EVALUATION OF THE USE OF RECYCLED PP FOR OBTAINING RIGID FOAM

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Abstract - Polymeric foams are composed of two phases, in which gas for pore forming is dispersed in a continuous phase formed by a polymer. Foams have interesting properties, such as thermal insulation and good mechanical performance. In this, rigid thermoplastic foams stand out, often formed by PE or PP, which can have structural properties, having applications such as civil construction and automobile components. This study aims to evaluate the influence of blowing agent in recycled PP (PPr) to obtain rigid foams. The PPr used in the study has an IF of 6.6 g/10 min and, azodicarbonamide (AZO) and sodium bicarbonate were used as blowing agents (BC). The mixtures were prepared in a twin screw extruder and expanded in a press. The samples were characterized by density and impact strength tests IZOD, whose results showed the best performance for mixing with AZO and the difficulty of controlling the expansion process in hot press.
Keywords: *Recycled resin, polypropylene, rigid foam.*

Introduction

Polymeric foams are materials composed of two phases, in which gas from a blowing agent for the formation of pores is dispersed in a continuous phase formed by a polymer (of the most diverse, such as Polyethylene - PE, Polypropylene - PP, Polystyrene – PS, Ethylene Vinyl Acetate Copolymer - EVA...). This makes this type of material can have an especially low density when compared to dense polymer (without the pores) [1]. This low density is due to the insertion of pores that can give a wide range of properties to the material, such as: great thermal insulation capacity; good sound insulation effect; high specific mechanical strength (especially for rigid foams); chemical resistance and high impact absorption capacity [1, 2]. Due to this, foams have been applied in the most diverse functions, which range from shoe soles to separation membranes [3].

Polymeric foams are divided into two groups, flexible and rigid. Of these two groups, rigid foams stand out, which are those that have structural properties. It is noteworthy that these are different from foams such as those used in upholstery, as they have properties similar to the original dense polymer [2-4]. Among the possible polymers to produce this material, polyolefins such as PE and PP stand out. Which it can be applied in the manufacture of shockproof materials, in packaging, in articles for civil construction, in thermal insulators and in the manufacture of various automobile components [1-5].

The process of producing polymeric foams consists of creating pores (also called cells) in the molten material. This pore creation process is done through blowing agents that can be of physical or chemical origin [2]. Physical expansion is done by injecting gas (such as CO_2 or N_2) directly into the molten material. Now, the process through chemical agents consists of adding a reagent that decomposes at the temperature at which the material is molten, and this decomposition process releases gas that creates pores. The expansion is processed during extrusion (at the exit of the extruder), or injection or pressing of the material [6].

The formation of pores in the molten polymer in short form takes place in 3 steps. The first step is the formation of cells, this step is when the pore starts to grow in the molten material, this occurs because the gas from the blowing agent reaches a state of supersaturation in the molten mass. Upon reaching this state, the gas begins to come out of solution and create pores. The second stage is the growth of cells, as the gas exits the solution, the pores begin to grow. This step must be controlled, as too vigorous expansion can cause the pores to overgrow and fuse together. This pore melting process is called coalescence, and this is detrimental to foams as large voids are created in the material, leading to a decrease in mechanical properties. The last step is to stabilize the expansion process, that is, to make the process stop. This is done by cooling the material, upon cooling the polymer solidifies and expansion is terminated [1-6].

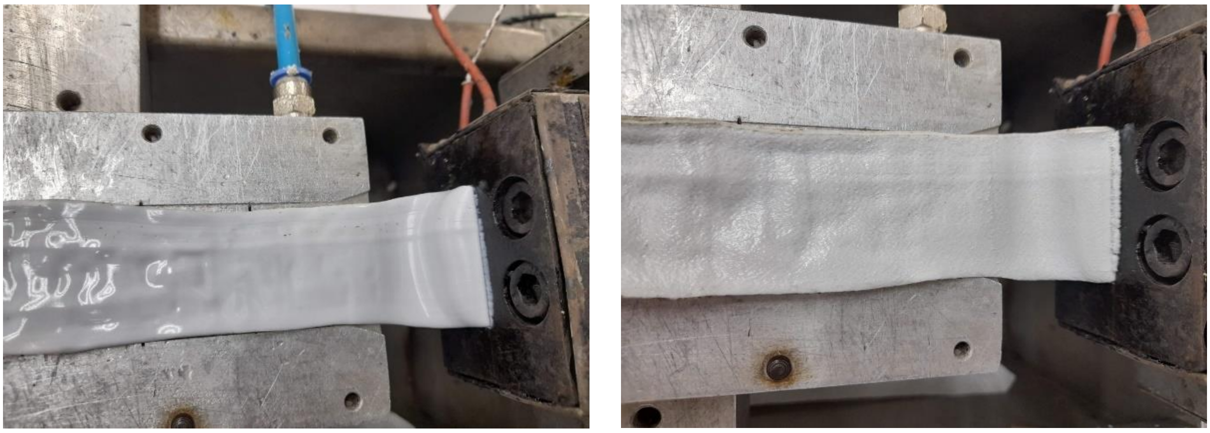
Considering the possible applications of rigid foams and their production process, the aim of this study was to evaluate the influence of the blowing agent on the recycled PP (PPr) to obtain rigid foams.

