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Study of the termal and mechanical properties of the magnetite/polypropylene composite

Estudio de las propiedades térmicas y mecánicas del composito magnetita/polipropileno

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Abstract

Currently, innovation in materials is a highly explored area, due to the requirements to satisfy the industrial needs for intelligent materials that arise mainly with an improvement in physical and mechanical properties. Within the classification of intelligent materials are composites and in this work it is proposed to combine a very versatile and low-cost polymer such as polypropylene and the important mineral called magnetite. By manual injection, three compounds are obtained and evaluated the effect on the thermal and mechanical properties of the polypropylene (PP) composite reinforced with different concentrations of mineral magnetite (5%, 10% and 20%) is evaluated. The three composites obtained (MP5, MP10 and MP20), were characterized by thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC) and Dynamic Mechanical Analysis (DMA). A favorable effect with MP20 composite is achieved on the thermal properties of polypropylene, managing to extend the thermal stability up to 420°C and improve the storage modulus up to almost 2 GPa.

Composite, Magnetite, Reinforcing agent

Resumen

En la actualidad la innovación en materiales es un área muy explorada, debido a los requerimientos para satisfacer las necesidades industriales por materiales inteligentes que surgen con un mejoramiento en las propiedades físicas y mecánicas. Dentro de la clasificación de los materiales inteligentes se encuentran los compositos y en este trabajo se propone combinar un polímero muy versátil y económico como lo es el polipropileno y un mineral importante como lo es la magnetita. Mediante inyección manual se obtienen tres compositos y se evalúa el efecto en las propiedades térmicas y mecánicas del composito de polipropileno (PP) reforzado con diferentes concentraciones de magnetita mineral (5%, 10% y 20%). A los tres compositos obtenidos (MP5, MP10 y MP20), se les caracterizó mediante Análisis de Termogravimetría (TGA), Calorimetría Diferencial de Barrido (DSC) y Análisis Dinámico Mecánico (DMA). Se observa un efecto favorable con el composito MP20, logrando aumentar la estabilidad térmica hasta 420°C y aumentando el módulo de almacenamiento hasta 2 GPa.

Composito, Magnetita, Refuerzo

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Introduction

Thanks to the excellent properties of polypropylene such as high thermal stability, high chemical durability, easy processability and low cost, it is a very versatile material for different applications, not to mention its reusability [1, 2, 3 and 4]. Polypropylene composites are attracting attention among other aspects for their versatility in different applications ranging from medical [5 and 6], industrial [7] and aerospace [8, 9 and 10] as well as in the production of composites with interesting properties such as light weight, low cost, high resistance to elastic deformation, etc.
It is known that polypropylene among thermoplastics is one of the most attractive thermoplastics to reinforce and improve its properties making it compatible with most processing techniques [11].

Magnetite is a very abundant mineral in the earth's crust and in addition to possessing important physical properties such as high density, thermal and electrical conductivity, it is also known to be opaque to x-rays and can block radiation, including microwaves and radar [12]. Glass is currently used for this purpose and has also been used for its modification to obtain composites [13].

In this work we propose to obtain three composites with polypropylene matrix with different concentrations of magnetite as a reinforcing agent.

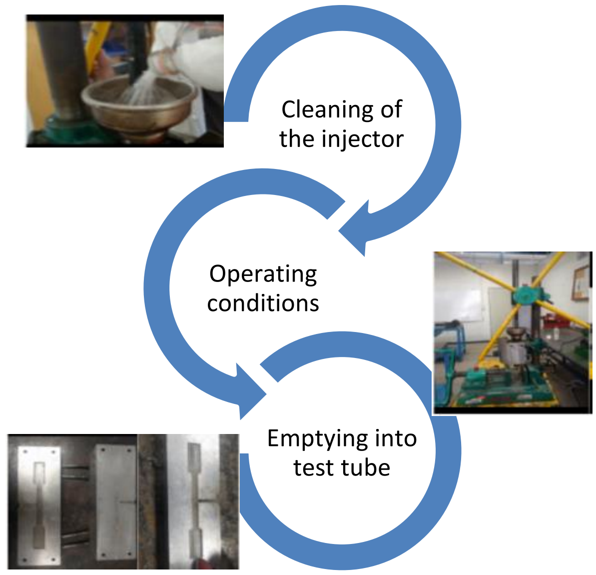
Experimental development

Obtaining the composite

To obtain the composite, magnetite mineral from a mine in Oaxaca was used as a reinforcing agent and the versatile thermoplastic polypropylene (PP) pellets with a density of 900 kgm-3 and a melting temperature of 170°C were used as a polymeric matrix.

In the process of obtaining the composite, the injection method was used using a manual injector Vulcano brand/model, the injection of the composite with the reinforcement of the clays was deposited in a mould for tensile specimens with measures of 2.5X8 in.

Based on the literature review, 3 concentrations of magnetite were established: 5% (MP5), 10% (MP10) and 20% (MP20) of the total PP, and then the mixture was mixed with the polypropylene, where the injector hopper was used for the mixing process, which was preheated to 130°C.



