of attention was paid to this problem [e.g. 3-8].

Recently, the mentioned composites found an application to the automotive and insulating materials industries. Advantageous physical and mechanical properties of the thermoplastic/cellulose composites result in extending their application to other areas. Therefore, the flammability characteristics of the composites based on polypropylene and natural fibers are of essential importance, especially when the composites are used as a part of a car or as an insulator.

One of methods for testing the fire performance of different materials is Cone Calorimeter method in accordance to ISO 5660 [9]. The above calorimeter is the most advanced apparatus among all bench-scale reaction-to-fire test instruments developed during the last few years. The main property, which is determined during tests, is heat release rate (HRR) - the basic factor for fire modeling. The rate of heat release is determined by measuring oxygen

consumption derived from oxygen concentration and flow rate in the combustion product stream [9, 10]. This test method is based on the observation that, generally, the net heat of combustion is proportional to the amount of oxygen required for combustion, namely heat energy of approximately 13.1 MJ is released per kilogram of oxygen consumed, irrespectively of the type of organic material tested [9, 10]. It is of importance that materials can be tested in two positions - horizontal or vertical (depending on application) in a wide range of heat flux intensities from 5-100 kW/m^2.

EXPERIMENTAL

Materials

Thermoplastic Matrix

A commercial grade isotactic polypropylene (PP) Malen F-401 was used. Its characteristics are as follows: density 0.9 g/cm^3, MFI index 2.4–3.2 g/10 min and tacticity 95%.

Natural Fibers

Flax fibers were used as a reinforcing material. The fibers were 150-300 mm in length.

Technology of Composite Preparation

Flax fibers were placed between polypropylene sheets and compressed at 205°C for 10 min. Details of the method of preparing the composites were described in Ref.[11]. In this work we report results of a study on properties of composites containing 12.5%, 20%, 30% and 40% of flax fibers.

Preparation of Specimens for the Flammability Tests

The plates for tests were squares of 100 mm x 100 mm and their preparation was performed by pressing according to specifications of the method mentioned above. The thickness of the obtained samples was 5 mm.

Flammability Test Method

The reaction-to-fire tests were conducted in accordance with ISO 5660 (Cone calorimeter method) at heat flux of 35 kW/m^2. During the tests the following parameters were determined: time to sustained ignition (IT), average HRR from ignition to 60 and 180 s, HRR peak, total heat released (THR), mass loss rate (MLR), heat of combustion (HOC) and specific extinction area (SEA).

RESULTS AND DISCUSSION

Parameters determined in the tests, namely heat release rate, mass loss rate, time to sustained ignition, total heat released, effective heat of combustion and smoke obscuration (expressed as extinction coefficient) are shown in Figs. 1-5. Results for composites with increasing contents of flax fibers are compared to results for PP.

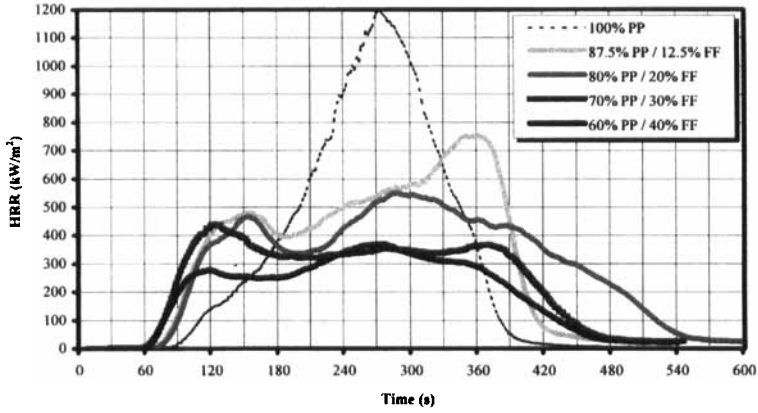

FIGURE 1. Heat release rate (HRR) for composites based on PP and flax fibers (FF) compared to PP

Heat release rate (HRR) and mass loss rate (MLR) curves recorded for the composites show that thermal decomposition and combustion of the samples investigated proceed in a different way, depending on fiber content. When fiber

content exceeds 20%, they become similar to curves typical of lignocellulosic materials with two characteristic peaks. Thus the addition of lignocellulosic fibers resulted in advantageous changes in fire performance of PP in the way similar to that observed when other efficient flame retardants were added.

The most visible effect can be seen in the case of HRR peak. For the composite containing 20% of flax fibers, the HRR peak is by 50% lower than that for PP.

