



## MECHANICAL AND THERMAL COMPARISON ANALYSES IN POLYAMIDE 6 COMPOUNDS WITH TALC MINERAL FILLER AND AEROSIL®

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**Abstract:** In order to have sustainable development, it is very desirable that the possibilities of obtaining ecologically acceptable raw materials that increase dimensional properties and reduce cost in the industrial sector are explored. In this sense, the possibility of replacing mineral talc powder with the colloidal silicon dioxide (AEROSIL®) as a mineral filler in polyamide 6 (PA 6) compounds was tested. AEROSIL® is an amorphous substance with low density that satisfies consumer demands. In this study both fillers – talc and colloidal silicon dioxide – used with PA 6 were explored. Moreover, their density and properties in terms of thermogravimetric analysis (TG) were evaluated. Additional mechanical tests such as tensile strength, elongation at break and impact resistance were also carried out. The tests concluded both compounds (PA 6 with colloidal silicon dioxide and PA 6 with talc) demonstrated the same behavior. The results have demonstrated that colloidal silicon dioxide may be viable alternative filler for replacing talc as mineral filler in polyamide 6 compounds. Thus, this work contributes to minimizing environmental problems by enabling the use of colloidal silicon dioxide in the productive process.

**Keywords:** Polyamide 6, Talc, Colloidal Silicon Dioxide, AEROSIL®, Mineral filler.

### 1. INTRODUCTION

Over the last few years, engineering plastics have been used in different areas such as packaging, construction, electronics and automotive industry, as an alternative of metals due to the fact that their characteristics are very similar. Due to the necessity for modern materials, the polymers' structures have been modified to attend the sustainable development and the market requirements. Perhaps, pure polymers do not represent some properties and behavior for determined functions and that is why new materials started to be studied [1].

Polyamides (PA'S) are pioneer of the engineering plastics applications because they ensure formulations with excellent properties. Therefore, they have been used for activities with good mechanical, thermal and chemistry resistance. In addition, polyamides allow the inclusion of filler, which can improve these properties, dimensional stability and reduce the cost [2].

In the group of the mineral fillers, talc, glass fiber and carbon fiber are the most common mineral fillers used by the polymer factories. Furthermore, mineral filler are substances that have some characteristic such as low and high temperature resistance, water absorption decrease, casting contraction decrease, and a really low cost when compared with the pure polymer [3].

Talc also has a large application as filler in polymers and is used in automotive, mechanical and electrical industries due to the fact it has characteristics such as a density of around  $2.7 \text{ g/cm}^3$ , high resistance to thermal shock lightness and low moisture content, thermal conductivity, electrical and low chemical inertness [4].

On the other hand, composites materials have characteristics such as allowing incorporation of nanoparticles, which they have low density and it can also be produced by polymer process easily. Indeed, with the world economy expansion, the oil industry has been seeking to increase demand for basic petroleum products and light hydrocarbon [3].

Colloidal silicon dioxide (AEROSIL<sup>®</sup>) is an amorphous substance with the ability to retain fluids; low density and it can also improve the stream processes, such as for the manufacture powder process. Because AEROSIL<sup>®</sup> has a great commercial price, many industrial sectors, such as adhesives, powder coatings, cosmetics, lubricants, plastics, elastomers and pharmaceutical, are now using this substance [5].

The aim of this study is the analysis of mechanical and thermal comparison on polyamide 6 compounds with talc mineral filler and AEROSIL<sup>®</sup>. As main observations are the possible uses as alternative filler to substitute talc and to obtain lighter automotive parts looking for a residue that is economically viable for the industrial factories [6, 7].

## 2. EXPERIMENTAL

The polyamide 6 (PA 6) and the mineral filler talc used for this study were donated by “Rhodia Poliamida & Especialidades Ltda/Brazil” and the colloidal silicon dioxide (AEROSIL<sup>®</sup>) was bought at Evonik Degussa Corporation. Cromex S/A Company also made the masterbatch with 15 % of polyamide 6 and AEROSIL<sup>®</sup>.

