Study of Different Process Additives Applied to Polypropylene

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Abstract There are several additives aimed on improving the processing characteristics as well as mechanical properties of the plastic materials. Being polypropylene is one of the main polymers used in the plastic processing industry due to its easy processability and application versatility, was chosen as the base resin for this study. Additives can aid the processing of polypropylene, either by promoting a better slip between the chains (lubricants), or by contributing to nucleation and crystallinity (nucleating). In this study, the raw materials copolymer polypropylene, lubricant (internal and external action), organic nucleating agent (metallic salt) and inorganic nucleating agent (metallic oxide) were considered. Mechanical tensile tests, Charpy impact and spiral flow to verify melt index were performed to characterize the samples with additives and standard (copolymer polypropylene). The interference of these additives with polymeric matrix was observed.

Keywords Polypropylene · Lubricant · Nucleating · Characterization

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Introduction

Nowadays, polymers available on the market have a wide variety of properties. There are polymers capable of replacing metals, ceramics, and even glasses for certain applications [1].

The purpose of add an additive in a polymer is to obtain synergy between the constituents and to produce a material with superior properties when compared to original polymer. Additivation may also provide other results such as cost reduction of the final polymer and achievement of stability during processing and final product life cycle [2].

Polymers have high molar mass, thus, become viscous when melted. The higher the molar mass, the greater the viscosity. The high viscosity makes it difficult to process, especially in injection process, since the plastic must often pass through injection channels with narrow diameters. Therefore, it is necessary to reduce the viscosity of the polymer mass to ensure less wear of the machines and molds, higher productivity (faster cycles) and, consequently, electrical energy savings [3].

There are two different ways to achieve lower viscosity in a molten mass:

- By increasing processing temperature (which is not recommended, as the rate of degradation of the molecules will be higher, as well as the cooling time of the product and, consequently, the cycle time);
- By introducing auxiliary processing additives.

Lubricants facilitate the processing of polymers by increasing flow properties and decreasing the interaction of the melting with the walls of the machine [2].

When the polymer is processed, the melting temperature is higher than the temperature of the lubricant; thus, it fuses before than the polymer. The lubricant penetrates the plastic, and the level of penetration will depend on its solubility [3].

The nucleating agents may not significantly affect the rate of crystallization of all polymers. In order to a polymer be sensitive to nucleation during its crystallization process, the growth rate of the crystal must not be extreme (too high or too low). In case of polypropylene (PP), the rate of crystalline growth is intermediate, being one of the easiest polymers to form nuclei [4].

The physical or chemical nature of the nucleating agents may be quite diverse. A nucleating agent may be:

- an impurity, for example, a catalyst residue;
- an organic compound, such as benzoic acid;
- an inorganic compound, such as talc or a pigment.

For this study, a lubricant based on fatty acid ester, an organic nucleating of the metallic salt type and an inorganic metal oxide nucleating were used.

Experimental

The following raw materials were used:

- polypropylene Copolymer (PPC) with flow index of 40.0 g/10 min;
- internal and external lubricant;
- organic nucleating agent of the metal salt type;
- inorganic nucleating agent of the metal oxide type.

The proposed formulations are presented in Table 1.

In order to obtain test samples, an injection standardized test Type I tool was used according to ASTM D-638-10 [5], obtaining 20 test samples without additive (A—standard sample) and 20 test samples with each additive, characterizing samples B, C and D.

Tensile test provides information on the mechanical properties of the materials, such as tensile strength, elongation at break and modulus of elasticity. ISO 527-1 [6] specifies the general principles for determining the tensile properties of plastics and plastic composites under defined conditions.

Results and Discussion

Figures 1, 2, 3 and 4 show the behavior of the samples for the mechanical assays. Table 2 presents the results of the tests.

Charpy impact strength test may be used to investigate the behavior of certain sample types under defined impact conditions and to estimate the fragility or hardness of samples within the limitations inherent to the test condition. The results of this test are shown in Table 3.

In order to identify how much the fluidity index of the polymer is changed with the addition of the additives, this material characteristic was measured according to the method described in Table 4.

In this method, the molding flow of the thermoplastic material was evaluated. It was injected into a constant trapezoidal section spiral with subdivisions in centimeters or inches. The mold was filled from the center of the spiral and the pressure was maintained until the flow stops, indicating the flow distance. The results for the spiral flow test can be seen in Fig. 5.