Graphic 1 Process of obtaining the Magnetite-PP composite
Source: Own elaboration

Once the specimens with the corresponding magnetite concentration were obtained, dynamic mechanical analysis (DMA) tests were carried out with a deformation sweep from room temperature of 25°C to 200°C with a heating ramp of 10°C/min. These tests were carried out on a TA Instruments RSA III.

Thermal analysis (TGA-DSC)

In order to know the thermal behaviour of the composites, a standard DSC-TGA-SDT Q600V20 was used.

Stress Test

An INSTRON INS-001 tensile testing machine was used to determine the maximum stress of the composites obtained. The tests were carried out at room temperature and with a humidity of 20% under the procedure of the ASTM D638 standard (stress properties of plastics) with a speed of 100 mm/min.

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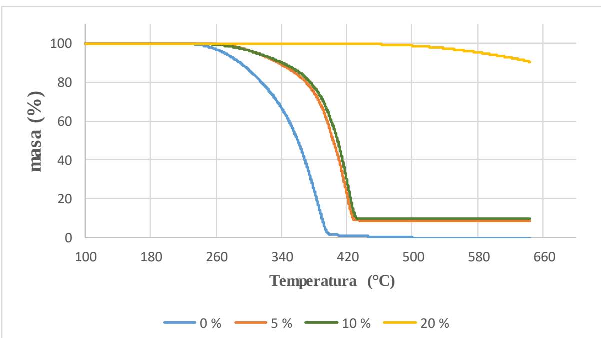
Rotational rheology (viscosity)

A Physica MCR 501 rotational rheometer was used to obtain the flow curve. A gap=1mm was used, from a temperature of 200°C, with a geometry of 25 mm parallel plates and a shear rate range of 0.0001-100 (1/s), recording the stress values (Pa).

Results

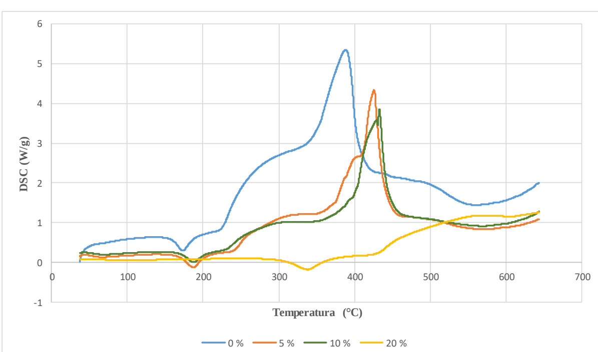
Thermal analysis (TGA-DSC)

Graph 2 shows the behaviour of pure polypropylene, as well as the composites with different concentrations of magnetite.



Graphic 2 Thermogravimetric analysis of the obtained composites and pure PP
Source: own elaboration

In the thermograms (graphic 2), a significant decomposition of PP and the composites MP5 and MP10 can be observed in the temperature range from 240 to 420 °C, achieving a positive thermal reinforcement by the magnetite from the lowest concentrations (5 and 10%) resisting up to a temperature of 280°C in comparison with the pure PP. It can be seen that with the highest concentration of magnetite (MP20) the thermal stability of the composite has been increased by approx. 50%, remaining stable up to 500°C.



Graphic 3 Differential scanning analysis of the obtained composites and pure PP
Source: Own elaboration

Graphic 3 shows that the melting temperature of the MP5 and MP10 composites achieves a delay of 30°C compared to pure PP. In a favourable way, the MP20 composite achieves a delay of the crystallisation phase up to a temperature of 430°C compared to pure PP.

Tensile test

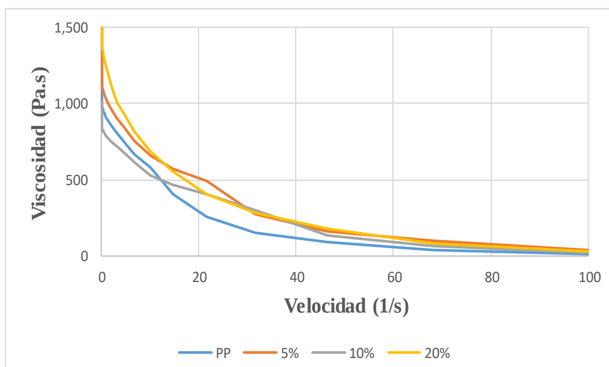
Table 1 shows the storage modulus achieved by each composite compared to neat PP.

Sample	Module E (kPa)
PP	464503.336
MP5	264269.543
MP10	572806.501
MP20	1991694.450

Table 1 Tensile test on PP and the composites obtaine
Source: Own elaboration

It is observed that the incorporation of magnetite in the MP5 composite has a negative effect by lowering the storage modulus of pure PP. However, with the highest concentration of the reinforcing agent (MP20), a significant increase in the storage modulus of~ 2 GPa is achieved.

