Use of Organic Filler in Plastic Materials

Ravago

Student(s)
Çağla Girişken
Ceyda Yanmaz

Faculty Member(s)
Yusuf Ziya menceleoğlu

Company Advisor(s)
Buse Nur Can
Yakup Ülçer

Sabancı Üniversitesi

ABSTRACT

The increasing usage of polymers in automotive industry requires low density and high modulus polymers without losing its tensile strength. Therefore, the main challenge is to replace high density talc-based additives with low density and sustainable filler for density reduction. At this context, wood fiber is remarkable in terms of its low density. The wood fiber filler incorporated into polymer by using ultrahigh speed thermo kinetic mixing method. A series of experiment was performed by using totally 100 grams of sample in different loads (30% or 40%) of organic filler. In addition, 2% compatibilizer was used for comparison. After compounding, test samples were prepared by using mini injection molding and then their mechanical properties as well as thermal properties and homogeneity of the mixture were characterized by UTM, TGA, DSC and SEM. The test results showed that 40% wood fiber addition increased the tensile modulus 14% (from 3095 MPa to 3599 MPa) than the talc added PP. Meanwhile the tensile strength increased more than 3 times (from 8.6 MPa to 27 MPa) of the talc added PP. Also, density measurements proved that wood fiber addition decreased density by 14%. SEM images revealed that addition of compatibilizer increased the homogeneity and results confirm tensile strength increase. Likewise talc added PP, crystallinity increase with wood fiber addition also proves that wood fiber can replace talc.

INTRODUCTION

The need of high performance plastics in automotive industry is increasing constantly. High performance plastics being low weight but high strength, provides more fuel efficient vehicles. For every 10% reduction of vehicle weight brings in 5-7% reduction in fuel consumption [2,7]. So, the environmental and economic concerns encourage the automotive industry to produce more fuel efficient vehicles by using high performance plastics. Being the most commonly used high performance plastics in this project polypropylene (PP) is used.

Due to the low weight high strength demand of automotive industry, main task of the project is to replace the inorganic material talc that causes density increase in PP with low density and sustainable organic fillers.Wood fiber (WF) offering some significant advantages like low density, high specific properties, non-abrasive to processing equipment, low cost and biodegradability, it is chosen as the most appropriate organic filler for this task [1], and replaced with the talc by using ultrahigh speed thermo kinetic mixing method. This method provides a compound of polymer and the organic filler by mixing them at high temperatures subjected to high turbulence [4].

OBJECTIVES

The prior aim of this project is to reduce density of the polymer without causing a decreasing change of the tensile modulus of the polymer and even trying to improve the mechanical properties of the polymer.

EXPERIMENTAL PROCESS

In the scope of the project a series of experiments are performed by incorporating wood fiber into polymer in different loads reinforced with compatibilizer. Wood fibers are named Kastamonu wood fiber which is provided by Kastamonu Entegre Company.and Ravago wood fiber which are provided from Ravago Company. A series of test samples are prepared by using totally 100 grams of samples. Wood fiber is incorporated into PP in different loads such as 30% and 40%. Also, by adding 2% compatibilizer totally 4 sets of experiments are prepared. Details of test samples are given in Table 1.

Table 1. Number of experiment set with experiment contents

Number of experiment sets	Content of the experiment set		
	Amount PP (%)	Amount Wood Fiber (%)	Amount Compatibilizer (%)
Set 1	70	30 (Kastamonu)	-
Set 2	60	40 (Kastamonu)	-
Set 3	68	30 (Kastamonu)	2
Set 4	58	40 (Kastamonu)	2
Set 5	70	30 (Ravago)	-
Set 6	60	40 (Ravago)	-
Set 7	68	30 (Ravago)	2
Set 8	58	40 (Ravago)	2

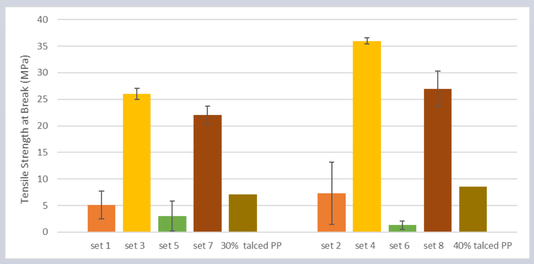
Prepared set mixtures are fed into the thermo kinetic mixing machine (Gelimat, Dusatec) and the materials are compounded with reached temperature around 200o C, at 5600 rpm and during around 100 seconds. After the mixing process the compounded samples are obtained.