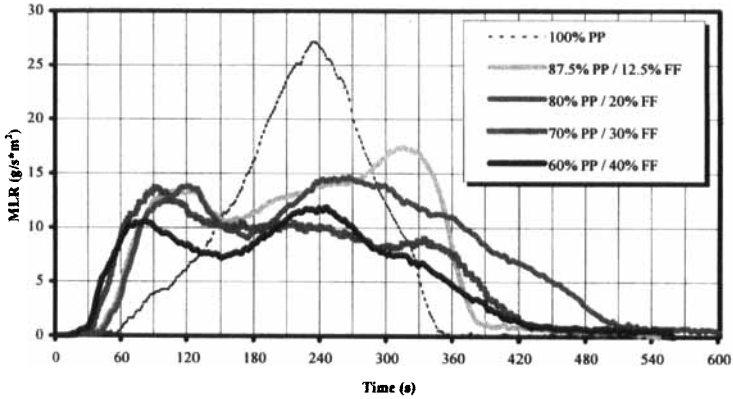

FIGURE 2. Mass loss rate (MLR) for composites based on PP and flax fibers (FF) compared to that recorded for PP

Other fire performance parameters such as total heat released (THR) and effective heat of combustion (HOC) as well as average MLR also underwent a reduction as a result of flax fiber addition. This advantageous effect became even more significant when flax fiber content was increased to 30 and 40%.

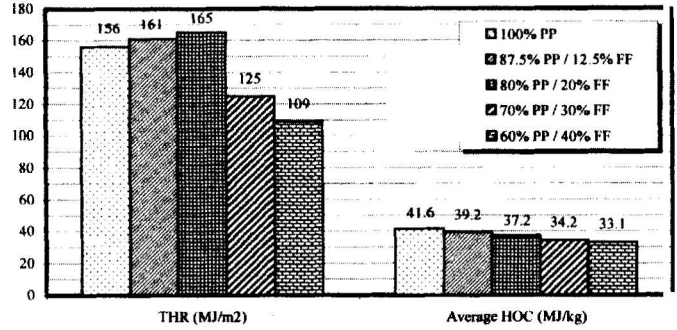

FIGURE 3. Average values of total heat released (THR) and effective heat of combustion (HOC) for composites based on PP and flax fibers (FF) compared to those recorded for PP

Only two somewhat disadvantageous effects of flax fibers addition were observed. The composites are characterized by a shorter time to ignition (IT) and slightly increased smoke production (expressed by SEA). It worth to add that peak of extinction coefficient was reduced.

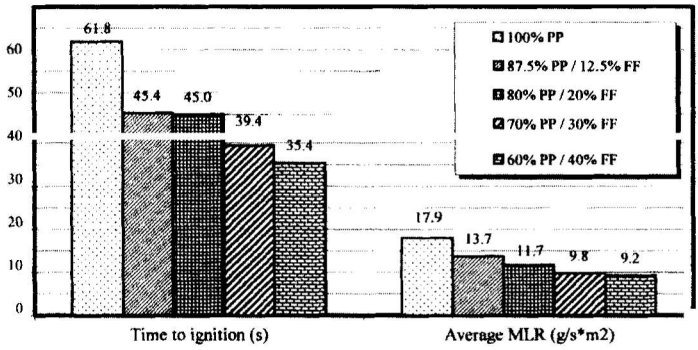

FIGURE 4. Average values of time to sustained ignition and mass loss rate (MLR) for composites based on PP and flax fibers (FF) compared to those recorded for PP

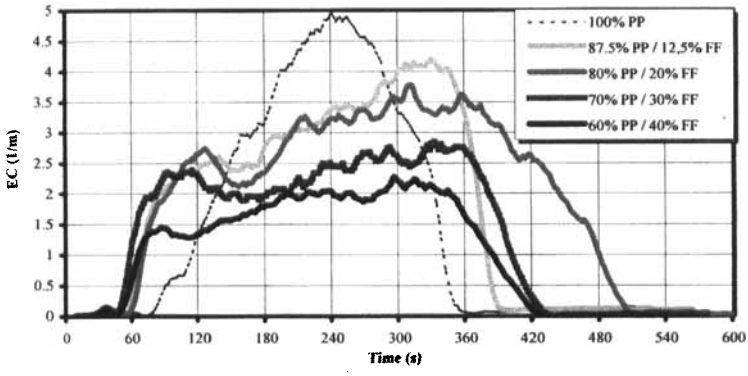

FIGURE 5. Smoke production, expressed as extinction coefficient (EC), determined for composites based on PP and flax fibers (FF) compared to that for PP

Physical and mechanical parameters of the composites will be presented in a separate paper.

CONCLUSIONS

The fire performance characteristics of composites consisting of PP and short flax fibers are considerably closer to those of lignocellulosic materials than to PP.

The addition of fibers, especially in the amount of 30%, resulted in a significant decrease of such an important parameter as HRR peak. Also other parameters characterizing heat released during combustion, as well as MLR, underwent a reduction. However, such parameters as time to ignition and smoke production became slightly worse in comparison with PP.

Attempts at upgrading fire retardancy by appropriate treatment of flax fibers with selected fire retardants could be very promising and research on this subject will be carried out in the future.

Acknowledgments

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