Rotational rheology (viscosity)



Graphic 4 Viscosity of the PP and composites obtained
Source: Own elaboration

Graphic 4 shows that regardless of the concentration of the reinforcing agent (magnetite), the four samples show a decrease in the loss modulus or viscosity of the material; however, as the speed increases, the composites show a damping in the decrease of viscosity, which is a direct contribution of the reinforcing agent.

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Conclusions

The characterisation of the composites obtained with different concentrations of the reinforcing agent (magnetite) shows a favourable effect by improving the thermal and dynamic-mechanical properties of the polypropylene. With the MP20 composite it was possible to increase the thermal stability up to 420°C and to increase the storage modulus up to 2 GPa.

In this way, we contribute with information for the processing of this versatile and economical material.

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References

[1] Dylan Jubinville, Elnaz Esmizadeh, Costas Tzoganakis, Tizazu Mekonnen, Thermo-mechanical recycling of polypropylene for the facile and scalable fabrication of highly loaded wood plastic composites, Composites Part B: Engineering, Volume 219, 2021, 108873, ISSN 1359-8368, https://doi.org/10.1016/j.compositesb.2021.108873.

[2] Sergi, C., Tirillò, J., Iacovacci, C., & Sarasini, F. (2023). Influencia de los ciclos de reprocesamiento en las propiedades morfológicas, térmicas y mecánicas de compuestos de polipropileno híbridos de lino/basalto. Materiales y tecnologías sostenibles. https://doi.org/10.1016/j.susmat.2023.e00648

[3] Bernd Weidenfeller, Michael Höfer, Frank Schilling, Thermal and electrical properties of magnetite filled polymers, Composites Part A: Applied Science and Manufacturing, Volume 33, Issue 8, 2002, Pages 1041-1053, ISSN 1359-835X. https://doi.org/10.1016/S1359-835X(02)00085-4.

[4] Ali. H.T., Akrami, R., Fotouhi, S., Bodaghi, M., Saeedifar, M., Yusuf, M., et al. (2021). Fiber reinforced polymer composites in bridge industry. Structures 30, 774-785. Doi:10.1016/j.istruc.2020.12.092

[5] Singh, J., Singh, S., & Gill, R. (2023). Applications of biopolymer coatings in biomedical engineering. *Journal of Electrochemical Science and Engineering*, *13*(1), 63-81. https://doi.org/10.5599/jese.1460

[6] Taha, M., Fouly, A., Abdo, H. S., Alnaser, I. A., Abouzeid, R., & Nabhan, A. (2023). Unveiling the Potential of Rice Straw Nanofiber-Reinforced HDPE for Biomedical Applications: Investigating Mechanical and Tribological Characteristics. *Journal of Functional Biomaterials*, *14*(7), 366. https://doi.org/10.3390/jfb14070366

[7] Özen, İ., Haskan, H., Okyay, G., & Demiryürek, O. (2019). Characterizing the thermal and mechanical properties and improvement in sound insulation performance of magnetite containing nonwovens depending on coating conditions. *Composite Structures*, *211*, 254-263. https://doi.org/10.1016/j.compstruct.2018.12.040

[8] Thabit, HA, Es-soufi, H., Abdulmalik, DA, Al-Fakih, AM, Alraddadi, S. y Sayyed, MI (2023). Investigación estructural, térmica y mecánica del vidrio de teluro-borato-bismuto para protección contra la radiación. Revista de Investigación y Tecnología de Materiales, 24, 4353-4363. https://doi.org/10.1016/j.jmrt.2023.04.082

[9] Wu, T., Pan, Y., Liu, E., & Li, L. (2012). Carbon nanotube/polypropylene composite particles for microwave welding. *Journal of Applied Polymer Science*, *126*(S2), E283-E289. https://doi.org/10.1002/app.36832

[10] A. Riccio, A. Raimondo, A. Sellitto, V. Acanfora, M. Zarrelli, Multifunctional Polypropylene Core for Aerospace Sandwich Composite Panels, Procedia Engineering, Volume 167, 2016, Pages 64-70, ISSN 1877-7058, https://doi.org/10.1016/j.proeng.2016.11.670

[11] R Shanmugavel et al 2016 IOP Conf. Ser.: Mater. Sci. Eng. 152 012053 10.1088/1757-899X/152/1/012053

[12] dos Reis, F. C., Gomes, N. A. S., Baldan, M. R., Ribeiro, B., & Rezende, M. C. (2022). The influence of carbonyl iron and magnetite ferrite on the electromagnetic behavior of nanostructured composites based on epoxy resin/buckypapers. *Journal of Magnetism and Magnetic Materials*, *563*, 170007. https://doi.org/10.1016/j.jmmm.2022.170007

[13] Carosio, F., Fina, A., & Coïsson, M. (2010). Polypropylene-based ferromagnetic composites. *Polymer bulletin*, *65*, 681-689. https://doi.org/10.1007/s00289-010-0282-1.