Table 1 Formulations with different process auxiliary additives (%, by mass)

Components	A	B	C	D
PPC	100.0	99.5	99.5	99.5
Lubricant	–	0.5	–	–
Metal salt	–	–	0.5	–
Metal oxide	–	–	–	0.5

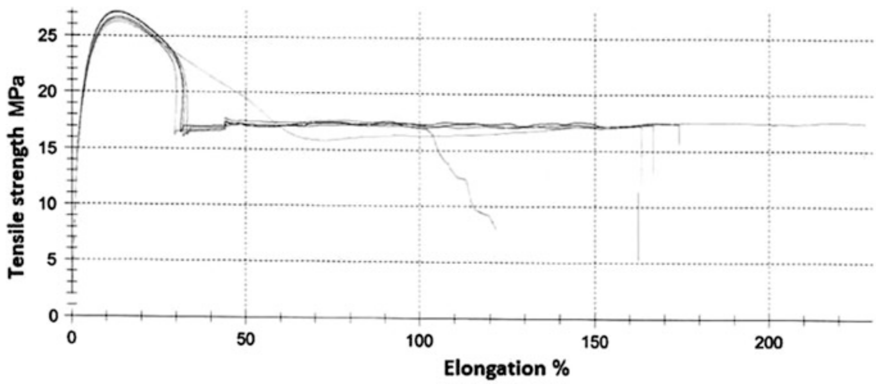

Fig. 1 Tensile properties of sample A (PPC)

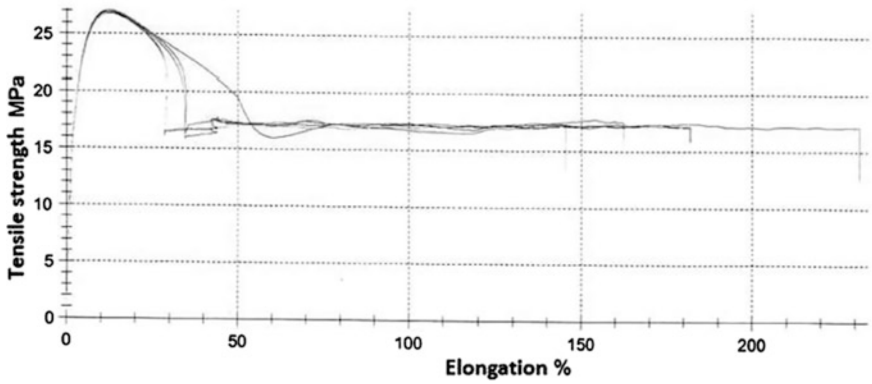

Fig. 2 Tensile properties of sample B (lubricant)

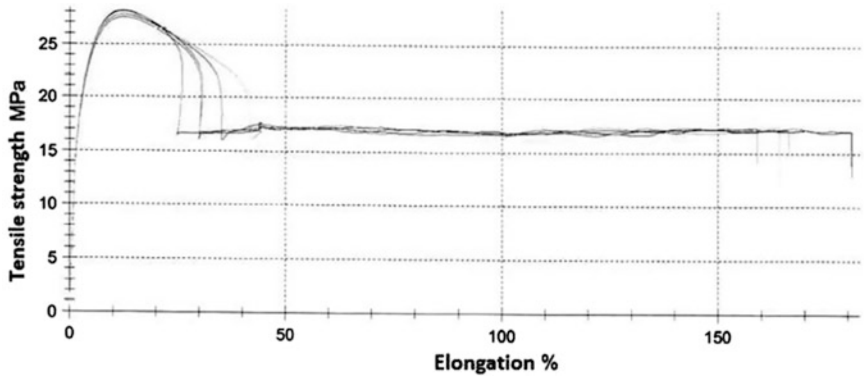

Fig. 3 Tensile properties of sample C (metal salt)

