

USING SODIUM HYDROGEN CARBONATE FOR FOAMING POLYMERS

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Abstract

All plastics products are made of the essential polymer mixed with a complex blend of materials known collectively as additives. Without additives, plastics would not work, but with them, they can be made safer, cleaner, tougher and more colourful. Additives cost money, but by reducing production costs and making products live longer, they help us save money and conserve the world's precious raw material reserves. In fact, our world would be a lot less safe, a lot more expensive and a great deal duller without the additives that turn basic polymers into useful plastics. One of these additives is sodium bicarbonate. Influence of sodium bicarbonate on properties of the product made of polystyrene was observed in the research described in this paper. Since polystyrene is typically used as a material for electrical components, the mechanical properties of tensile strength and inflammability were measured as a priority. Inflammability parameters were measured using a cone calorimeter.

Key words

sodium bicarbonate, sodium hydrogen carbonate, polymers, filler, foaming

INTRODUCTION

Sodium hydrogen carbonate is a white, crystalline powder that is commonly used as a pH buffering agent, an electrolyte replenisher, systemic alkalizer and in topical cleansing solutions. Chemical formula of sodium bicarbonate is NaHCO_3 (1). It is also commonly known as baking soda or bicarbonate of soda. Although Sodium Bicarbonate is a crystalline compound, it typically appears as a powder in its dry form (2). As an additive, sodium bicarbonate significantly influences many parameters. Mechanical parameters were measured by tensile strength test, and flammability parameters were measured in cone calorimeter. Influence of

other additives (for example fibres or natural fibres) on the polystyrene has already been examined with the results according to sources (4, 5).

EXPERIMENT

Sodium hydrogen carbonate was selected to save a quantity of polymer. Zero per cent, 0.5 per cent and 1 per cent filler of polymer concentrate was used in this experiment (Fig. 1). The additive saves the main material, however other properties could be degraded. The aim of the research was to determine the change of selected properties. It belongs to the wiring materials. Therefore, we selected mechanical and flammability characteristics.

To determine mechanical properties, we used tensile test. The measurement was carried out on the Tinius Olsen 300 machine (Fig. 2). The ultimate strength and elongation at break were recorded. To determine flammability characteristics, flammability test was used. The measurement was conducted on the machine cone calorimeter.



Fig. 1 Polystyrene specimens with 0 %, 0.5 % and 1 % fillers of sodium hydrogen carbonate

TENSILE TEST

Tensile test is used to determine some of the mechanical properties such as elongation, strength at break etc. Different weight of additives shows different changes in these parameters. Tensile test was carried out on the tensile machine called Tinius Olsen. Elongation was carried out at a constant speed rate. The speed was 25 mm/min. During the test, strength was recorded into the chart. The test was carried out until the specimen fractured (Fig. 3).