RESULTS & DISCUSSION

For the mechanical tests (UTM, Instron, ISO 527-2), tensile strength at break and modulus values are examined. Comparing the 30% and 40% talc added PP results with the wood fiber added PP compounds, one can observe that the best tensile modulus improvement is observed by set 8 which is composed of 58% PP + 40% Ravago wood fiber + 2% compatibilizer. Meanwhile it preserves and even improves its tensile strength at break.

Graph 1. Mechanical test results (a) tensile modulus values of compounds compared with 30% and 40% talc added PP (b)) tensile strength at break values of compounds compared with 30% and 40% talc added PP

(a)



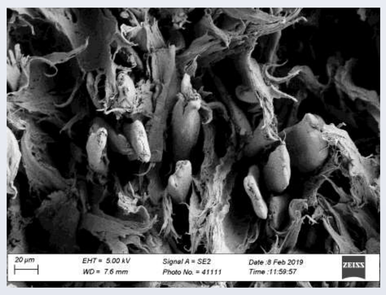
(b)

Also density measurements are done in order to observe the intended density decrease between talc added PP and wood fiber added PP.

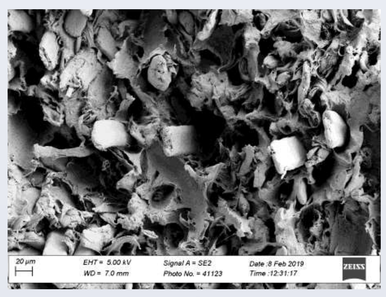
Graph 2. Density measurement results of wood fiber added PP and comparison with the results of talc added PP

According to results 30% wood fiber addition instead of talc decreased the density nearly 12% and 40% wood fiber addition decreased the density around 14%.

Figure 1. Comparison of compatibilizer effect between PP with and without compatibilizer. (a) 40% Ravaago wood fiber added PP without compatibilizer with 1 kx magnification (b) 40% Ravago wood fiber added PP with compatibilizer wtih 700x magnification



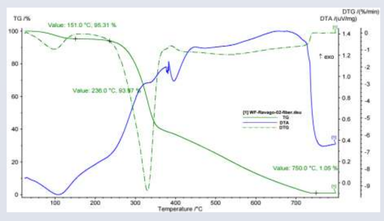
(a)



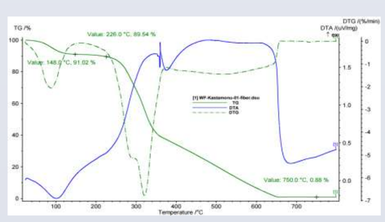
(b)

During the SEM studies of wood fiber added PP with and without compatibilizer addition, the effect of compatibilizer on the homogeneity of the compound is analyzed. When the breaking surface of the mechanical test bars are studied under SEM, it is observed that PP with compatibilizer addition shows a more homogeneous structure.

Figure 2. TGA results of (a) Ravago wood fiber (b) Kastamonu wood fiber



(a)



(b)

Thermal properties of wood fiber was studied by thermo gravimetric analysis instrument (TGA; DTG60H, Schimadzu) up to 800 C with heating rate 10 K/min. As shown in fig. 2, the mass decrease around 100 C corresponds to evaporation of the water inside the fibers. Kastamonu wood fiber's mass loss (9%) is higher than Ravago wood fiber (5%) which means that the humidity in Kastamonu wood fiber is higher than the humidity of Ravago wood fiber. As ratio of the humidity decreases, the mechanical properties, especially the modulus of elasticity, increase as observed when Set 4 and 8 are compared [3].