To evaluate the mechanical analysis properties, the PA 6 was elongated with the AEROSIL<sup>®</sup> and the talc. Three formulations with different filler percentage, such as 1 %, 3 % and 6 %, of AEROSIL<sup>®</sup> were also prepared. Likewise, we prepared one formulation with 10 % of talc, which was used as a standard for PA 6 elongated with AEROSIL<sup>®</sup> (Table 1). The process was developed at the laboratory of “Rhodia Poliamida & Especialidades Ltda”, where the material was obtained by extrusion using the double-screw extruder ZSK 30 (screw elements suitable for the processing of polyamides).

The tests on the samples were produced by the injection process following ISO1874-2 standard, where the plastics injection machine was Romi 65R Primax. Furthermore, the material was kept in closed packages over a period of 48 hours, in controlled temperature and humidity ( $23 \pm 2 \text{ }^\circ\text{C}$  and  $50 \pm 5 \text{ \% RH}$ ) according to ISO / R291 due necessary to guarantee that formulated samples would not present any interference in their properties.

The density test was performed on an analytical balance Kern mark of  $\pm 0.1 \text{ mg}$  accuracy. The analysis was performed using the liquid tetrahydrofuran for immersion (due polyamide being hygroscopic). Thermal analyses were carried out using TA Instruments TG under a flow rate  $100 \text{ mL.m}^{-1}$  of synthetic air, heating rate of  $10 \text{ }^\circ\text{C m}^{-1}$ ; and the sample mass was around 9 mg.

The tensile strength and elongation at break test specimens were injected into the tie shape having dimensions with 115 mm long, 10 mm wide and 4 mm thick and it was used the Emic DL 200 machine for this analysis. The IZOD impact resistance test was conducted on a CEAST equipment brand using a pendulum of 2.75 J, according to the ISO 180 standard.

### 3. RESULTS AND DISCUSSION

According to TG curves (Fig.1) described below the process of thermal decomposition that PA 6 with 1 % (brown curve) and 3 % (green curve) of AEROSIL<sup>®</sup> filler. Both did not have significant variation among each other. It is equally important to emphasize that the final temperature was around 463 °C and mass loss was around 99 % for both curves presented. By comparing those curves with the talc standard (red curve) it was possible to observe that both of them had significant variation, where it was possible to describe that talc final temperature was 468 °C and the mass loss 92 %. In this manner, it was possible to observe that polyamide 6 with AEROSIL<sup>®</sup> filler presents a small difference in the mass-change behavior when compared with polyamide 6 with talc filler standard.

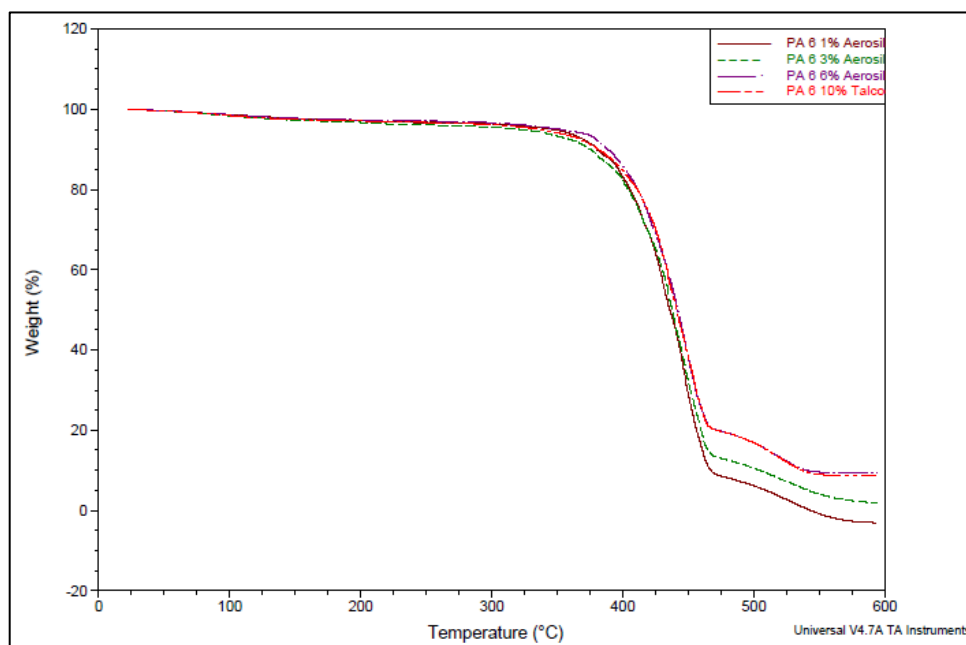


Figure 1: Polyamide 6 compounds with AEROSIL<sup>®</sup> filler and talc filler.