Experimental

The material used for the work was recycled PP, donated to the institution, with a melt flow index of 6.6 g/10 min. The blowing agents used were azodicarbonamide (AZO) in combination with zinc oxide and sodium bicarbonate (BC) in combination with citric acid. These two mixtures of blowing agents were chosen due the fact that these ones are widely used in the industry. Also, the process conditions of these two have broad reviews for a great range of polyolefins [1, 2, 6]. The polymer was mixed with the blowing agents in a co-rotating twin screw extruder (L/D = 40) with manual feed, with a feed temperature of 40°C and a die temperature of 160°C. The screw rotation speed was 75 RPM. The content of blowing agent was 1% by mass for both used. The expansion of the mixtures was carried out in a thermal press, with a mold with a square plate format of 20 cm x 20 cm with a depth of 3 mm, with a temperature of 215 °C and a pressure of 153 kgf/cm^2. The mass of material used to make the expansion in the press was 100 g. The characterization analyzes of the materials obtained were apparent density and Izod impact test (according to ASTM D256) with a 2.75 J hammer, Ceast Impactor II equipment.

Results and Discussion

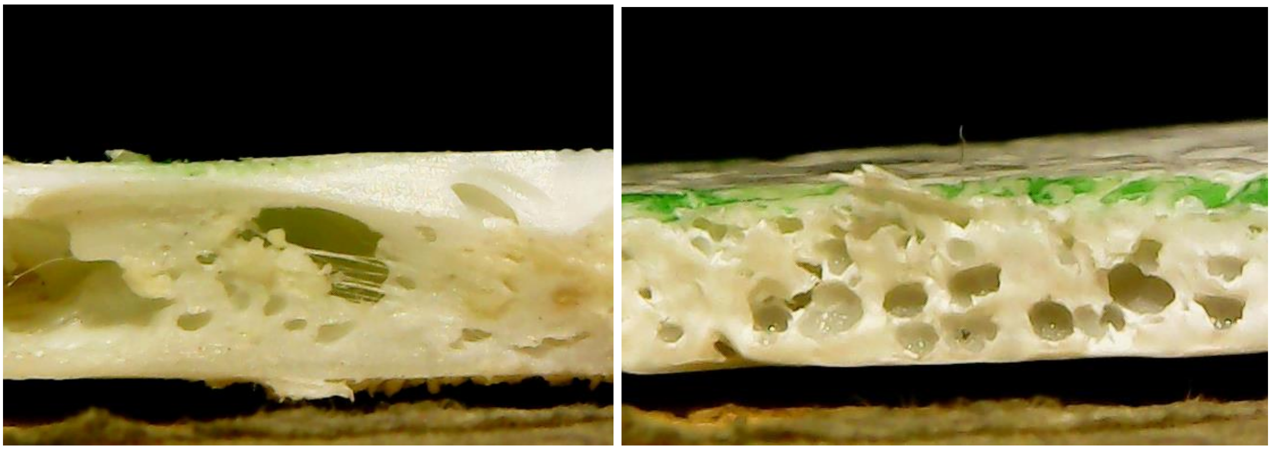
During the preparation of the mixtures in the twin screw extruder, it was observed that the samples presented a different behavior during processing. The sample that was prepared by mixing PPr with azodicarbonamide had have constant processing, while the PPr sample with the addition of bicarbonate had have inconsistent processing, causing variation in the screw rotation speed throughout the process. This behavior is attributed to the high shear conditions plus the process temperature initiating the sodium bicarbonate decomposition reaction inside the extruder. This fact is supported by the decomposition temperature of bicarbonate with citric acid being close to 160°C [7], while azodicarbonamide has a decomposition temperature that can vary between 150 and 210°C, depending on the amount of added zinc oxide [1]. Processing at lower temperatures was not possible, the equipment could not operate. Fig. 1 shows the blends being processed by the extruder.