Fig. 2 Tensile machine of Tinius Olsen 300ST



Fig. 3 Specimen after the fracture

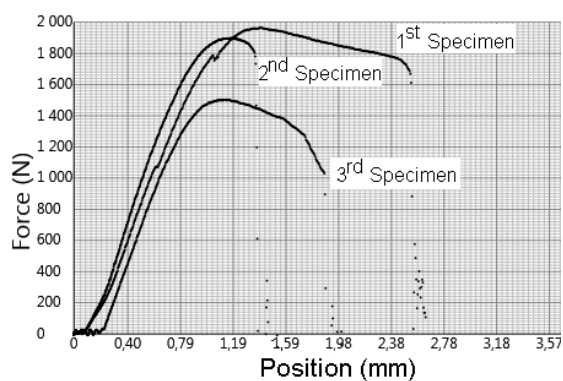


Fig. 4 Dependence of force on elongation of specimens

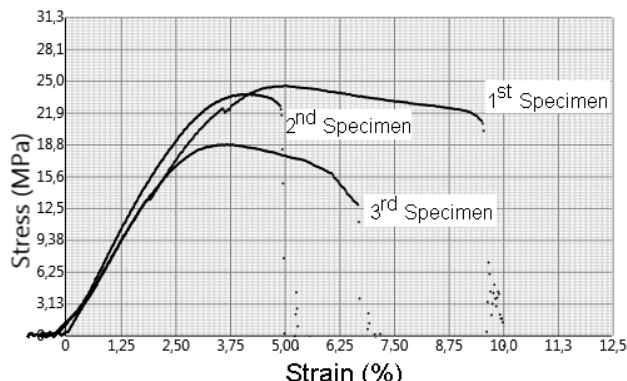


Fig. 5 Dependence of stress on strain of specimens

From the tensile test, two dependencies were obtained. The first one was the dependence of force on elongation of specimen (Fig. 4) and the other one was dependence of stress on strain of specimens (Fig. 5). Dependence shows the behaviour of all three specimens. Specimen No. 1 is unfilled polystyrene, specimen No. 2 polystyrene containing 0.5 % share of sodium hydrogen carbonate and specimen No. 3 represents 1 % of sodium hydrogen carbonate and polystyrene.

Strength of material with an increasing proportion of ingredients slowly declined. The greatest strength was manifested in the unfilled plastics (24.6 MPa). Lower strength was recorded at 0.5 % (23.7 MPa) and the lowest strength was reported in 1 % filling of plastics (18.8 MPa). The greatest elongation was measured in the unfilled plastic (9.55 %). However, the smallest extension was in the 0.5 % filled with plastic (4.91 %). In the 1 % filled plastics of sodium, secondary extension was measured (6.12 %). The values of the modules are approximately the same. Surprisingly, the greatest module of extension was 0.5 % filling of plastic (816 MPa). The lower level was manifested in a polymer with 1 % content of hydrogen carbonate (735 MPa). The lowest modulus was that of a polymer without added hydrogenated carbonate content (726 MPa).

CONE CALORIMETER

Principle

The principle of measurement by cone calorimeter is based on the observation that, generally, the net heat of combustion is proportional to the amount of oxygen required for combustion. Specimens in the test burned under ambient air conditions, while being subjected to a predetermined external irradiance within the range of 0 kW/m² to 100 kW/m², and measurements of the oxygen concentrations and exhaust gas flow rates are performed. The test method is used to determine whether the product can help increase the heat during combustion.

Apparatus

The cone calorimeter consists of several main parts. The parts are shown in Fig. 6.

- Cone-shaped radiant electrical heater.

The active element of the heater shall consist of an electrical heater rod, capable of delivering 5000 W at the operating voltage, tightly wound into the shape of a truncated cone. The heater shall be encased on the outside with a double-wall stainless-steel cone, filled with a refractory fibre blanket of nominal thickness and nominal density. The irradiance from the heater shall be maintained at a preset level by controlling the average temperature of three thermocouples, symmetrically positioned and in contact with, but not welded to, the heater element. Either 3 mm outside diameter sheathed thermocouples with exposed hot junction or 1 mm to 1.6 mm

outside diameter sheathed thermocouples with unexposed hot junction shall be used. The heater shall be capable of producing irradiance on the surface of the specimen of up to 100 kW/m^2 .

- Radiation shield

The cone heater shall be provided with a removable radiation shield to protect the specimen from the irradiance prior to the start of a test. The shield shall be made of a non-combustible material, with a total thickness not exceeding 12 mm.

- Other apparatuses are weighing device, specimen holder, retainer frame, exhaust gas system with flow measuring instrumentation etc.