For polyamide 6 samples with 6 % of AEROSIL<sup>®</sup> filler and polyamide 6 with 10 % of talc filler, the TG curve (Fig. 1) underwent thermal decomposition, allowing us to observe that both samples did not present significant variations between each other. It was important to note that both curves had final temperature around 468 °C and the mass loss was around 91 %. Therefore, we did not observe any differences in the mass-change and as well a similar behavior.

Test results of breaking strain and elongation with standard deviation (Table 1) and density and IZOD impact (Table 2) performed to compare the use of AEROSIL<sup>®</sup> filler such as a potential replacement for talc filler in polyamide 6.

Samples of polyamide 6 with AEROSIL<sup>®</sup> filler responded to three different situations. First, PA 6 samples with 1 % and 3 % of AEROSIL<sup>®</sup> filler showed 48.70 and 48.37 MPa breaking strain on average respectively between them, where we could observe a similar result. Second, PA 6 produced with 6 % of AEROSIL<sup>®</sup> filler showed 50.11 MPa breaking strain on average, where it was possible to observe that 6 % of AEROSIL<sup>®</sup> filler has a breaking strain that is a little bit higher when it is compared with the previous formulations. Third, we observed that PA 6 samples with 10 % of talc filler presented 73.30 MPa breaking strain on average.

Table 1: Test results of breaking strain and elongation with standard deviation of the PA 6 samples with AEROSIL® (1 %, 3 % and 6 %) and with talc (10 %) fillers.

Formulations	*Breaking Strain (MPa)	*Elongation (%)
PA 6 + 1 % AEROSIL®	2.67 ± 0.38	0.27 ± 0.04
PA 6 + 3 % AEROSIL®	2.91 ± 1,23	0,31 ± 0.17
PA 6 + 6 % AEROSIL®	3.23 ± 0.84	0.30 ± 0.08
PA 6 + 10 % Talc	2.93 ± 0.96	0.24 ± 0.11

\*Results with standard deviation

In addition, it is important to note that polyamides with AEROSIL® formulations presented a ductile behavior, where it was necessary to apply a lower tensile for the deformation of the material and a lower elasticity modulus of it.

On the other hand, talc demonstrated to be a stiff material and did not present a plastic deformation (Fig 2).

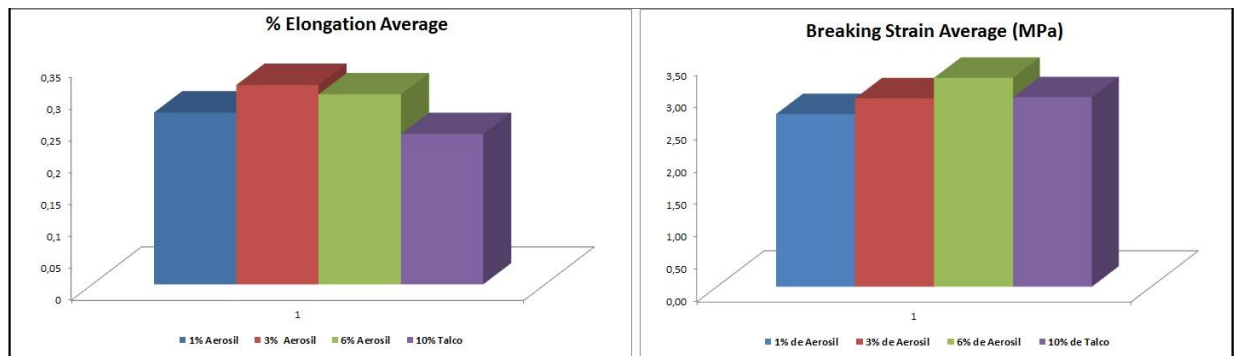


Figure 2: Elongation and Breaking Strain average.

Through the mechanical elongation tests we observed that formulations with 3 % and 6 % of AEROSIL® did not present a significant variation between them. On the other hand, PA 6 produced with 1 % of AEROSIL® and standard sample presented a lower elongation when compared with the previous formulations, even though, we could observe that samples produced by 1% AEROSIL® stretches their resistance higher when compared with the standard.