(a) (b)

Figure 1 – Mixture of PPr with the blowing agent at the outlet of the extruder die: (a) sample with sodium bicarbonate, and (b) sample with azodicarbonamide

In the foam formation in the press, a great difficulty in controlling the expansion was observed. Since the samples were expanded in a mold, it was not a process that allowed direct observation of the expansion. The residence time in the press in which a more homogeneous material was obtained was 25 minutes.
The PPr mixtures with azodicarbonamide as blowing agent showed expansion, while the samples with bicarbonate did not show expansion. This confirmed the initial hypothesis that the bicarbonate degraded during the mixing process in the twin screw extruder. However, an attempt was made to obtain an expanded board with this agent (BC), for that, an attempt was made to mix the blowing agent directly in the press. However, this resulted in plates with large voids and a very uneven distribution of the pores, given the difficulty of uniformly distributing the blowing agent. This caused very inaccurate density measurements, varying according to the measured region. On the other hand, the plates produced with azodicarbonamide presented a more homogeneous distribution of the pores, which allowed a consistent determination of the foam density. The density obtained for this sample (mixed with AZO) was 0.156 g/cm^3. Fig. 2 shows the difference between the foams obtained with the different expanders. The images show, as already mentioned, the difference between the distribution and size of the pores.



(a) (b)

Figure 2 – Cross-sectional image of PPr foams formed with the blowing agents: (a) sodium bicarbonate (hand-mixed directly in the press), and (b) azodicarbonamide

The impact strength results did not show a great difference between the expanded samples. This behavior is credited to be due to the fact that the formation of large voids in both cases, despite the more homogeneous distribution of the pores for the samples expanded with azodicarbonamide, there was still a lot of cell coalescence. This was due to the difficulty of controlling expansion in the press. The results of the impact tests can be seen in Fig. 3.

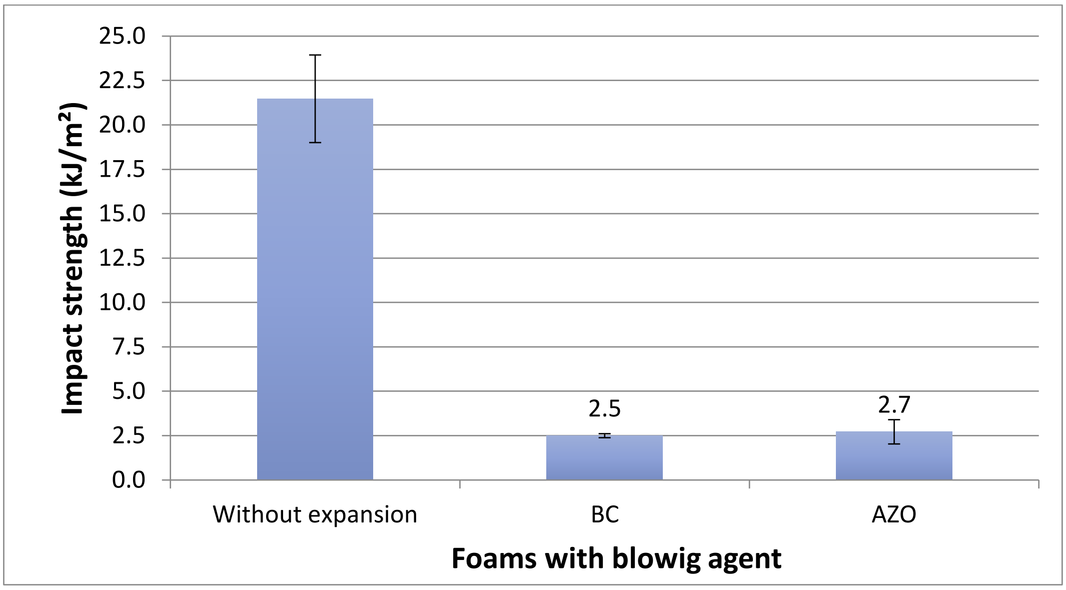


Figure 3 – Impact Test results of the evaluated samples - Foams with blowing agent: BC – sodium bicarbonate, AZO – azodicarbonamide

In Fig. 3 it is still possible to observe a great reduction in the impact resistance of the expanded samples compared to the same material without expansion. This great difference again highlights the difficulty found in controlling the material's expansion. Overgrowth of cells, large coalescence and poor distribution contributed to a high drop in material density, resulting in the observed fragility.

Conclusions

The use of the twin screw extruder to mix PPr with the blowing agent was only possible with azodicarbonamide. Mixing with bicarbonate in the twin screw extruder was not possible due to its low decomposition temperature. It was not possible to control the expansion of the material with the apparatus used (thermal press), resulting in the formation of a foam with low density and brittle. The sample expanded with AZO had a better distribution of the porous. The possibility of using recycled PP resin to obtain rigid foams was demonstrated. For a better evaluation of the use of this material and the blowing agents, the control of foam growth should be improved, along with the evaluation of expansion in a single screw extruder for production in a continuous process.

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