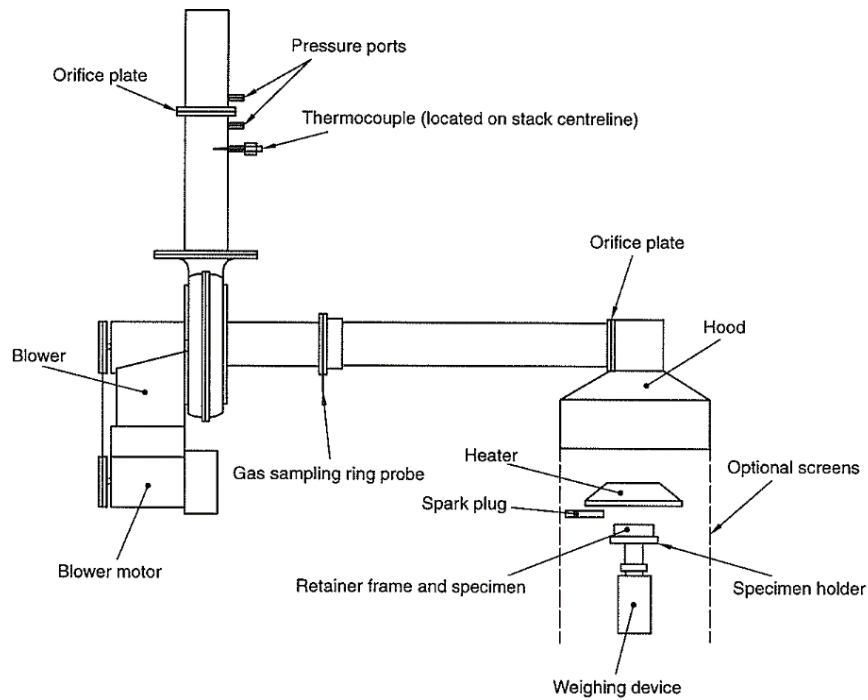


Fig. 6 Schematic representation of the apparatus (3)



Fig. 7 Specimen before burning



Fig. 8 Burning at the start of the process



Fig. 9 Burning at the end of the process



Fig. 10 Specimen after burning

The specimen was placed into a special specimen holder (Fig. 7) and then put into a conical calorimeter that tries to burn the specimen by sparks. Then specimen burns (Figs. 8 and 9). During the burning, some parameters such as the heat and emissions production were recorded. After that, the burnout measurement ends. Ash remains from the sample (Fig. 10). It contains some fixed parts of the samples, which did not burn or were not blown away from the flame.

The parameters monitored on a cone calorimeter were several. The first outcome measurement was the rate of heat release (Fig. 11). The measurements showed that specimen No. 1 was ignited at the latest after 45 seconds. Specimens Nos. 2 and 3 caught the fire almost simultaneously, in about 30 seconds. The largest calorific value was for the specimen No. 1, where the maximum reached 7 kW. Lower values were reached for the specimen No. 2 and No. 3. The specimen No. 2 reached a little less calorific value, and therefore its maximum was about 6 kW. The maximum lowest calorific value of specimen No. 2 was 5.6 kW. All specimens went out at about the same time, i.e. within 125-160 seconds. Such behaviour of the specimens can be explained by burning the additive such as sodium hydrogen carbonate that delayed combustion and reduced thermal heating value.