Therefore, it was possible to observe that 3% of AEROSIL® and the standard sample presented the same breaking strain behavior, which means both of them need the same force to be broken. For the samples with 1 % of AEROSIL® the breaking strain was lower when compared with the previews samples. However, PA 6 with 6 % of AEROSIL® filler demonstrated the highest breaking strain when compared with all the formulations. Indeed, we can conclude that this sample is the formulation with the highest stiffness according to the Fig 2.

Table 2: Test results of density and IZOD impact with standard deviation of the PA 6 samples with AEROSIL<sup>®</sup> (1 %, 3 % and 6 %) and with talc (10 %) fillers.

Formulations	*Density (g cm <sup>3</sup> )	*IZOD Impact (kJ/m <sup>2</sup> )
PA 6 + 1 % AEROSIL <sup>®</sup>	1.12 ± 0.01	4.79 ± 0.01
PA 6 + 3 % AEROSIL <sup>®</sup>	1.12 ± 0.01	6.18 ± 0.39
PA 6 + 6 % AEROSIL <sup>®</sup>	1.12 ± 0.01	3.90 ± 0.89
PA 6 + 10 % Talc	1.17 ± 0.01	4.27 ± 0.52

\*Results with standard deviation

For the density analyses indicated in Table 2 that samples produced by polyamide 6 and AEROSIL<sup>®</sup> filler did not have a significant variation between the three different formulations. On the other hand, we observed that the standard talc filler has more density if compared with AEROSIL<sup>®</sup>, which could be a great way to obtain a lighter polyamide 6.

In the IZOD impact resistance analyses, the polyamide 6 formulations with 1 %, 3 % and 6 % of AEROSIL<sup>®</sup> filler responded to three different situations. First, PA 6 samples with 1 % of AEROSIL<sup>®</sup> filler demonstrated similar results when compared with the standard talc filler. Second, PA 6 samples with 6 % of AEROSIL<sup>®</sup> filler indicated that talc has the higher impact resistance. Third, contrasting with the previous formulations, the polyamide 6 samples with 3 % showed that AEROSIL<sup>®</sup> filler presented a significant impact variation. While AEROSIL<sup>®</sup> formulations presented 6.18 kJ/m<sup>2</sup> and talc ones had 4.27 kJ/m<sup>2</sup> and ± 0.5 of standard deviation. We observed that AEROSIL<sup>®</sup> formulations with PA 6 sample with 3 % showed better results for the impact resistance test.

#### 4. CONCLUSIONS

All of the samples used this study were produced and injected without any differences in the production process. Even though the parameters of the process used for the production of PA 6 with AEROSIL<sup>®</sup> were kept for the processing of PA 6 with talc, the parameters remained unchanged for the evaluated tests.

Through the use of thermogravimetry, we observed that AEROSIL<sup>®</sup> filler with 1 % and 3% had small differences in the mass-change; by undergoing thermal decomposition behavior when it is compared with polyamide 6 with talc filler standard. However, it is important to emphasize that PA 6 with 6 % of AEROSIL<sup>®</sup> filler did not demonstrate any difference in the mass-change; consequently, similar behavior could be observed when compared with PA 6 with 10 % of talc. We also suggest a Differential Scanning Calorimetry (DSC) analyses in order to have a better conclusion about the thermal analyses.

Tests on mechanical tensile demonstrated that 6 % of Aerosil filler is most stiffer formulation when compared with the standard filler. Nonetheless, it is important to rebut those samples with 3 % of AEROSIL<sup>®</sup> filler has their stiffness closer to the samples standard. Moreover, mechanical elongation analyses demonstrated that 3% of AEROSIL<sup>®</sup> filler has a higher elongation resistance when it is compared with the standard and the other formulations. It is important to emphasize that for future works AEROSIL<sup>®</sup> will be analyzed with higher percentages.

Lastly, analyses on the IZOD impact resistance conclude that polyamide 6 with 3 % of AEROSIL<sup>®</sup> filler represented a significant impact variation, where AEROSIL<sup>®</sup> improved the impact resistance for polyamide 6. These results have demonstrated that colloidal silicon dioxide can be a viable alternative filler by replacing talc as mineral filler in polyamide 6 compounds. By enabling the

use of colloidal silicon dioxide in the productive processes, this replacement can contribute to minimize environmental issues during production.

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