Table 2. Crystallisation of wood fiber added PP compounds compared to pure PP

	T_c (ºC)	ΔH_c (J/g)	$\Delta H_{normalized}$	X_c (% increased)
Pure PP	171. 32	65.16	-	-
Set 1	168.71	56.07	81	24
Set 2	168.23	44.44	88	35
Set 3	167.28	51.19	86	32
Set 4	167.76	44.58	85	30
30% talc added PP	168.97	52.50	87	33
40% talc added PP	169.85	39.30	99	52

Also thermal properties of wood fiber added PP are studied by Differential Scanning Calorimetry (DSC; TA2000, TA instruments). The increase in wood fiber addition between set 1 (30% WF) and set 2 (40% WF) increases the crystallinity of compounds by 11%. Also increase in crystallinity by 8% due to addition of compatibilizer can be observed by comparing set 1 and set 3 (30% + 2% compatibilizer). These increases can indicate that fibers are acting as nucleating agent [5]. The increase in crystallinity has a contribution in increase of the strength of the PP [6].

CONCLUSION

In this project, the incorporation of wood fiber into PP is carried out and aimed to decrease the density of compound while increasing the tensile modulus without losing mechanical strength. It is observed that 40% wood fiber addition can be considered as a replaceable filler for inorganic talc material in PP. It increased the tensile modulus by 14% (from 3095 MPa to 3599 MPa). Also density measurements supported that wood fiber addition decreased density by 14% while also improving tensile strength by 3 times (from 8.6 MPa to 27 MPa). The increased homogeneity effect of compatibilizer is observed from the SEM images and also proved by the tensile strength increase. Furthermore the increasing crystallinity trend of both talc added PP and wood fiber added PP proves that wood fiber is an organic filler that can replace inorganic talc.

REFERENCES

1. A. Karmarkar, S. S. Chauhan, J. M. Modak, M. Chanda, "Mechanical properties of wood–fiber reinforced polypropylene composites: Effect of a novel compatibilizer with isocyanate functional group", (2006), pp.228-233, available at https://www.sciencedirect.com/science/article/pii/S1359835X06001722
2. "Automotive Industry Seeks Light-Weight and High-Performance Materials", (2012), available at https://www.icis.com/explore/resources/news/2012/07/27/9581541/automotive-industry-seeks-light-weight-and-high-performance-materials/
3. C. C. Gerhards, "EFFECT OF MOISTURE CONTENT AND TEMPERATURE ON THE MECHANICAL PROPERTIES OF WOOD: AN ANALYSIS OF IMMEDIATE EFFECTS", (1980), pp. 5-7
4. Gelimat™ Technology Ultrahigh-Speed Thermokinetic Mixing,Compounding & Fluxing, available at https://www.academia.edu/34219550/Gelimat_Technology_Ultrahigh-Speed_Thermokinetic_Mixing_Compounding_and_Fluxing
5. Reixach, R., Puig, J., Méndez, J. A., Gironès, J., Espinach, F. X., Arbat, G., Mutjé, P., "Orange Wood Fiber Reinforced Polypropylene Composites: Thermal Properties", (2015), pp. 2156-2163 available at https://www.researchgate.net/publication/276426380_Orange_Wood_Fiber_Reinforced_Polypropylene_Composites_Thermal_Properties
6. Sharma, R., Maiti, S.N., "Effects of crystallinity of polypropylene (PP) on the mechanical properties of PP/styrene-ethylenebutylene-styrene-g-maleic anhydride (SEBS-g-MA)/teak wood flour (TWF) composites", (2015), pp. 631
7. Szeteiová, K., "AUTOMOTIVE MATERIALS PLASTICS IN AUTOMOTIVE MARKETS TODAY", available at https://pdfs.semanticscholar.org/e2d3/16ca62ec296bfc66ef3f2f5a4daf974bd65c.pdf