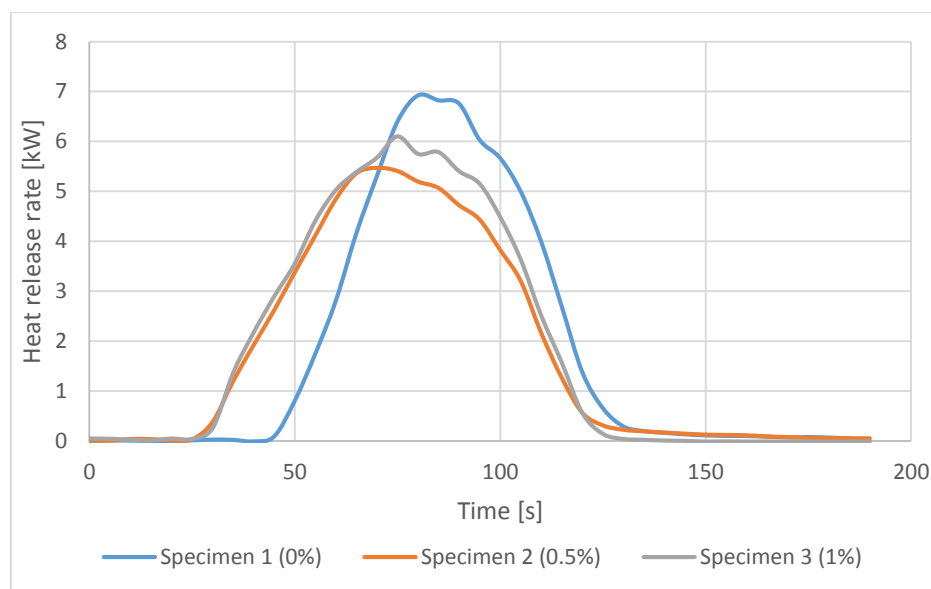


Fig. 11 Heat release rate

Another measurement is the smoke emission of the sample (Fig. 12). The smoke release of sample No. 1 reached the maximum of 0:23 m²/s. Another major issue of the smoke follows the sample No. 3, which peaked at a value up to 0:20 m²/s. The smallest release of smoke was that of sample No. 2, which reached its maximum value 0:17 m²/s. The samples show that the addition of additives increases the production of smoke.

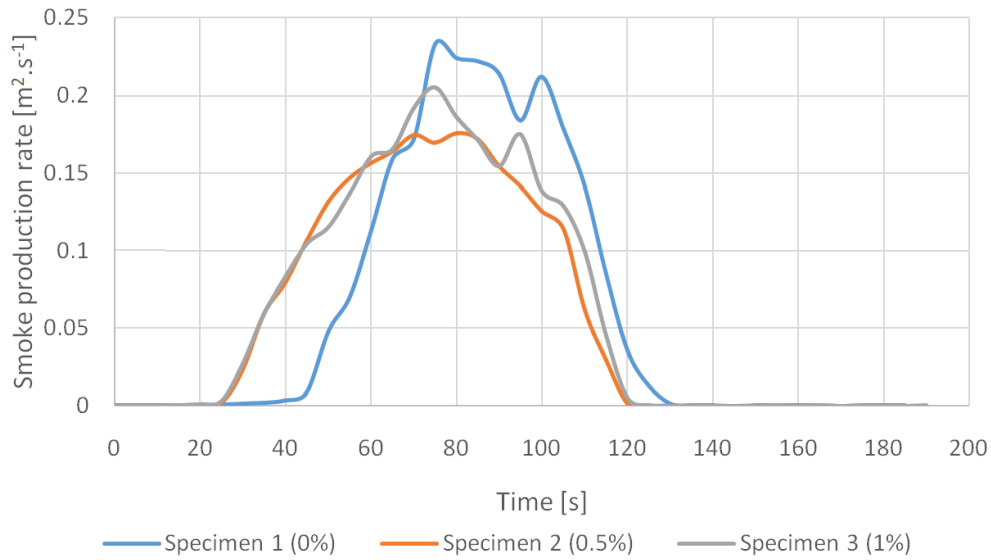


Fig. 12 Smoke production rate

Another measurement recorded the production of CO₂ and CO during combustion (Fig. 13 and Fig. 14). Most of the gases was produced by sample No. 1, reaching up to 16 mg/g of CO gas, and up to 500 mg/g of CO₂. Sample No. 3 produced up to 13 mg/CO gas, and up to 429 mg/g of CO₂. Sample No. 2 produced 11 mg/g and 393 mg of CO/CO₂ gases. The production of gas in these samples can be explained by additive such as sodium hydrogen carbonate, which reduces the weight of the material, and therefore, has less impact on the production of CO and CO₂.