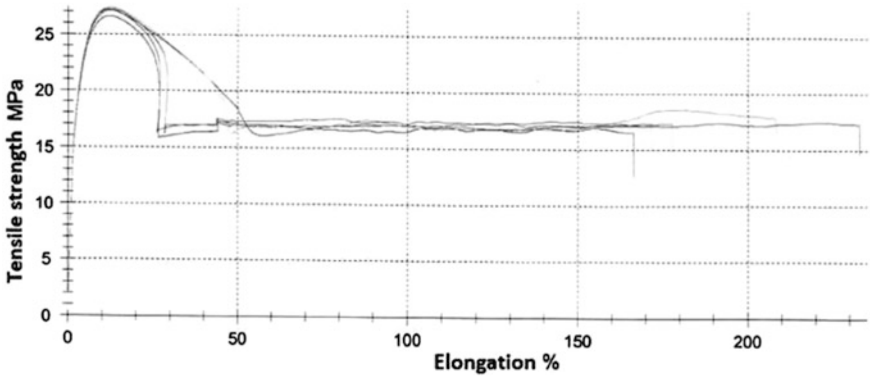

Fig. 4 Tensile properties of sample D (oxide)

Table 2 Results of the tensile strength test

Tensile properties	A $\bar{x}$	A s	B $\bar{x}$	B s	C $\bar{x}$	C s	D $\bar{x}$	D s
Modulus of elasticity E (MPa)	889.00	31.80	1020.00	34.90	982.00	25.90	933.00	35.70
Maximum tensile strength δ (MPa)	26.70	0.38	26.90	0.11	27.80	0.24	27.10	0.29
Tensile elongation ε (%)	13.00	0.15	12.40	0.15	12.50	0.19	12.30	0.18

Table 3 Results of the charpy impact strength test (kJ/m^2)

Charpy impact	A $\bar{x}$	A s	B $\bar{x}$	B s	C $\bar{x}$	C s	D $\bar{x}$	D s
Without notch (kJ/m^2)	99.81	0.00	99.80	0.00	87.68	20.02	99.81	0.00
Notched (kJ/m^2)	7.09	0.72	6.62	0.46	6.32	0.55	4.64	0.54

Table 4 Spiral flow method

Parameter	Unit	Value
Toll temperature	°C	50
Dosing	cm^2	20
Injection pressure	bar	700
Pack and hold pressure	bar	700
Pack and hold time	s	10
Cool time	s	10
Molding temperature	°C	200
Injection speed	cm^2/s	20

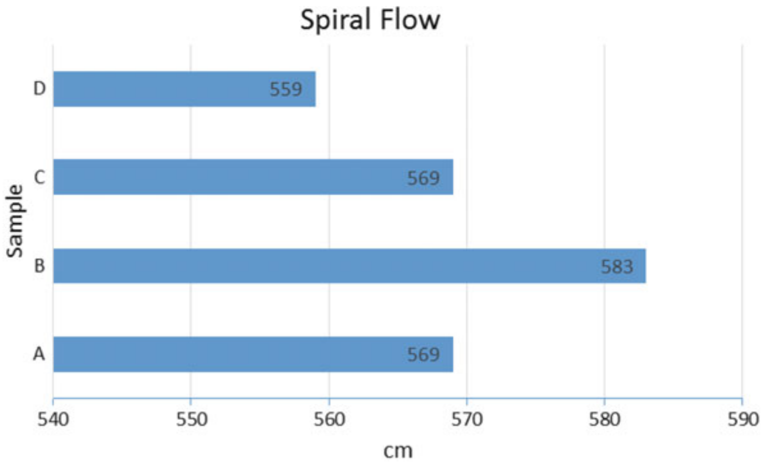

Fig. 5 Spiral flow test results

Conclusions

In general, samples B (lubricant) and D (metal oxide) presented different performance when compared to standard sample A (PPC).

Concerning the results of the tensile properties, it was observed that the sample B (lubricant) showed higher elastic modulus result when compared to the other samples, it had similar results in maximum tensile stress and elongation at maximum force.

For the Charpy impact test, sample D (metal oxide) presented the most outstanding result in relation to the notched test, being 30.43% lower than the other samples, on average. This can be explained by the greater fragility caused by the increase of the degree of crystallinity in this sample.

In relation to possible interferences with the melt index of the base polymer and / or standard A (PPC), it was observed that sample B (lubricant) showed a spiral flow result about 3% higher than the average of the other samples. Thus, it is concluded that sample C (metal salt) was interfered less with the base polymer, keeping the results very close to the standard sample. Sample D (metal oxide) presented a more interfering character, since it increased the crystallinity and made the sample more fragile. Sample B (lubricant) was considered an interesting alternative for the processing facilitation of the studied polymer due to the promotion of higher flow, without presenting losses in the mechanical properties evaluated.

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