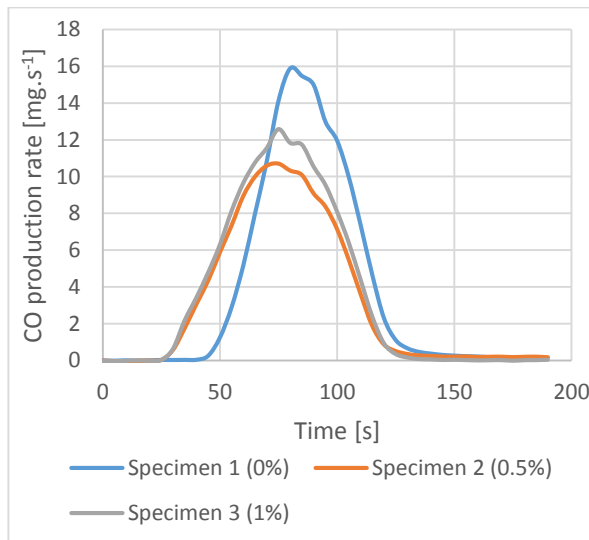


Fig. 13 CO production rate

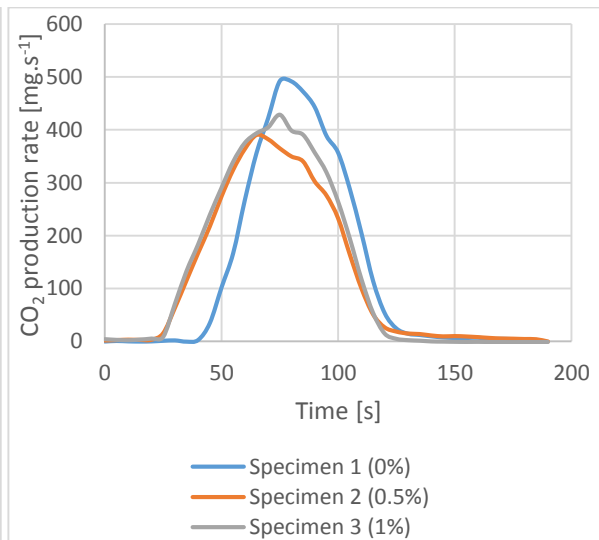


Fig. 14 CO₂ production rate

The main parameters of this measurement are recorded in Table 1.

Table 1 Main parameters of burning test

	Specimen 1	Specimen 2	Specimen 3
Time to ignition [s]	44	26	27
Peak HRR [kW]	7.03	5.64	6.1
Time to peak HRR [s]	85	70	75
Total heat release [kJ]	343.52	334.82	341.75
Total smoke production [m ²]	11.57	10.94	11.76

CONCLUSION

In this paper, we compared the selected properties of polystyrene filled with different proportions of sodium hydrogen carbonate. The component is used as part of a power line, and it is therefore important that it did not start burning in case of emergency. The slight deterioration of mechanical properties is acceptable.

For determining the mechanical properties of the polymer with filled hydroxide carbonate, tensile tests were carried out. The largest modulus of strength was shown sample No. 1 that was not filled with sodium bicarbonate. Sample No. 3 (1 % filler) recorded the minimum breaking strength. Sample No. 2 (0.5 %) exhibited the smallest elongation. This can be explained by the fact that the unfilled material has the greatest extension. The polymers which contain a small quantity of additives have impaired the ability of elongation. However, the progressive addition of these additives increases the elongation again. Also, the measured values show that the gradual addition of additives will only worsen the fracture strength.

The test to determine flammability properties was carried out on a cone calorimeter. The test demonstrated the fact that the specimen 1 (unfilled) caught fire later than the specimens with added filler. Unlike filled specimens, the unfilled specimen produced more heat, more smoke and more CO₂ and CO fumes.

The measurement suggests that the unfilled specimen had best mechanical properties. However, in terms of burning, the situation is more complicated. The unfilled specimen may start burning later, while producing the highest heat and the biggest emissions. The specimen No. 2 produces the smallest heat and least emissions of all specimens. Therefore polystyrene with 0.5 % of additive can be recommended for industrial usage. On the other hand, the significant reduction of the CO and CO₂ generation was observed due to the combustion of polystyrene with additive ratio. Moreover, decrease of tensile strength of polystyrene was only minimal, which can be an important factor for the electrical components manufacturing.

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